Responses to the External Scientific Peer Review for the Amendment to the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California, Mercury Reservoir Provisions — Mercury TMDL and Implementation Program for Reservoirs

Statewide Mercury Control Program for Reservoirs

September 2018

CALIFORNIA
Water Boards
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

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Appendix S. Responses to the External Scientific Peer Review

Peer Reviewers are as follows:

1. Janina M. Benoit, Ph.D. (JMB)
   Professor and Chair of Chemistry
   Wheaton College
   Norton, MA

2. Cynthia C. Gilmour, Ph.D. (CCG)
   Senior Scientist
   Smithsonian Environmental Research Center
   Edgewater, MD

3. Daniel A. Jaffe, Ph.D. (DAJ)
   Professor, Atmospheric Sciences
   University of Washington-Bothell
   Bothell, WA

4. Robert P. Mason, Ph.D. (RPM)
   Professor
   Department of Marine Science
   University of Connecticut
   Groton, CT

Numbered Conclusions to be Evaluated by Scientific Peer Reviewers

Conceptual Model for Mercury Methylation and Bioaccumulation

1. **Many factors—not just the amount of inorganic mercury in water and sediment—influence methylmercury concentrations in reservoir fish.**

California-Specific Linkage Analysis

2. **The three most important factors that control fish methylmercury concentrations are: the ratio of aqueous methylmercury concentration to chlorophyll-a concentration, aqueous total mercury concentration, and annual reservoir water level fluctuations.**

3. **Inorganic mercury sources alone are not the primary driver of mercury impairments in California reservoirs. Multiple factors drive reservoir fish methylmercury levels: amount of mercury, methylmercury production, and bioaccumulation.**

4. **Inorganic mercury levels in many reservoirs would need to be lower than natural background to achieve the TMDL targets and mercury water quality objectives if no other factors are addressed.**

Mercury Source Assessment

5. **Mercury sources are not evenly distributed across the State and no one source type is responsible for all reservoir impairments.**

6. **The most important anthropogenic sources to impaired reservoirs are historic mine sites and atmospheric deposition from global and local (California) industrial emissions.**

7. **Reducing watershed mercury sources is not expected to result in substantial reductions in reservoir sediment mercury concentrations and fish methylmercury concentrations in many reservoirs.**

8. **Global industrial emissions are the predominant anthropogenic source to about 20 percent of mercury-impaired reservoirs.**

Potentially Controllable Processes and Predictions for Improvement

9. **There are a variety of mercury source control options and reservoir water chemistry and fisheries management practices that may be effective for reducing fish methylmercury concentrations.**

10. **A combination of source control actions and reservoir and fish management practices—versus source control alone—will be needed to achieve both timely and measurable fish methylmercury reductions in most of California's mercury impaired reservoirs.**

11. **Actions to reduce fish methylmercury levels may need to vary for each reservoir because of the many combinations of different mercury sources (e.g., some are natural or global and therefore not regulated by state and federal agencies), competing factors that control methylmercury production, and reservoir operational constraints. Reservoir-specific characteristics and operational requirements and mandates may not allow for all methylmercury management tools to be used in all reservoirs. Even so, there should be a possible solution to mercury impairment for every reservoir.**

TMDL and Load Allocations

12. **The TMDL loading capacity and allocations, combined with reservoir water chemistry and fisheries management pilot tests and implementation actions identified in the proposed program of implementation), are adequate to achieve the proposed mercury water quality objectives and TMDL numeric targets for methylmercury in reservoir fish.**

13. **The allocations are adequate for both current and future mercury sources to the mercury-impaired reservoirs.**

Margin of Safety, Seasonal Variations, and Critical Conditions

14. **The Reservoir Mercury TMDL incorporates an adequate margin of safety.**

Implementation and Monitoring

15. **The Mercury Reservoir Provisions requirements for inorganic mercury controls are adequate to reduce anthropogenic discharges of inorganic mercury to reservoirs.**

16. **During the first phase of the implementation program for the impaired reservoirs, the Mercury Reservoir Provisions require reservoir water chemistry and fisheries management practices pilot tests. Implementing reservoir pilot tests to develop and evaluate and water chemistry and fisheries management practices in a phased approach is an adequate approach to reduce reservoir fish methylmercury levels. This phased approach includes State Water Board review of the Mercury Reservoir Provisions prior to full scale implementation of effective and feasible management practices.**

Assessment of Compliance with the Proposed Water Quality Objectives

17. **The upper 90th confidence limit of the mean is an appropriate statistical method to determine compliance with water quality objectives based on an annual average fish methylmercury concentration. In addition, it is appropriate to use consistent fish trophic levels and sizes, sample type and quantity, and sampling locations when determining compliance with water quality objectives.**

18. **Biosentinel fish monitoring provides a means to evaluate relatively rapid changes to biotic methylmercury levels.**

The Big Picture

Reviewers were not limited to addressing only the numbered conclusions (1–18), and were asked to contemplate a broader perspective.

(a) In reading the Staff Report and Mercury Reservoir Provisions, are there any additional scientific conclusions that are part of the scientific basis of the proposed rule not described above in Section A? If so, please comment on these with respect to the statute language given above.

(b) Taken as a whole, is the scientific portion of the proposed rule based upon sound scientific knowledge, methods, and practices?

S.1 Consolidated Proposed Changes to the Draft Mercury Reservoir Provisions

This section provides the proposed changes made to the draft Mercury Reservoir Provisions in response to the external scientific peer review. Only changed sections are provided here; comment numbers are provided in [brackets] at the end of titles and paragraphs.

These responses are being made available as a courtesy to stakeholders. Please note that no written public comments will be accepted on these responses (including proposed changes to the Mercury Reservoir Provisions) at this time. A formal notice will be provided to the public, likely in mid-2019 at the earliest, identifying the public review period along with release of documents for review and comments, including proposed Mercury Reservoir Provisions, Staff Report, and other relevant supporting documents.

IV. Implementation Program for Impaired Reservoirs

IV.B. Time Schedule and Phased Approach~~ 1 and Phase 2~~ [CCG-36 and RPM-33]

First paragraph:

The implementation activities required in Chapter IV shall occur on or after the Effective Date of the MERCURY RESERVOIR PROVISIONS, as provided. Discharges from mines sites and reservoir pilot tests are~~, and may be~~ subject to a two-phased approach (discussed in Chapters IV.D [*Discharges from Mine Sites*], IV.H [*Reservoir Owners and Operators*], and V.B [*Fisheries Management*])~~, depending on the type of discharger~~. PHASE 1 commences at the Effective Date of the MERCURY RESERVOIR PROVISIONS and ends 10 years thereafter. PHASE 2 will commence after the State Water Board completes its program review of PHASE 1 activities (discussed in Chapter VI). [CCG-36 and RPM-33]

No changes to subsequent paragraphs in IV.B.

IV.D. Discharges from Mine Sites

Changes only to second paragraph of section 1.c, as follows.

IV.D.1.c. MINE SITE Cleanup Plan. A MINE SITE Cleanup Plan shall describe measures to control mercury discharges and a time schedule to control the discharges. The MINE SITE Cleanup Plan shall contain the following at a minimum: (a) proposed designs and specifications to control discharges of mercury from the MINE SITE to surface waters; (b) a schedule for completion of the MINE SITE cleanup; and (c) description of the plans and specifications of the post-construction long-term, operations, maintenance, and monitoring necessary to ensure continued effectiveness of the control measures.

Insofar as the cleanup plan includes erosion and sediment control measures, such measures shall be designed to MINIMIZE or prevent the discharge of mercury from mining in storm water discharges and authorized non-storm water

discharges through the use of controls, structures, and management practices that achieve best conventional pollutant control technology for erosion and sediment control. If applicable, the plans shall also describe control measures (i.e., best management practices) to MINIMIZE or prevent the discharge of mercury not attached to sediment. If applicable, such as because more than seven years to complete cleanup, the plans shall also describe construction and maintenance of interim measures to collect mercury before it discharges from their property, e.g., sedimentation basins. [CCG-97]

IV.F~~G~~. Municipal and Industrial Wastewater Non-Stormwater NPDES Dischargers

3. Within one year of the Effective Date of the MERCURY RESERVOIR PROVISIONS, for any permittee with a direct discharge of mercury to an IMPAIRED RESERVOIR or a surface water that is tributary to an IMPAIRED RESERVOIR (including those identified in Table 5) that uses one or more treatment pond systems (e.g., oxidation, facilitative, settling, or stabilization ponds), the WATER BOARD will either issue an order pursuant to Water Code sections 13267 or 13383, or modify, re-issue, or adopt the applicable NPDES permit to require effluent methylmercury monitoring. The effluent methylmercury monitoring shall occur at a minimum on a quarterly basis for two calendar years and shall occur in the same calendar years in which monitoring in reservoirs listed in Tables 3A and 3B occurs as required by Chapter IV.H~~F~~.4.e, and the monitoring results may be submitted in an annual report. If all methylmercury sample results in the first calendar year are below the detection limit of 0.02 ng/L, then the permittee may discontinue the monitoring. [CCG-84]

IV.G~~H~~. Storm Water NPDES Dischargers

1.b. The WATER BOARD will either issue an order pursuant to Water Code sections 13267 or 13383, or modify, re-issue, or adopt the applicable NPDES permit to require methylmercury monitoring in representative urban runoff discharges to the reservoir or its tributaries at least twice during each of one dry season and one wet season and to submit the monitoring results to the WATER BOARD within eight years of the Effective Date of the MERCURY RESERVOIR PROVISIONS. The methylmercury monitoring shall occur in the same calendar year in which monitoring in reservoirs listed in Tables 3A and 3B occurs as required by Chapter IV.H~~F~~.4.e. [CCG-84]

IV.~~F~~H. Reservoir Owners and Operators [CCG-4: *moved IV.F to IV.H*]

IV.~~F~~H.1.a Pilot Test Work Plan.

IV.~~F~~H.1.a.i.a Oxidant addition to reservoir bottom waters (near the sediment-water interface) to reduce anoxia or adjust redox potential when reservoirs are stratified to suppress methylation of mercury. Oxygen addition to reservoir mid-depth waters (near the thermocline) to reduce anoxia when reservoirs are stratified to

suppress methylation of mercury. Oxidant addition directly to reservoir sediments, such as solid manganese oxides, to suppress methylation of mercury. Evaluate various oxidants (e.g., dissolved oxygen, ozone, nitrate, manganese oxides, others) for (a) efficacy for methylmercury reduction, (b) multiple benefits (e.g., drinking water quality, algal controls), and (c) avoidance of adverse consequences (e.g., application of nitrate only when a reservoir is stratified and not discharging bottom waters from the dam, with monitoring to ensure that added oxidant does not increase nutrient levels in the reservoir or downstream); [RPM-3, JMB-12, CCG-97]

IV.~~F~~H.2. Individual or Coordinated Plans and Reports.

a. A coordinated approach may only encompass "representative reservoirs." "Representative reservoirs" means that each reservoir proposed to be coordinated must be sufficiently similar to other reservoirs such that the management practices pilot tested at a specific reservoir or reservoirs are expected to be effective to ~~achieve or~~ aid in achieving the mercury water quality objectives in each similar reservoir included in the coordinated approach, and for which the management practices pilot tested could be implemented in PHASE 2 in each similar reservoir. [RPM-33]

IV.H.3. Monitoring in Coordinated Reservoirs Not Undergoing Pilot Testing.

An owner or operator that elects to develop and implement coordinated plans and reports described in Chapter IV.H.1 shall additionally comply with the following requirements for IMPAIRED RESERVOIRS listed in Tables 3A and 3B not undergoing pilot testing, to support development of the Long-term Reservoir Management Strategy Report:

a. Monitoring Plan. The monitoring plan shall include the following elements.

i. A description of the monitoring activities and methods, expected types of data, data quality assurance, and data analysis methods that will be used to characterize (a) mercury and methylmercury inputs, outputs, cycling, and bioaccumulation; and (b) reservoir limnology and water quality; in sufficient detail to support development of a reservoir-specific long-term reservoir management strategy report.

ii. A description of the monitoring timing and frequency. Monitoring should occur in calendar years, if applicable, before and after changes in reservoir operations or management made for reasons other than mercury, or before and after re-fill after prolonged drawdown due to drought or reservoir management. Where applicable, reservoir monitoring must be coordinated with and occur in same calendar year(s) as methylmercury discharge monitoring required by Chapters IV.F.3 and IV.G.1. If not specified otherwise in the monitoring plan, monitoring shall occur in the fourth and eighth calendar years

after the Effective Date. Monitoring frequency is no less than quarterly during two calendars years.

iii. Time schedules for the following, at a minimum: (a) projected calendar years of monitoring; and (b) reporting dates in accordance with Chapter IV.H.5.

b. Monitoring Progress Report. Monitoring progress reports shall describe the progress made to date on the monitoring, any preliminary findings or results, and any recommendations to revise the monitoring work plan.

c. Monitoring Final Report. Monitoring final reports shall describe results of the monitoring and how this information will be incorporated (in conjunction with results from the coordinated pilot tests) in each long-term reservoir management strategy report. [CCG-84]

IV.H~~F~~.4. Time Schedule Requirements for Reservoir Owners and Operators:

e. Implement Pilot Tests and Monitoring. Beginning not later than six months after WATER BOARDS approval of each pilot test and monitoring work plan, the owner and operator shall implement the approved individual ~~or coordinated~~ pilot test work plan or coordinated pilot test and monitoring work plan. [CCG-84]

V. Recommendations

V.B. Fisheries Management

6. CDFW require all fish stocking of RESERVOIRS and lakes be reported to a central, on-line database (stocking by date to report species, sizes (length and weight ranges of size classes), and count and total weight by size classes. [CCG-84]

C. Reductions in Atmospheric Mercury

2.a. Which agencies will revise and validate the REMSAD model by nine years after the Effective Date;

2.b~~a~~. Which agencies will track progress towards achieving the goals for atmospheric deposition; and

2.c~~b~~. The potential steps to identify and implement additional mercury controls for California emissions and/or additional national and international actions if monitoring and modelling indicates the deposition load allocations likely will not be achieved, or additional deposition hotspots are observed in California. [DAJ-19]

VI. Program Review: State Water Board Reconsideration of Mercury Reservoir Provisions

A. At the conclusion of PHASE 1, but no later than 12 years after the Effective Date of the MERCURY RESERVOIR PROVISIONS, the State Water Board will evaluate and review the MERCURY RESERVOIR PROVISIONS ("Program Review"). Implementation actions required by Chapters III and IV.D–G will continue during Program Review. Pilot tests required by Chapter IV.H [Reservoir Owners and Operators] are scheduled to conclude prior to Program Review. The Program Review will include the following: [CCG-36]

1. Evaluate the results of each of the pilot tests submitted in PHASE 1 in accordance with Chapters IV.~~F~~H.1, 4, and 5.

2. Consider the statewide technical review committee's advice and report (see Chapter IV.~~F~~H.4.d), if available.

3. Review each long-term reservoir management strategy report submitted in accordance with Chapters IV.~~F~~H.1.d, IV.~~F.4.h~~H.4.h, and IV.~~F~~H.5, and, if approved by the State Water Board, direct each owner and operator ~~on whose behalf the long-term reservoir management strategies were submitted~~ to implement actions informed by the PHASE 1 pilot tests and monitoring during PHASE 2. [CCG-84]

4. Consider whether any RESERVOIR determined to be impaired by mercury after the Effective Date of the MERCURY RESERVOIR PROVISIONS should be subject to the requirements set forth in Chapter IV.~~F~~H.

5. Consider whether to require any owner and operator to conduct a new or an additional pilot test in any of their IMPAIRED RESERVOIRS. [RPM-33]

6. Consider whether any additional or new information bears on the efficacy of the MERCURY RESERVOIR PROVISIONS, and if so, consider amendments thereto.

7. Consider whether to exercise reservations of authority included in each Clean Water Act section 401 water quality certification issued to owners or operators of reservoirs subject to a license issued by FERC pursuant to the Federal Power Act. In particular, the review shall consider if the reservoir exceeds or threatens to exceed water quality standards for mercury at the reservoir and include the actions and time schedules consistent with the requirements contained in Chapter IV.~~F~~H.

Appendix A: Glossary of Terms

PHASE 1: PHASE 1 generally refers to the first of two phases of the program of implementation for discharges from MINE SITES and RESERVOIR pilot tests (discussed in Chapters IV.D, IV.H, and V.B), and commences at the Effective Date of the MERCURY RESERVOIR PROVISIONS and ends 10 years thereafter. [CCG-36]

PHASE 2: PHASE 2 generally refers to the second of two phases of the program of implementation for discharges from MINE SITES and RESERVOIR pilot tests (discussed in Chapters IV.D, IV.H, and V.B) ~~IMPAIRED RESERVOIRS~~, and will not begin until the effective date of the State Water Board's amendment to the MERCURY RESERVOIR PROVISIONS, which will occur in accordance with Chapter VI. [CCG-36]

RESERVOIR: A natural or artificial water impoundment that: 1) has constructed structures such as dams, levees, or berms to contain or otherwise manage water, and/or was excavated; and 2) provides year round habitat for fish other than those specifically introduced for vector control purposes.

However, the term RESERVOIR does not include the following types of impoundments, unless the impoundment is expressly identified as a reservoir in a water quality control plan and/or provides year round habitat for fish other than those specifically introduced for vector control purposes:

1. Potable water treatment and storage facilities;

2. Industrial (including mining) supply water treatment facilities including water storage facilities that are part of the industrial process;

3. Ponds or facilities designed and operated to collect or treat municipal, industrial, process or mining wastewaters;

4. Storm water runoff and flood control basins containing water ephemerally or intermittently, including constructed storm water detention ponds and storm water best management practice impoundments; and

5. Ponds primarily created for purposes of agricultural and ranching operations, irrigation, storage for beneficial reuse of wastewater, or percolation to groundwater; and

6. Ponds created to impound saline waters, e.g., salt evaporation ponds; and ponds open to tidal exchange of water with estuary. [CCG-62]

S.2 Janina M. Benoit (JMB)

Dr. Benoit has organized her comments by conclusion number. Between numbered conclusions she provides comments on the staff report. Dr. Benoit addressed Conclusions 1–6, 8–11, and The Big Picture. Reviewers are not obligated to address all conclusions[1], and Dr. Benoit did not address Conclusions 7 and 12–18.

Conclusion 1.

COMMENT JMB-1

Conclusion 1 is supported in Chapter 4 and Appendix A. Overall, Chapter 4 provides a thorough literature review, and it largely accomplishes the stated goal of: "identifying factors that affect mercury methylation and bioaccumulation" (p. 4-1, 1st paragraph). Those two processes are widely recognized as key to controlling fish MeHg concentrations. A number of important factors influencing methylation are reviewed: sediment inorganic Hg (HgI) concentration and organic matter content, water column HgI and DOC concentrations, bioavailability of HgI, and type of landscape. In addition, factors affecting bioaccumulation are described, including lake/watershed characteristics (e.g., MeHg concentration in water, MeHg and total Hg (HgT) in sediment, forest cover, water column DOC and pH) and food web dynamics (e.g., primary productivity and food chain length). Reservoir stratification and turnover are described, and the impacts of those processes on MeHg production and bioaccumulation are explained. The chapter uses appropriate support from the literature to illustrate that sediment and water HgI concentrations alone cannot explain MeHg concentrations in fish. An understanding of the variables discussed in the chapter can provide an underpinning for modelling MeHg bioaccumulation and developing approaches to reduce MeHg in fish.

The review presents a conceptual model that is largely summarized in figures 4.2 and 4.3. In this model, inorganic mercury settles from the water column to sediments (p. 4-4, 4th paragraph), where it is converted to MeHg (p. 4-4, 1st – 3rd paragraphs). Subsequently, MeHg is taken up by algae (Figure 4.3), and ultimately biomagnifies through the food web causing elevated levels in top predatory fish. As a result, MeHg in water is a strong predictor of MeHg in fish (p. 4-2, 4th bullet point and p. 4-4, 4th paragraph).

<u>RESPONSE TO JMB-1</u>

The reviewer's support for conclusion 1 is noted.

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[1] Reviewers are not obligated to address all conclusions. See top of page 2 of August 7, 2017 transmittal letter from Bowes to Mumley: "Each reviewer was asked to address each topic, as expertise allows, in the order given." Each of the transmittal letters to reviewers also states this.

COMMENT JMB-2

This description is valid as far as it goes, but a weakness in the conceptual model is that it doesn't strongly link sediment MeHg production to water concentrations. The accumulation of MeHg in anoxic hypolimnetic waters is mentioned in section 4.3.2 (p. 4-18, 3rd paragraph), but a more thorough consideration of factors influencing MeHg transport from sediment to water would strengthen the model.

RESPONSE TO JMB-2

The scientific literature points to diffusion being the main mechanism for transport of methylmercury from sediment to water. Accordingly, the staff report in section 4.1.1 describes diffusion as the mechanism for transport of methylmercury out of sediment porewater and into reservoir water. Matthews and other researchers (2013) at Onondaga Lake noted, "However, substantial uncertainty remains regarding the mechanisms that control the mobilization of methylmercury from sediments." Despite this uncertainty, the Onondaga Lake researchers proceeded to first pilot test, and after success, proceeded to full-scale application of nitrate application to the sediment-water interface in Onondaga Lake (see staff report section 7.3.2).

Bioturbation is another mechanism for transport of methylmercury from sediment to water. Bioturbation, that is organisms digging into bottom sediments, could release methylmercury into the hypolimnion. In contrast to nitrate application or anoxic conditions, application of oxygen at the sediment-water interface could support additional organisms, which in turn could increase bioturbation. However, oxygen should reduce the production of methylmercury, so that bioturbation likely will not result in a net increase in transport of methylmercury from sediment to water.

COMMENT JMB-3

Furthermore, it isn't clear if initial bioaccumulation occurs in the pelagic or benthic environment (or both).

RESPONSE TO JMB-3

Significant, initial bioaccumulation (i.e., bioconcentration from water to organism) occurs in reservoirs in the pelagic environment. Section 4.2.1 describes that "the single largest increase in methylmercury concentration in the pelagic food web occurs between water and phytoplankton or seston with a ~100,000-fold increase in methylmercury concentration (Wiener et al. 2003). Subsequent trophic level transfers (e.g., herbivores to zooplankton, prey fish to piscivorous fish) typically have methylmercury concentration increases of only two to five-fold (Figure 4.3)."

Although bioconcentration also occurs in the benthic environment, it is of less interest for control purposes. For control purposes, it is appropriate to focus on ways to reduce bioconcentration to less than ~100,000-fold increase, because lower methylmercury concentrations in phytoplankton would be transferred up the food chain. Stewart and

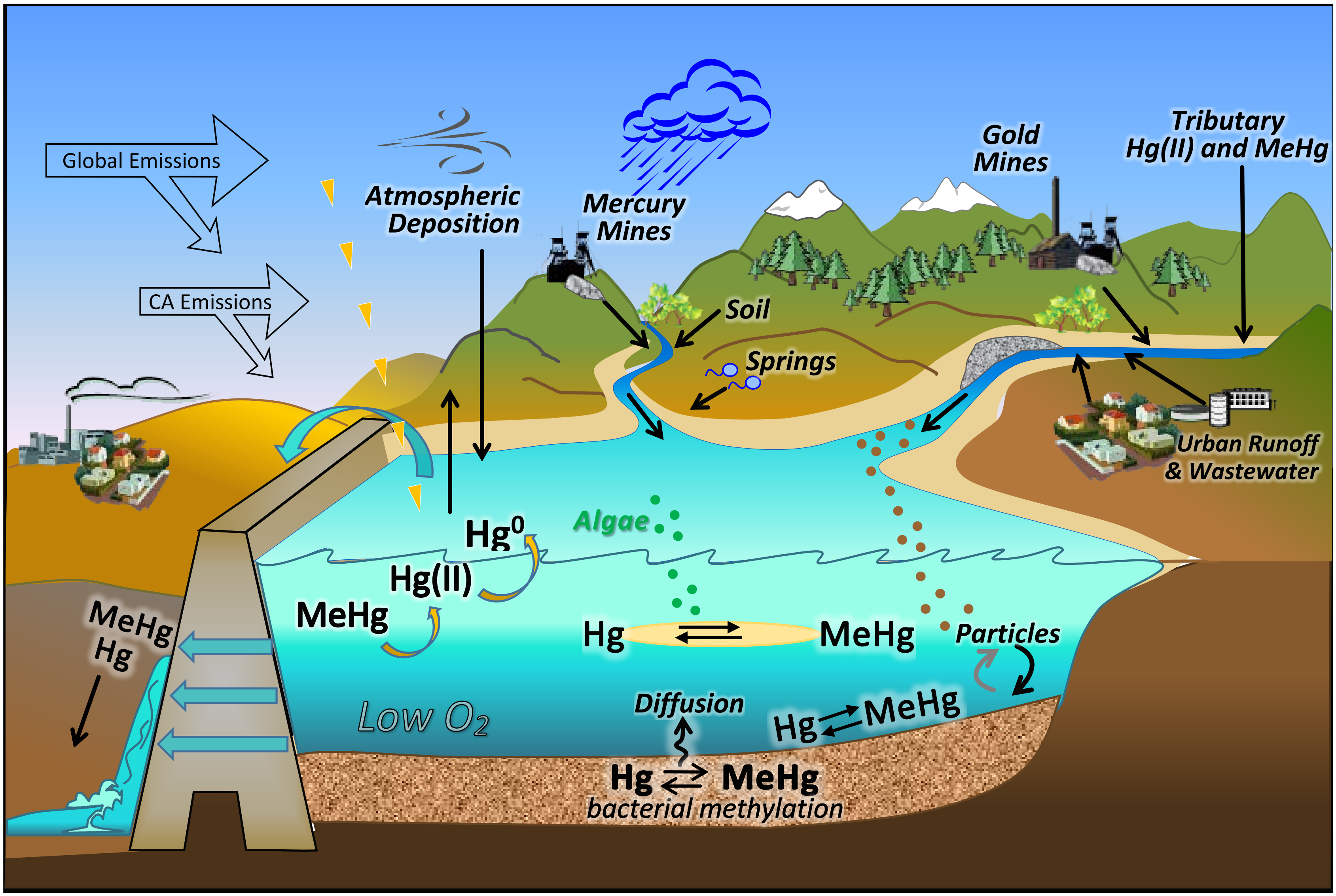
others (2008) studied the food web and methylmercury cycling in Camp Far West Reservoir and found overall higher methylmercury concentrations in the pelagic-based food web relative to the benthic-based food web, and confirmed that the difference was set at the base of the food webs.

However, recognizing that in some cases methylmercury controls will address the benthic food web, such as oxidant application to the hypolimnion, the conceptual model in the staff report in section 4.2.1 has been revised, as follows.

> **[*Third paragraph*] Biomagnification, the process where a contaminant concentration increases in each step of the food web, is especially important at the bottom of the food web. This is because the single largest increase in methylmercury concentration in the pelagic food web occurs in the photic zone between water and phytoplankton or seston with a ~100,000-fold increase in methylmercury concentration (Wiener et al. 2003). Subsequent trophic level transfers (e.g., herbivores to zooplankton, prey fish to piscivorous fish) typically have methylmercury concentration increases of only two to five-fold (Figure 4.3).**
>
> **[*New fourth paragraph*] Although the ~100,000-fold increase in methylmercury in the pelagic food web in the photic zone makes it an enticing control point, the benthic food web may also offer opportunities for control. Eagles-Smith and others (2008) studied Clear Lake by chance before and after a non-native prey fish, threadfin shad, was introduced. The introduced shad outcompeted native planktivorous species for zooplankton, causing native fishes to shift from pelagic to benthic prey, which resulted in a 50% increase in methylmercury bioaccumulation in native planktivorous fish. Stewart and others (2008) found that dietary and stable isotopic evidence also suggests there is an important role for benthic organisms (crayfish and midge larvae) in mitigating methylmercury bioaccumulation.**

Also in response, Figure 4.1 (Mercury cycling in reservoirs) has been revised to show, from left to right: multi-depth water discharge (applicable to some reservoirs); photodemethylation; algae settling and methylation in the metalimnion; settling of particulates; and emergent vegetation and cattle grazing in upstream tributary.

Caption (changes in underline): The top of the graphic depicts sources of mercury (both natural and anthropogenic) to reservoirs, which are primarily inorganic mercury. Once the mercury is transported to the reservoir some of the mercury is lost back to the atmosphere through demethylations and evasion and some is transported downstream; however, the majority of the mercury settles in the bottom sediment of the reservoir. The inorganic mercury that remains in the reservoir can be converted to methylmercury by anaerobic sulfate-reducing bacteria in anoxic sediment or in the anoxic hypolimnion (dark blue) or in the metalimnion during thermal stratification. Some methylmercury is converted back to inorganic mercury through both abiotic and biotic processes, and some of the methylmercury is bioaccumulated up the reservoir's food web. The revised Figure 4.1 follows.


Global Emissions
CA Emissions
Atmospheric Deposition
Mercury Mines
Gold Mines
Tributary Hg(II) and MeHg
Soil
Springs
Urban Runoff & Wastewater
Algae
Hg0
Hg(II)
MeHg
MeHg
Hg
Hg
MeHg
Particles
Low O2
Diffusion
Hg MeHg
Hg MeHg
bacterial methylation

<u>COMMENT JMB-4</u>

Section 4.2.2 describes biodilution, the process whereby higher phytoplankton density leads to lower MeHg concentration (p. 4-12, 2nd paragraph, and Appendix A). Some further discussion of other factors that control MeHg concentrations at the base of the food web would provide a stronger linkage between MeHg production and bioaccumulation in fish.

<u>RESPONSE TO JMB-4</u>

In response to comments JMB-5 and CCG-69, staff reviewed a new synthesis paper, and the staff report was revised as described in response to JMB-5. However, the new synthesis paper does not provide any further discussion of factors other than those discussed in the staff report that control methylmercury concentrations at the base of the food web. Therefore, no changes were made to the staff report in response to JMB-4.

Specific comments on Chapter 4:

<u>COMMENT JMB-5</u>

p. 4-3, 3rd paragraph, line 4. Although fewer mercury methylating iron-reducing bacteria have been identified, they may methylate at rates comparable to SRB and may be important Hg methylators in iron-rich environments (e.g. Fleming, E.J. et al. 2006. App Env Microbiol 72:457-464).

<u>RESPONSE TO JMB-5</u>

In response to JMB-5, the third paragraph of section 4.1.1, The Mercury Methylation Process: Inorganic Mercury Transforms to Aqueous Methylmercury, has been revised as follows.

> **In the aquatic environment, mercury is methylated into methylmercury most commonly by anaerobic sulfate-reducing bacteria primarily at the sediment-water interface, but also in anoxic waters. Other bacteria, such as iron-reducing bacteria, also are known to methylate mercury <u>and may be important mercury methlylators in iron-rich environments</u>~~to a lesser degree than anaerobic sulfate-reducing bacteria~~ (Benoit 2017). <u>Other methylating microorganisms include methanogens and some fermentative and syntrophic Firmicutes (Hsu-Kim et al. 2018). Hsu-Kim and others (2018) describe methylation occurring in low-oxygen conditions: “Methylating organisms are prevalent in benthic aquatic settings (e.g., saturated soil and sediment…) as well other microenvironments with steep redox gradients (e.g., periphyton, biofilms, microbial flocs).”</u> Methylmercury <u>produced in sediments</u> can diffuse out of sediment porewater and bind to organic matter in suspended particulates and detrital matter, or it can be absorbed by phytoplankton directly from water. Methylation can occur in both lake sediment and in upstream river banks and wetlands.**

Importantly, methylation only occurs after oxygen and nitrate have been partly or mostly depleted, whether by iron- or sulfate-reducing bacteria. Therefore, the reservoir program's focus on anoxia (i.e., water chemistry pilot tests) remains appropriate.

COMMENT JMB-6

p. 4-4, 3rd paragraph, lines 1-4. This citation doesn't illustrate a relationship between sediment HgI and MeHg, which is the focus of the section. It belongs in the discussion of stratification, low oxygen and MeHg (p. 4-18).

RESPONSE TO JMB-6

The staff report in section 4.1.2, Inorganic Mercury Concentration in Sediment, first sentences of third paragraph, has been revised as follows:

Increasing methylmercury concentration with depth is another indicator that sediment inorganic mercury is correlated to aqueous methylmercury (also see section 4.3.2). ~~Also,~~ ~~a~~Aqueous methylmercury increased with water depth in a boreal lake, and the authors suggested that the methylmercury was formed in sediment (Sellers et al. 2001). Aqueous methylmercury also generally increased with depth in the hypolimnion (areas of low oxygen during summer stratification) in Guadalupe River watershed reservoirs.

COMMENT JMB-7

p. 4-6, 2nd paragraph. The last sentence in the paragraph is unclear. Since the reservoirs have different Hg sources, differences in bioavailability *are expected* among them.

RESPONSE TO JMB-7

The staff report in section 4.1.2, Bioavailability of Inorganic Mercury, last sentence, has been revised as follows:

Consequently, relative differences in bioavailability are not germane to ~~these~~ reservoirs whose mercury is dominated by one source.

COMMENT JMB-8

Section 4.1.2. This section reviews factors that influence MeHg production, but the effect of pH on methylation isn't discussed until the 6th paragraph on p. 4-11. Perhaps that paragraph should be moved here.

RESPONSE TO JMB-8

The discussion in section 4.2.2, Factors Affecting Bioaccumulation of Methylmercury, discusses correlations between pH and *aquatic biota* methylmercury concentrations (page 4-11), whereas section 4.1.2 discusses "Factors Affecting Aqueous Methylmercury Concentrations." Therefore, no change was made to the staff report.

COMMENT JMB-9

p. 4-8, 1st paragraph. Sediments don't have to be suspended to be available for methylation. Peak methylation rates often occur just below the sediment water interface. Sedimentation "removes" HgI when lower Hg materials rapidly cover sediments with higher Hg concentrations.

RESPONSE TO JMB-9

Staff report section 4.1.3 has been revised as follows:

4.1.3 *Potential Loss Pathways for Inorganic Mercury and Methylmercury*

Both methylmercury and inorganic mercury can be lost from the aquatic reservoir environment in a variety of ways, which are discussed below.

…

Sedimentation

Sediment-bound mercury commonly becomes trapped in reservoirs through sedimentation, which is when mercury in water settles out of the water column to sit on the reservoir bottom. ~~This~~ Settled mercury can be methylated; peak methylation rates often occur just below the sediment-water interface. Recently settled mercury can be re-suspended into the water column and thus be available for methylation~~, or.~~ Eventually, settled mercury-laden sediments ~~it~~ can be buried by incoming sediment with lower mercury concentration making the deeper sediments ~~and~~ unavailable for methylation.

COMMENT JMB-10

p. 4-16, 2nd full paragraph. The second sentence is a little misleading because the mechanisms overlap and because fall turnover doesn't increase methylmercury production. It would be more correct to summarize that thermal stratification can cause low oxygen concentrations in sediments and bottom waters; therefore, it can lead to enhanced production and/or release of MeHg to the water column.

RESPONSE TO JMB-10

Staff report section 4.3.2, page 4-16, has been revised as follows:

Four~~Five~~ important reservoir-specific processes with potential to increase methylmercury production are described below. These processes are (1) thermal stratification (because it can cause anoxia); (2) anoxia; (3) ~~fall turnover; (4)~~ redox potential and sulfate reduction; and (4)~~(5)~~ reservoir water level fluctuations.

COMMENT JMB-11

Section 4.3.2. This section would be clearer with some reorganization. Specifically, if the section on “Redox Potential and Sulfate Reduction” were inserted between the 3rd and 4th paragraphs on p. 4-18, all of the consequences of stratification would be discussed together before considering fall turnover.

RESPONSE TO JMB-11

Comment noted.

COMMENT JMB-12

p. 4-19, 2nd paragraph. Given the somewhat conflicting evidence given here, should epilimnetic sediments be considered significant sources of MeHg to the water column in California reservoirs?

RESPONSE TO JMB-12

Agree that the scientific literature identifies that methylation occurs in epilimnetic sediments; text was added to the staff report in response to JMB-12: “Methylating organisms are prevalent in benthic aquatic settings (e.g., saturated soil and sediment….” Moreover, manganese oxides are another developing technology intended to reduce methylation, and may be effective to reduce methylation in either or both epilimnion or hypolimnion sediments. In response to CCG-97, the staff report and Mercury Reservoir Provisions were revised to add manganese oxides as a potential pilot test.

COMMENT JMB-13

p. 4-21. 2nd full paragraph. An additional reference showing increased fish MeHg concentrations due to water level fluctuations: Selch, T.M. et al. 2007. Bull Environ Contam Toxicol 79:36-40.

RESPONSE TO JMB-13

Appreciate this and next (JMB-14) constructive comments. Staff report section 4.3.2, Reservoir Water Level Fluctuations, was revised to incorporate these additional references, as follows:

Reservoir water level fluctuations influence the methylmercury levels in biota in lakes and reservoirs. For example, a statistical positive correlation was observed between largemouth bass mercury concentrations and the magnitude of reservoir fluctuations in California reservoirs (Melwani et al. 2011). Evers and others (2007) identified large water level fluctuations, in addition to elevated atmospheric mercury deposition and high landscape sensitivity (e.g., more wetlands), as the major mechanisms in contributing to biological (fish and birds) mercury hotspots in northeastern United States and southeastern Canada. Similarly, Selch and others (2007) identified a large water level fluctuation as the major mechanism contributing to an increase in methylmercury in sport fish in North Dakota. In addition, Sorensen and others (2005) …

Using laboratory experiments, Gilmour and others (2004) hypothesized that methylation stimulation from drying and rewetting was likely due to the oxidation of organic matter and sulfate while the sediment was dry. This oxidized material could later fuel bacterial sulfate reduction once the soil was rewetted. Oxygen levels in the rewetted sediments began to decline within 24 hours, and anoxia was fully developed within 5 days.

<u>In sediments from an Oregon reservoir located downstream of a mercury mine, Eckley and others (2017) found sediment methylmercury concentrations were more than three-fold higher in areas experiencing water-level fluctuations compared to permanently inundated sediments.</u> In the field, Roulet and others (2001) measured methylmercury production in the sediment …

<u>COMMENT JMB-14</u>

p. 4-21, 3rd full paragraph. An additional reference supporting stimulated methylmercury production due to water level fluctuations: Eckley, C.S. 2017. Environ Pollut 22:32-41.

<u>RESPONSE TO JMB-14</u>

See response to JMB-13.

Conclusions 2–4.

<u>COMMENT JMB-15</u>

Conclusion 2, 3 and 4 are supported in Chapter 5 and Appendices A and B. Chapter 5 describes a quantitative linkage analysis aimed at identifying predictors of fish MeHg concentrations in California Reservoirs. First, associations between seventy reservoir variables and fish MeHg concentrations are determined using correlation analysis (section 5.1.2). Next, strong correlates from the first step are used in a multiple linear regression model to identify the combination of variables controlling reservoir fish MeHg (Model 1, section 5.1.3). Further regression analyses are used to determine target levels for water column MeHg (Models 2 and 3, section 5.2) and sediment HgT (Models A and B, section 5.3) concentrations.

Throughout the chapter, the term “aqueous” is used for water column HgT and MeHg concentrations. The description of the water data states that “the linkage analysis uses results for unfiltered samples collected throughout the water column…”

<u>RESPONSE TO JMB-15</u>

The reviewer’s support for conclusions 2–4 is noted.

<u>COMMENT JMB-16</u>

(p. 5-7, 2 paragraph) The term “aqueous” normally refers to the dissolved phase, so it should be replaced with “water column” to be consistent with common scientific usage and to avoid confusion. This overlap occurs in some places in Chapter 4 as well, and care should also be taken there to indicate whether “aqueous” refers to filtered or unfiltered samples from the water column or pore water.

RESPONSE TO JMB-16

Water Board regulatory work uses the term “aqueous” to distinguish the water matrix from soil and sediment matrices. For clarity, the list of acronyms and terms in the staff report has been revised to include the following:

Aqueous	**Aqueous refers to water column, and is used to distinguish water matrix from soil and sediment matrices. Reservoir water column samples may be filtered (dissolved) or unfiltered (total).**
Water column	**Water column refers to aqueous media, and is used to distinguish water matrix from soil and sediment matrices.**

For clarity, staff report p. 5-7 description of water data has been revised as follows:

Water Data

Water column c~~C~~oncentration data for each reservoir were summarized using geometric means if the data did not contain non-detect values.[2] Appendix B describes the summary methods used for data with non-detect values.

Aqueous (reservoir water column) methylmercury concentration data are available …

Conclusion 2.

COMMENT JMB-17

Conclusion 2 is consistent with the results of multiple regression Model 1. This model explains 84% of the variability in standardized fish MeHg concentration across reservoirs with three variables: ratio of water column MeHg to chlorophyll concentration, water column HgT concentration and mean annual water level fluctuation. These variables have been seen as important predictors of fish MeHg in previous studies, as discussed in Chapter 4.

RESPONSE TO JMB-17

The reviewer’s support for conclusion 2 is noted.

COMMENT JMB-18

Although those three variables are identified as “most important”, two of them are not pursued for further evaluation in models 2 and 3. The reasons for not considering water level fluctuations are outlined on p. 5-11 (5th full paragraph). Further explanation should be provided for: 1) why water column HgT concentration isn't further evaluated, and 2) why sediment HgT concentration is pursued instead as a factor to control. All of the statistical methods show the strengths of relationships, rather than cause-and-effect. Therefore, it is essential to provide a reasonable and literature-supported mechanism for how sediment HgT influences (controls) fish MeHg levels. Overall, a better description of the insights gained from Model 1 is needed.

RESPONSE TO JMB-18

The staff report explains that there were models developed to predict *fish* methylmercury (section 5.1.3) and other models to predict *aqueous* methylmercury (section 5.2). Model 1 is the best of several models to predict fish methylmercury, and the various mechanisms are described on pp. 5-10 and 5-11. The reviewer is correct that p. 5-11 explains why the implementation plan does not consider water level fluctuations. The staff report p. 5-10 has been revised to explain that mercury source controls, aqueous methylmercury, and chlorophyll a are further evaluated, as follows.

Aqueous total mercury concentration. Methylmercury is produced by the methylation of inorganic mercury. In laboratory experiments, positive correlations have been observed between total mercury and methylmercury in the environment. The total mercury in the aquatic environment primarily is comprised of inorganic mercury, so increasing the amount of total mercury in the water column of a reservoir will likely result in higher methylmercury concentrations. Incoming inorganic mercury, which is primarily particulate bound, settles to the bottom of reservoirs where it can become methylated. Mercury source controls are further evaluated in Chapter 7 and included in the implementation plan (see Chapter 9).

Ratio of aqueous methylmercury to chlorophyll. …

Last paragraph: **Model 1 and other statistically significant multiple linear regression models (Appendix B) included reservoir chlorophyll a concentration as a negatively correlated predictor variable, either independently or as a ratio with aqueous methylmercury. This indicates that the amount of chlorophyll a is likely an important environmental factor in predicting reservoir fish methylmercury concentrations. Controls for each of aqueous methylmercury and chlorophyll a are further evaluated in Chapter 7 and included in the implementation plan (see Chapter 9).**

Conclusion 3.

COMMENT JMB-19

The first part of **conclusion 3** is supported by the correlation analysis (Table B.3, B.4 and discussion in 5.1.2), which shows that some of the strongest correlates with fish MeHg are factors not associated with HgT loading, e.g., MeHg:chlorophyll-a ratio, longitude and water level flux; all of which had $r \geq 0.3$ (Table B.3). Correlations between Hg sources and fish MeHg concentrations vary from not significant (e.g. watershed development, facilities, mine density, upstream wetlands) to moderately significant (e.g., soil HgT and atmospheric Hg deposition to the watershed). Furthermore, internal Hg pools are strongly correlated with each other, suggesting intensive internal cycling (Table B.4). Considering the results of the correlation analysis, it is reasonable to conclude that a variety of factors influence MeHg concentrations in reservoir fish.

The second sentence in **conclusion 3** is likely true, but it isn't fully supported by the linkage analysis in Chapter 5. Although sediment Hg concentration was strongly correlated with fish MeHg concentration, the linkage analysis doesn't directly include MeHg production or bioaccumulation as factors (Table B.3). The conclusion about the role these two processes makes sense in view of the literature review in Chapter 4, but doesn't follow from results of the modelling efforts in Chapter 5.

RESPONSE TO JMB-19

The reviewer's qualified support for conclusion 3 is noted.

Conclusion 4.

COMMENT JMB-20

Conclusion 4 is supported by two lines of evidence presented in Chapter 5 (and Appendix B). First, many California reservoirs currently have natural background sediment Hg levels, but are still impaired (i.e., fish MeHg levels are higher than the target). For example, among the mercury impacted lakes included in models A and B, 21% and 12% had sediment mercury levels at and below natural background levels, respectively (Table 5.6). Second, these same models predict that only a small percent of reservoirs (<5%) would fully recover if sediments mercury concentrations were reduced to natural background levels, if no other factors were addressed.

The linkage analysis shows that sediment mercury reductions alone are not an effective approach for reaching the MeHg sport fish target.

The end of Chapter 5 analyzes the possibility of using light fertilization to boost primary productivity of oligotrophic reservoirs (reviewed in detail in Appendix A). Models 2 and 3 are used to predict how changes in chlorophyll would affect Hg fish concentrations, and it is determined that fertilization could lower MeHg [*in*] fish independent of any changes in Hg. It would be worthwhile to adapt these models to predict an optimal MeHg:chlorophyll ratio, considering that this ratio was the strongest predictor of fish MeHg concentration. Optimizing this ratio could increase the implementation options; for example, less substantial decreases in MeHg might be effective in more productive reservoirs.

RESPONSE TO JMB-20

The reviewer's support for conclusion 4 is noted and appreciate the constructive comment for how to go about optimizing the methylmercury to chlorophyll ratio.

However, it is crucial to evaluate fertilization on a reservoir-specific basis so there is no need to develop a general ratio.

<u>COMMENT JMB-21</u>

Overall, the linkage analysis identifies important variables associated with (and presumably controlling) fish MeHg concentrations in California reservoirs. It uses multiple linear regression, a straightforward statistical method that is commonly used to ascertain important controlling factors in complex environmental systems. The apparent controlling factors are consistent with the literature review in Chapter 4 and can be explained based on known mercury cycling processes.

<u>RESPONSE TO JMB-21</u>

The reviewer's agreement with the approach is noted.

Specific comments on Chapter 5:

<u>COMMENT JMB-22</u>

p. 5-6 3rd and 4th paragraphs. Both of these paragraphs refer to TL4 fish, but the second is probably about TL3 fish. There is also appears to be mistake in the explanation under the caption for Figure 5.2, where TL4 fish are parenthetically described as 150-500 mm.

<u>RESPONSE TO JMB-22</u>

Figure 5.2 shows correlation between *standardized* **fish methylmercury concentrations (length 150 – 500 mm both TL3 and TL4) used in the linkage analysis and** *average* **concentrations corresponding to the sport fish water quality objective (length 200 – 500 mm TL4 or 150 – 500 mm TL3); the caption is correct. However, the staff report has been revised in section 5.1.1, Fish Data, as follows:**

An average methylmercury concentration of 0.2 mg/kg in legal-sized <u>top trophic level</u>~~TL~~4 fish equates to virtually the same concentration in standardized fish methylmercury. Consequently, later in this chapter the sport fish target of 0.2 mg/kg is compared directly to model-predicted standardized fish methylmercury concentrations without adjustment.

An average methylmercury concentration of 0.2 mg/kg in legal-sized <u>top trophic level</u>~~TL~~4 fish is equivalent to 0.21 mg/kg in standardized fish. The two values are almost identical, which confirms the robustness of using standardized fish methylmercury concentrations for assessing compliance with the sport fish target.

<u>COMMENT JMB-23</u>

p. 5-7, 2nd paragraph. Is this paragraph suggesting that bioaccumulation of MeHg *only* occurs in the hypolimnion after fall turnover? This point should be clarified.

<u>RESPONSE TO JMB-23</u>

This topic is discussed in section 4.3.2, which explains that hypolimnetic methylmercury can be transported into epilimnetic waters and bioaccumulated year round. These sentences are not relevant to section 5.1.1, Water Data. Accordingly, they have been deleted from the second paragraph, as follows:

Aqueous methylmercury concentration data are available for 53 reservoirs, though generally there are few measurements for each site. Much more information is available for near-surface, unfiltered water samples than for lower (hypolimnion) in the water column or for filtered samples. Consequently, the linkage analysis uses results for unfiltered samples collected throughout the water column and throughout the year. ~~Methylmercury is largely accumulated in surface waters (epilimnion), even though, as described in the conceptual model, much of it is initially formed in sediments and discharged into the hypolimnion. Methylmercury may accumulate to very high levels in the hypolimnion, as, for example, in Davis Creek Reservoir (Slotton et al. 1997) and reservoirs in the Guadalupe River watershed when they were thermally stratified (Tetra Tech 2005b). This methylmercury bioaccumulates in the food chain at fall overturn when deep waters mix with shallow surface water.~~

<u>COMMENT JMB-24</u>

p. 5-7, 4th paragraph. The term “modern” is used here to describe soil mercury levels and later to describe reservoir sediment levels. This term should be explained more fully here.

<u>RESPONSE TO JMB-24</u>

The term “modern” is defined in Chapter 6 and not relevant to section 5.1.1, Other Reservoir Data. Accordingly, this sentence has been deleted from the first paragraph, as follows:

Sediment total mercury concentration data are available for 62 reservoirs; 43 reservoirs have only 1 or 2 samples, and the remaining have between 3 and 98 samples. Soil total mercury concentration is for upland watershed soils. Soil data was available for 59 reservoirs. ~~These samples are thought to represent modern background soil concentrations.~~

<u>COMMENT JMB-25</u>

p. 5-8, 5th full paragraph. Some of the mercury sources listed here are expected to be sources of MeHg and other predominantly HgI. Perhaps these different types of sources should be considered separately.

<u>RESPONSE TO JMB-25</u>

Not only were these different types of sources considered separately, all variables were considered separately (see first sentence of section 5.1.2).

COMMENT JMB-26

p. 5-9, 3rd full paragraph. A little further explanation is needed of how the variables were chosen for the model. Table B.3 shows that a few non-significant correlates were included and a few significant correlates were not. What was the rationale?

RESPONSE TO JMB-26

The staff report in third and fourth full paragraphs on page 5-9 explains that, "… all (17) variables with statistically significant associations with fish methylmercury were evaluated … in a suite of multiple linear regression models … As described in Appendix B, best subsets regression was used to determine the combination of factors that explained the greatest amount of variability in fish methylmercury. The overall measures of quality (Mallow's Cp, PRESS, and adjusted R^2) of the models were used to determine the best models."

The rationale for non-significant and significant correlates is provided in Appendix B, Part 3, Correlations.

COMMENT JMB-27

p. 5-11, 3rd full paragraph. The statement that "water level fluctuations do not increase aqueous MeHg concentrations" seems unlikely in view of the literature. The lack of correlation may result from the nature of the dataset, and a stronger relationship would likely be observed for hypolimnetic samples.

RESPONSE TO JMB-27

Agree.

COMMENT JMB-28

p. 5-11, 4th full paragraph. Given the importance of benthic biota as food for aquatic organisms, what is the potential for MeHg transfer via this route? The role of the benthic food web in pelagic bioaccumulation should be briefly reviewed in Chapter 4 (as mentioned above).

RESPONSE TO JMB-28

See response to JMB-3.

COMMENT JMB-29

p. 5-13, last paragraph. For the sake of comparison, it would be helpful to calculate the target water column MeHg concentration predicted from these BAF values.

<u>RESPONSE TO JMB-29</u>

Comment noted.

Conclusions 5–7.

<u>COMMENT JMB-30</u>

Conclusions 5, 6 and 7 are supported in Chapter 6. This chapter assesses potential sources of inorganic Hg to California reservoirs, by considering the watersheds of 74 impaired 303(d)-listed reservoirs.

This assessment begins by determining the natural (BG) and modern (MBG) Hg concentrations in the reservoir watersheds. This determination uses surface soils to reflect modern Hg levels and deep core soils and sediments to reflect natural background. Since California has varying native Hg levels, representative BG and MBG concentrations are determined for each of three areas, defined as trace mercury, mercury-enriched and mineralized. The BG and MBG levels are compared to surface sediment concentrations in 44 reservoirs for which this data is available (Table 6.4). This analysis shows that a significant proportion of the reservoirs have sediment Hg concentrations at natural (15) or modern (13) background levels. Therefore, for 64% of the reservoirs the dominant source is likely background Hg in watershed soil. Although MBG Hg concentrations have resulted from industrial-era Hg deposition, the term “background” is used because watersheds will continue to provide this legacy mercury to reservoirs for centuries. For reservoirs at or below MBG levels, source reductions in the watershed (e.g. mining and point sources) are not likely to reduce sediment Hg loads or lower MeHg concentrations in fish. This analysis is consistent with conclusion 7. The key assumptions behind this conclusion are that 1) the measured soil and sediment concentrations adequately represent typical levels in California, and 2) watershed Hg concentrations with modern backgrounds will remain high for a long period of time. In view of the large datasets presented in Tables 6.2, 6.3 and 6.4, the first assumption is likely valid. The second assumption is supported by the literature.

The remainder of Chapter 6 evaluates a number of potential sources of Hg to reservoirs including mining waste (section 6.3), atmospheric deposition (section 6.4), urban run-off (section 6.5), facility discharges (section 6.6), and other sources (section 6.7). Assessments of mining, urban run-off and facilities discharges use a geographical approaches to identify the presence of those sources within watersheds of the 74 impaired reservoirs. Mercury deposition is assessed using the USEPA’s Regional Modeling System for Aerosols and Deposition (REMSAD, details in Appendix D). The other sources (groundwater, springs, coastal fog and anthropogenic erosion) are identified as possible contributors of Hg to reservoirs, although adequate data is not available to characterize the magnitude of the contributions.

RESPONSE TO JMB-30

The reviewer's support for conclusions 5, 6, and 7 is noted.

Conclusion 5.

COMMENT JMB-31

Conclusion 5 is consistent with the overall assessment. Evidence for the "uneven distribution of mercury sources" is provided by the geologic data, which show that 40% of the reservoirs occur in the enriched zone (Figure 6.3), so they receive more Hg from soil than those in low Hg areas. Also, historical mining sites are not evenly distributed among the watershed, both in terms of type (mercury, gold, silver) and density (Figure 6.9). In fact, about 40% don't contain any historical mines in their watersheds at all (p.6-12, 3rd bullet point). Although the majority of the 303(d)-listed reservoirs are upstream of urban areas and their associated facilities, one may receive substantial facilities discharges (p. 6- 36, third bullet point). The REMSAD model identifies variability in both the magnitude of Hg deposition (Figure 6-17) and the relative contribution of local versus global sources across California (Figure 6-18). Thus, there is not a single source of Hg to all impaired reservoirs.

RESPONSE TO JMB-31

The reviewer's support for conclusion 5 is noted.

Conclusion 6.

COMMENT JMB-32

As stated in **conclusion 6**, the assessment indicates that historic mine sites and atmospheric deposition are the most important current anthropogenic sources of Hg to impaired reservoirs. The evaluation of historic mine sites as Hg sources uses a number of federal and state datasets (p. 6-18, bullet points) representing the locations of historical mercury, gold, and silver mining features, including prospects, productive mines, tailings, etc. These features are mapped (Figures 6-6 to 6-8) to identify the number, density, and production of historic mines in the watersheds of the 303(d)-listed reservoirs (Figure 6.9). In this way, it is determined that 48 (65%) of the reservoirs could be affected by mining waste, because they have at least one mining feature in their watersheds. Of those 48 reservoirs, 41 have more than 50 productive sites (p. 6- 19, 2nd bullet point). After historical mines are located within watersheds, their importance as a source is inferred from sediment Hg concentrations in the 44 reservoirs with sediment data. Of the 26 (60%) of those reservoirs that had elevated mine densities, 50% have elevated mercury levels, indicating mine waste as a probable Hg source (p. 6-20, last paragraph). The other half of the reservoirs have Hg levels below modern and even natural Hg levels. If this analysis is extrapolated more broadly, about one-third of impaired reservoirs in

California likely receive mining waste as an Hg source. This possibility warrants the conclusion that historic mines are an important source of Hg to California reservoirs.

A second major source of Hg identified in the Chapter 6 is atmospheric deposition. The assessment of this source (section 6.4) first reviews historical mercury emissions both globally and in California to identify key sources and trends. Facilities mapping reveals the "clustered" nature of emissions sources in the state (Figure 6.15). Although some wet deposition data is available, it is deemed too limited for a state-wide assessment, so atmospheric Hg deposition is modelled with REMSAD. This model calculates wet and dry deposition of atmospheric pollutants, and it is also able to track emissions (p. 6-27, 4th paragraph). The tracking feature, called "tagging", is useful for attributing Hg deposition to California emissions sources. First, the model is used to quantify anthropogenic Hg deposition from global, regional and local sources. Results of this simulation (Table 6.5) reveal that California anthropogenic sources account for about 10% of total Hg deposition in the state, whereas global anthropogenic sources account for about 60%. Atmospheric deposition is deemed to be a major source of Hg for reservoirs with few or no point sources or historic mining activity in their watersheds (p. 6-31, 2nd paragraph). Twenty-nine (62%) of the 47 303(d)-listed reservoirs fit those criteria, suggesting that atmospheric deposition is a primary source of Hg to a substantial proportion of California reservoirs.

RESPONSE TO JMB-32

The reviewer's support for conclusion 6 is noted.

Conclusion 7.

Note to readers: reviewers are not obligated to address all conclusions, and this reviewer did not address Conclusion 7, "Reducing watershed mercury sources is not expected to result in substantial reductions in reservoir sediment mercury concentrations and fish methylmercury concentrations in many reservoirs." However, in concluding "Big Picture" comments, the reviewer appears to state agreement with Conclusion 7, as follows:

The Staff Report shows that a variety of control options need to be applied on a reservoir-specific basis in order to meet the target sport fish MeHg concentration. This strategy is necessitated by the breadth of Hg sources, complex within-reservoir processes, and variable characteristics of reservoirs and their watersheds.

Conclusion [*8*].

COMMENT JMB-33

Conclusion [*8*] is also supported by output of the REMSAD model. Model-derived deposition maps characterize patterns throughout the state, including the patterns for total Hg deposition (Figure 6.17) and deposition attributed specifically to California sources (Figures 6.18 and 6.21). Those deposition maps show that global emissions dominate for much of the state, although there are hotspots where California emissions account for 20% or more of the total (Figure 6.23). Overlaying the REMSAD deposition patterns on the watershed map shows that 21 of the 303(d) listed reservoirs are in one of these hot spot areas. Further analysis reveals that among the 29 reservoirs where atmospheric deposition is the dominant anthropogenic source of Hg, 12 have a significant (>20%) contribution from California sources. For the remaining 17 reservoirs, Hg deposition is attributed to predominantly global anthropogenic sources (p. 6-31, 2nd paragraph). The finding that many reservoirs receive deposition from primarily global emissions is reasonable in view of the predominance of global deposition statewide and the magnitude of current emissions outside of North America (e.g. Figure 6.11 and section 6.4.3). Lowering local emissions will not diminish impairment in all deposition-dominated reservoirs in the state.

RESPONSE TO JMB-33

The reviewer's support for conclusion 8 is noted.

COMMENT JMB-34

An important assumption underlying **conclusions 6 and 7** is that the REMSAD model reliably recreates anthropogenic Hg deposition. The REMSAD model has been peer-reviewed (p. D-2) and validated through comparison to wet and dry deposition rates in California and Nevada (p. D-3). Although the model may underestimate point source emissions (p. D-3), discrepancies between modelled and actual deposition rates aren't likely to change the conclusions about the significance of atmospheric deposition as a source of Hg or the relative contribution of California emissions to total Hg deposition

RESPONSE TO JMB-34

The reviewer's agreement with the approach is noted.

COMMENT JMB-35

An important assumption of the overall assessment in Chapter 6 is that the 74 303(d)-listed reservoirs and their watersheds are characteristic of other reservoirs in California. This assumption seems logical given the broad geographic distribution of the reservoirs (Figure 6.1), their occurrence within both enriched and trace mercury areas (Table 6.4), the range of sediment mercury concentrations (Table 6.4), the variety of mine types and densities (Figure 6-9), and the broad range of atmospheric deposition in their watersheds (Figure 6-17).

<u>RESPONSE TO JMB-35</u>

The reviewer's agreement with the approach is noted.

Specific comments on Chapter 6:

<u>COMMENT JMB-36</u>

p. 6-7, last paragraph. What was the cutoff date between modern and natural for dated sediment cores?

<u>RESPONSE TO JMB-36</u>

The cut-off date for natural background is pre-industrial, i.e., 1850. For clarity, staff report section 6.2.2 has been revised as follows: Understanding natural background (pre-industrial<u>; prior to 1850</u>) conditions is critical for determining which reservoirs are substantially affected by modern, industrial-era sources.

<u>COMMENT JMB-37</u>

p. 6-9, last bullet point. Is this concentration determined from the data in Tables 6.3 and 6.4?

<u>RESPONSE TO JMB-37</u>

This concentration (0.3 mg/kg for modern background in Coast Ranges) is determined from the data in Tables 6.2 (sediment) and 6.3 (soil) and illustrated on Figure 6.4. See page 6-9, "The range of mercury concentrations in soils and sediments throughout the state also affects our understanding of modern background conditions (Tables 6.2 and 6.3, Figure 6.4). …"

<u>COMMENT JMB-38</u>

p. 6-20, last full paragraph, lines 2-5. This statement seems inconsistent with p. 6-11. The 7th bullet point on p. 6-11 says that of the 16 reservoirs with elevated Hg concentration, 13 are downstream of historic mine sites and 3 are in urban areas.

<u>RESPONSE TO JMB-38</u>

Page 6-11, the 7th bullet point is correct:

- **16 of 44 reservoirs have sediment mercury concentrations greater than modern background levels, 13 of which are downstream of historic mine sites and 3 of which are in heavily urbanized areas (see sections 6.3, 6.4, and 6.5 for more information about mining and urban sources).**

In response to JMB-38, the staff report on page 6-20, last full paragraph has been revised as follows:

As discussed in section 6.2.4, reservoir surface sediment mercury data are available for 44 of the 74 reservoirs on the 2010 303(d) List. <u>Of these 44, 13 have</u>~~16 of the 303(d)-listed reservoirs with~~ average sediment mercury concentrations elevated above modern background levels ~~have~~<u>and are in</u> watersheds with moderate to high mercury and gold mine site densities. <u>Of these 13, t</u>~~T~~<u>he</u> 9 reservoirs with high mine site densities and elevated sediment mercury concentrations include the following: …

Conclusions 9–11.

<u>COMMENT JMB-39</u>

Support for **conclusions 9, 10 and 11** is provided by Chapter 7 and Appendix H. Chapter 7 discusses strategies that could potentially lower Hg concentrations in reservoir sediments, waters, and/or fish. The chapter provides examples of successful remediation from previous studies reported in the literature, and points out limitations and drawbacks associated with each strategy. It also predicts the success of each of the strategies for the 303(d)-listed reservoirs.

The defining reservoir characteristics that are used for the prediction are summarized in Table H.1, and the chapter culminates with a summary of the remediation techniques that are likely to be successful in each of the reservoirs (Table 7.1).

The analysis in section 7.2 supports **conclusion 10** because it shows that source reductions alone will not be effective for reducing fish MeHg to the target in most of the reservoirs. It explains that reduced loading from mining sources will only be effective in a subset of reservoirs in mine- impacted watersheds, because many of these reservoirs already have sediment HgT levels below modern background levels (p. 7-11, 2nd paragraph). Furthermore, elevated fish MeHg levels are currently found in some reservoirs with background mercury levels, so reductions in mine waste might not achieve the fish MeHg target even if initially high sediment levels were reduced by mine mitigation (e.g., 7-12 2nd full paragraph). Similarly, only a small number of reservoirs with atmospheric deposition as the dominant source are expected to recover if California emissions are reduced, because most receive Hg primarily from global emissions (Chapter 6). Reducing local emissions is expected to lower fish MeHg concentrations in only four of the 303(d)-listed reservoirs (p. 7-17, 1st bullet point). Overall, reduction of anthropogenic Hg sources in the state are expected to measurably reduce MeHg levels in fish in 40% of 303(d)-listed reservoirs, but rapid and significant decreases due to source reduction are only expected for 7 (9%) of them (Table 7.1). Given the limitations of source reductions as a means of lowering fish MeHg, a variety of reservoir-specific interventions will be needed to reach the MeHg sport fish target.

Chapter 7 supports **conclusions 9 and 11** by presenting a range of options and assessing the likelihood of their success in California reservoirs. Section 7.2 considers mercury source reductions, and determines that it could be effective for *some* reservoirs. For example, reduction of mining wastes may be effective in reservoirs that have high mine density in their watersheds and high sediment and fish HgT concentrations (p. 7-11, 1st paragraph). Ten of the 46 reservoir with sediment Hg data fit this description. Previous research shows that reductions in atmospheric deposition can lead to relatively rapid (years to decades) reduction in fish Hg levels in water bodies where atmospheric deposition is the primary source of Hg (reviewed p.7-15, last paragraph). Similarly, reductions in California emission are likely to lessen impairment in reservoirs that receive > 50% of atmospheric deposition from California sources (p. 7-17, 1st paragraph). Forestry practices that minimize the transport of DOC-bound mercury are likely to lead to reductions in fish MeHg concentrations in reservoirs in rural areas (p. 7-27, 3rd and 5th paragraphs), whereas lowering MeHg in MS4 discharges could reduce MeHg in the water column and fish in reservoirs in urban areas (p. 7-37, last paragraph). Overall, section 7.2 shows that source reduction measures can have a positive impact, but their applicability varies among reservoirs.

Chapter 7 further supports **conclusions 9 and 11** in its discussion of approaches that lower MeHg production by reducing methylation rates or sediment HgT concentrations (section 7.3). Hypolimnetic oxygenation has been shown to reduce MeHg in the water column in previous studies in California and elsewhere (reviewed p. 7-42 and 7-43). The analysis in section 7.3.1 suggests that this method could work in reservoirs that have strong thermal stratification that leads to bottom water anoxia; this characteristic applies to more than 50% of the 303(d) listed reservoirs (p. 7-44, 1st paragraph). Those same reservoirs could see reductions in fish MeHg levels from hypolimnetic nitrogen additions (p. 7-45, 3rd paragraph), because this approach functions by raising redox potential, thereby lowering net methylation and reducing MeHg flux. Sediment removal and capping can lower sediment HgT, hence fish MeHg, in highly contaminated reservoirs that have nearby sources that have been remediated (p. 7-46, bullet points). At least three of the 303(d) listed reservoirs are candidates for this approach (p. 7-47, 1st paragraph). Among the strategies discussed in section 7.3, there are also limitations that make them applicable to only a subset of reservoirs. Oxygenation only applies to strongly stratified reservoirs with seasonally anoxic bottom water. Sediment capping or removal would only be effective after mine remediation and in reservoirs that have sediments Hg concentrations above the background in watershed soils (p.7-46, 3rd paragraph).

The analysis of fisheries management practices (section 7.4) is also consistent with **conclusions 9 and 11**. Light fertilization increases primary productivity and enhances biodilution, so it can lower fish MeHg concentrations (explained in detail in Appendix A). The linkage analysis used Models 2 and 3 to predict how doubling chlorophyll-a concentration would affect impairment of reservoirs with high fish MeHg and chlorophyll-a concentrations ≤ 3 ug/L (Table A.1). Although the two models gave somewhat different results, both indicate that all lakes with those characteristics would see at least a 25% improvement. Section 7.4 points out that 21 reservoirs have low enough chlorophyll-a levels to benefit from light fertilization (p. 7-52, 5th paragraph). Light fertilization is not a universal solution, because it would only be effective in oligotrophic lakes with sufficiently long residence times. Another approach that may be effective is altering stocking practices in the reservoirs where stocking is ecologically sound (p. 7-55, 3rd paragraph). The chapter also predicts that intensive fishing would be feasible for reducing fish MeHg concentrations in reservoirs that are oligotrophic, have elevated MeHg levels only in predatory fish and are not too large. It is suggested that this method could be effective in about half of the 74 303(d) listed reservoirs (p. 7-56, 2nd and 3rd paragraphs). Taken together, fisheries management practices might be applied in more than half of the impaired reservoirs, but specific strategies would need to vary among reservoirs.

Section 7.5 elucidates additional characteristics that necessitate reservoir-specific actions to reduce fish MeHg concentrations in reservoirs. This section underscores the complexity of processes leading to elevated fish MeHg levels, operational constraints that depend on reservoir uses, and differences in sediment and nutrient loads due to watershed characteristics. Table 7.1 summarizes the implementation options deemed to be appropriate for each of the 303(d)-listed reservoirs. Given the multiple options available for most reservoirs, it is reasonable to conclude that there will be a feasible strategy for every reservoir.

RESPONSE TO JMB-39

The reviewer's support for conclusions 9, 10, and 11 is noted.

The Big Picture

COMMENT JMB-40

Chapters 4-7 (and appendices) consistently support Conclusions 1-11 through literature review, statistical evaluation of controlling factors, source attribution and assessment of implementation options. Taken as a whole, the conclusions are predicated on sound science. Inferences are drawn from the evaluation of up-to-date, peer-reviewed literature, viable statistical methods (correlation and regression models), and a validated deposition modelling tool (RMSAD). The analyses use a large and comprehensive dataset, and the report steers clear of drawing conclusions where sufficient data is not available. The Staff Report shows that a variety of control options need to be applied on a reservoir- specific basis in order to meet the target sport fish MeHg concentration. This strategy is necessitated by the breadth of Hg sources, complex within-reservoir processes, and variable characteristics of reservoirs and their watersheds. Another conclusion that can be drawn from Chapters 4-7 is that *mitigation efforts will be most effective if they can adapt to an evolving understanding of reservoir processes and to fluctuations in environmental conditions brought about by climate change*. The need for additional surveys and pilot studies emerges throughout the chapters, and climate change impacts are addressed directly in section 7.7.5.

RESPONSE TO JMB-40

The reviewer's agreement with the approach is noted. The reviewer's support for additional data and pilot testing is noted.

S.3 Cynthia C. Gilmour (CCG)

Dr. Gilmour's letter repeats the conclusions to be evaluated; for compactness, the conclusions are not repeated in this section but rather are available at the beginning of this document. Dr. Gilmour has organized her comments into three sections, as follows: (1) by conclusion number for all 18 numbered conclusions; (2) summary comments on staff report; and (3) detailed comments on staff report. Although Dr. Gilmour did not explicitly comment on The Big Picture, some of her comments address Big Picture issues.

Thank you for the opportunity to participate in peer review of the proposed "Mercury TMDL and Implementation Program for Reservoirs."

COMMENT CCG-1

I commend the California Water Board Staff on a detailed and thoughtful evaluation of the problem, including a thorough summary of the available data. California has made significant progress toward understanding the magnitude of the mercury problem in reservoirs. The draft proposed "Mercury TMDL and Implementation Program for Reservoirs" is an ambitious program that should reduce MeHg risk to people and ecosystems in impaired California Reservoirs.

RESPONSE TO CCG-1

The reviewer's commendation of the approach is noted.

COMMENT CCG-2

My review includes review of the conclusions presented in Attachment 2 of the review request (pages 1–5) plus a review of the staff report follow on pages 6–14, and references, as requested. My comments are made in the spirit of finding the best strategies to reduce risk to Californians, and not to take away from the excellent work done by the Water Board Staff in preparation of the draft Mercury Reservoir Provisions.

RESPONSE TO CCG-2

The reviewer's constructive intention is noted.

<u>Conceptual Model</u>

Conclusion 1.

<u>COMMENT CCG-3</u>

I agree with this general statement based on the data and analysis provided and based on the wider scientific literature on MeHg production and bioaccumulation. However, I am concerned with the overall conclusion of this report that Hg source control will be insufficient to reduce fish MeHg levels in most impaired reservoirs to target levels. The linkage analysis relies on several measures of Hg (for example sediment Hg concentration instead of Hg load) that may not adequately capture the amount of Hg available for MeHg production (see detailed discussion below).

<u>RESPONSE TO CCG-3</u>

The reviewer's general agreement with conceptual model (Chapter 4 in staff report) is noted. After the first sentence, the reviewer's comment diverges from Chapter 4 and Conclusion 1.

Regarding mercury source control, see responses to CCG-28 and CCG-55 (especially closing quotation from western North America mercury synthesis effort, "Effective management … will require looking beyond simply controlling inorganic Hg sources control [*sic*], and will necessitate development of management tools associated with controlling the net production of MeHg, and ultimately its entry into, and bioaccumulation through, food webs."). Similarly, Dr. Benoit opined in comment JMB-39, "[g]iven the limitations of source reductions as a means of lowering fish MeHg, a variety of reservoir-specific interventions will be needed to reach the MeHg sport fish target."

Regarding loads, mercury loading used in the linkage analysis is described in response to CCG-7. This response to CCG-3 focuses on mines because they are the largest mercury sources to California reservoirs, and loading from mines was not used in the linkage analysis. This response describes the proxy approach used in the staff report and why it does adequately capture the amount of mercury available for methylation in reservoirs.

The mine factors evaluated in the linkage analysis were (Table 5.1): number of mines in watershed; number of productive mines in watershed; watershed mine density (mines/sq mile); and watershed productive mine density (productive mines/sq mile). Response to CCG-80 explains that mine density is a good proxy for mercury loading rates from mines. Nonetheless, fish methylmercury concentrations were not correlated ($p > 0.05$) with mine density.

Stream and river inflows to reservoirs bring sediment from upstream that settles on the reservoir bottom. Because mines are large sources of particulate mercury, highly elevated levels of mercury in reservoir sediment indicate high likelihood of local mines. The linkage analysis identified that fish methylmercury concentrations were correlated

($p < 0.05$) with reservoir sediment total mercury concentration (mg/kg) (Table 5.1). The conceptual model describes methylation in reservoir bottom sediments and subsequent bioaccumulation into the food web.

For the following practical reasons (some also provided in responses to CCG-20), staff recommends using proxy measurements in place of mercury loads from mines. Mercury and sediment loads from mines are highly variable, with the largest loads resulting from infrequent, large storm events (Kirchner et al. 2011). Infrequent means storm return intervals of five years or longer. It is not only expensive to maintain monitoring programs for five years or longer—waiting to sample large storms—it is dangerous to sample mine discharges in large storms unless there is a bridge nearby. (A bridge that is above the expected flood level and off of which sampling gear can feasibly be lowered through the water column. For safe egress after sampling, the bridge also must connect to a road unlikely to flood.) For these reasons, Water Board staff recommends using a proxy instead mercury load measurements from mines.

The proxy for mercury loads from mines used in this program is two-fold: (a) mercury levels in reservoir bottom sediment, and (b) discharges of mercury from mine site. Elevated mercury levels in reservoir bottom sediment indicates high likelihood of substantial mining waste contributions to the reservoir. Discharge of mercury is evaluated by both particulate mercury concentration in discharges and visual evidence of erosion of mining waste or contaminated soils. Response to comment CCG-72 describes how the proxy for mercury loads from mines is used to prioritize mine sites for cleanup.

COMMENT CCG-4

My interpretation of the extensive literature on Hg remediation is that mercury source control should always be the first approach to reducing MeHg risk. For example, Sweden's long experience with management of fish Hg levels showed that while some interventions (intensive fishing, liming) worked, they were short-term expensive fixes. Only reductions in Hg deposition to Sweden really improved the problem across large spatial scales. The strong spatial relationships between fish MeHg and mining sites in CA is obvious in the data presented here and in the Western Hg Synthesis [*Fleck et al.*, 2016]. Despite the linkage analysis showing a strong relationship between fish MeHg and chla:MeHg ratios, Occam's Razor says the most obvious solution is usually best. I wonder if the approaches to remediation proposed here may rely too heavily on chemical alterations to reservoirs, to the detriment of emphasis (and resources) on Hg source control.

RESPONSE TO CCG-4

In fact, the first action in this program is source control. Other, recent analysis by U.S. Geological Survey researchers supports the conclusions in this staff report that source control will not be sufficient. For example, the western North America mercury synthesis that concludes in several papers that the solution to mercury is to address methylation not sources (see response to CCG-3).

Agree that mercury is a necessary ingredient for any methylmercury problem, and agree that the most obvious solution is usually best. Consequently, agree that mercury source control should be the first approach to reducing methylmercury risk. In fact, this program incorporates source control. The staff report in Summary, section S-1 Scope, and also in Chapter 1, section 1.1, second paragraph, states, "The program of implementation includes control actions for (1) point and nonpoint sources of mercury, and pilot tests for (2) reservoir water chemistry to reduce methylmercury production, and (3) fisheries management to reduce methylmercury bioaccumulation." In other words, source control (action 1) will be undertaken at the same time that pilot tests are undertaken (actions 2 and 3).

For clarification, the following revisions to Mercury Reservoir Provisions and Staff Report were made to better correspond with the three control actions. The Mercury Reservoir Provisions have been re-ordered in Section IV. Implementation Program for Impaired Reservoirs so that mercury source controls (action 1) are listed prior to pilot tests (actions 2 and 3). Specifically, section IV.F is now section IV.H Reservoir Owners and Operators). In the staff report, the third and fourth paragraphs of the Summary and section 9.1 were replaced with the following: <u>Firstly, the Water Boards will ensure that mercury from sources upstream of reservoirs (priority mine sites, urban runoff, wastewater facility discharges, and dredging and earth-moving) are controlled to all mercury-impaired reservoirs. Secondly, in the first decade, reservoir owners and operators would test feasible reservoir management actions. The Water Boards encourage a coordinated approach for fewer, focused tests rather than tests in all mercury-impaired reservoirs. The test results will be evaluated by an independent, third-party Technical Review Committee before the Water Boards would develop long term requirements for all mercury-impaired reservoirs.</u>

Also, the Summary was revised in section S-5, Key Actions in Phase 1, so that "Mine sites upstream of reservoirs" is the first section and precedes "Reservoirs: Pilot tests." Similarly, in Chapter 9, sections 9.8 and 9.9 now follow "Dredging …" so that they are re-numbered to 9.9 Reservoir Water Chemistry Management Actions for Mercury-Impaired Reservoirs and 9.10 Fisheries Management Actions for Mercury-Impaired Reservoirs).

However, relying on source control alone is not expected to enable attainment of the proposed sport fish target in many reservoirs (see Chapter 7). For example, consider the two most important mercury sources to impaired reservoirs, historical mine sites and atmospheric deposition (the reviewer agreed in Comment CCG-14 these are the most important anthropogenic sources, see also CCG-13). Mine site cleanup would not help about 30% of mercury-impaired reservoirs because they do not have mines upstream (see section 7.2.1). The Water Boards lack regulatory authority over mercury emissions and subsequent atmospheric deposition onto California. Therefore, other means are necessary to address impairments caused by atmospheric deposition.

Moreover, California's Environmental Protection Agency (Cal/EPA) has severe limitations in its ability to compel cleanup of mines—and the hundreds of miles of mercury-contaminated streams downstream of mines—in a timely fashion. Over the last several decades, the two Cal/EPA agencies that oversee mine site cleanups (the Water Boards

and Department of Toxic Substances Control) have overseen cleanup of some major mercury and gold mine sites, however there are thousands of smaller mines yet to be addressed.

Also for example, in the San Francisco Bay Region, in the past three decades, 10 mines were addressed completely (including: Leona Heights sulfur mine in Oakland [*Link*], the Gambonini Mercury mine in western Marin County [*Link*], and many cleanup actions were undertaken—and many more are needed—in New Almaden mercury mining district [*Link*]). Currently, Bay Water Board staff are overseeing investigations at 10 mines, and there are 30 remaining mines that have not yet been addressed.

Even if the Water Boards had funding for staff, and California landowners had funding for undertaking cleanup, some mercury is simply not feasible to cleanup, either because it is widely dispersed over expanses of floodplains (Singer et. al 2013), or because the locations are too remote and steep. Therefore, not all mercury from mines can be cleaned up in a timely fashion and other means are necessary to address impairments caused by mines.

For these and other reasons described in Chapter 7, the program includes a pilot test program for reservoir water chemistry and fisheries management. The Water Boards encourage a coordinated approach to pilot tests that will leverage maximum benefit while minimizing resources expended.

Regarding the reviewer's last concern, that remediation may rely too heavily on chemical alterations to reservoirs—to the detriment of resources for mercury source control, see response to CCG-36 regarding source control is not "prioritized relative" to pilot tests (of water chemistry and fisheries management). Distinct, separate parties are responsible for source control from parties responsible for pilot tests.

CA-specific linkage analysis

Conclusion 2.

COMMENT CCG-5

The analysis presented is an exhaustive look at the substantial available data. Congrats to the team for such an in-depth thoughtful look. I agree that the data set shows that trophic status (chl a concentrations) may be a knob that can be tweaked to reduce MeHg concentrations in fish.

RESPONSE TO CCG-5

The reviewer's agreement with the approach is noted.

COMMENT CCG-6

Is more fish in a reservoir, but with lower MeHg levels the appropriate goal?

RESPONSE TO CCG-6

Fish with lower methylmercury levels are necessary to meet the water quality objectives and therefore this is the goal of the program; more fish is not a goal of the program.

COMMENT CCG-7

But I'm not sure I agree that the three factors that came out of the analysis are the most important in control of fish MeHg levels. The analysis presented is appropriate to the available data, and the resulting conclusions are consistent with good statistical analysis. However the data have substantial limitations. The linkage analysis did not include several parameters that may be strongly related to MeHg production and MeHg in water or fish, including the degree of stratification or anoxia, the organic content of sediments, growth of submerged aquatic vegetation (the last two enhance microbial activity and MeHg production), DOC, and critically the loading rate of Hg to reservoirs. No doubt these data are unavailable, but their lack does present limitations on interpretation of the analysis.

RESPONSE TO CCG-7

The reviewer's qualified agreement with the analysis is noted. Regarding the last factor, loading rate of mercury to reservoirs, the western North America mercury synthesis states (Eagles-Smith 2016), "although efforts to control and reduce inorganic [*mercury*] source loadings could likely achieve some reductions in biological [*methylmercury*] exposure in the West, avenues for addressing [*methylmercury*] production and bioaccumulation processes may be more effective."

The loading rate from atmospheric deposition was evaluated six ways for the linkage analysis (total deposition, wet deposition, and deposition from California emissions; each of these to both reservoir surface and reservoir watershed), see Table 5.1. Additionally, the loading rate from NPDES-permitted facility discharges was evaluated four ways for the linkage analysis, see Table 5.1.

The loading rate was not calculated from historic mine sites (one of two most important mercury sources see comment CCG-14 "6. The most important anthropogenic sources…") due to the particle-bound and episodic nature of these loads as discussed in Staff Report sections 6.1.2 and 6.3.2. Being particle-bound, much of the mercury rapidly settles to the reservoir bottom along with the sediment—reservoirs act as efficient sediment traps and there is some concern that California reservoirs are rapidly filling with sediment (Minear and Kondolf 2009). Additionally, the conceptual model describes in section 4.2.2 that mercury in sediment corresponds to fish methylmercury, and the linkage analysis in section 5.1.2 found that sediment total mercury has second strongest correlation to fish methylmercury levels.

Staff report section 5.5 has been revised to incorporate the following: "Third, data were not available for all factors identified in the conceptual model, particularly dissolved organic carbon, pH, degree of anoxia, and food chain length, and other factors identified by scientific peer reviewers that may be strongly related to methylmercury, including the degree of stratification, organic content of sediments, and growth of submerged aquatic vegetation."

However, Chapter 7, which focuses on potentially controllable factors, has not been revised to consider controls for dissolved organic carbon. Although dissolved organic carbon is often described in the scientific literature as being a factor in methylation and transport, it is also described as intrinsic to a watershed. Water Board staff has not found scientific literature that describes how dissolved organic carbon could be controlled whether on the landscape, in tributaries, or within reservoirs. Controls for several of these factors for which data were not available are considered in the staff report, as follows:

- **pH might be controllable by chemical addition to reservoirs (sections 7.3.4 Raise pH of acidic reservoirs and 7.4.4 Other options);**
- **Lack of submerged aquatic vegetation (Appendix A, part 3, Benthic Primary Production); and**
- **Manipulations of food chain length (section 7.4.4, Change fish assemblages).**

Chapter 7 has been revised to consider controls for additional factors for which data were not available, as follows:

- **Section 7.3.1, Anoxia, Potentially controllable processes, third paragraph from end**
    - **There are other types of oxygen delivery systems, such as Speece cones, that likely perform better than bubblers in this regard. Degree of anoxia and degree of stratification should be considered in system selection and design. A low degree of anoxia and/or stratification will limit choice of method and its effectiveness to increase oxygen. The organic content of sediments can be reduced by applying oxygen deep in the hypolimnion and particularly effective if applied to the sediment-water interface.**

COMMENT CCG-8

The use of unfiltered (and often spatially and temporally scarce) water MeHg data may be problematic in the linkage analysis. The collection of unfiltered MeHg data is a common problem in monitoring programs, and CA should work to fix this in monitoring going forward.

RESPONSE TO CCG-8

Staff agree that spatially and temporally scarce water methylmercury data may be problematic in the linkage analysis. In response, staff report section 9.13.1 has been revised to incorporate a new question regarding monitoring that could be put to the

Technical Review Committee. See response to CCG-84 for the text of the revision in "[*New first bullet*]."

Note to readers:
The reviewer often uses "unfiltered" mercury or methylmercury." Total is the same as unfiltered and total is used in response for consistency with staff report.

COMMENT CCG-9

And last, the linkage analysis only included data from Hg-impaired reservoirs. Would an analysis that included all reservoirs may have shown stronger relationships between total Hg, MeHg and MeHg in fish?

RESPONSE TO CCG-9

The linkage analysis included data from non-mercury-impaired as well as mercury-impaired reservoirs. As described in staff report section 5.1.1, "Fish methylmercury concentrations in these reservoirs spanned from 0.02 to 4.2 mg/kg (350 mm standardized size; see Table B.1), from well below the sport fish target level of 0.2 mg/kg, to 21 times higher than the sport fish target." Reservoirs with fish mercury levels above 0.2 mg/kg are impaired; 10 of 43 reservoirs evaluated for Model 1 were non-impaired. Also see determination that the reservoirs used to develop Models 2 and 3 covered a broad range from non-mercury-impaired to highly-mercury-impaired, have similar distributions of data, and therefore were an appropriate data set for linkage analysis (see staff report Appendix B, Part 6, Aqueous Methylmercury and Chlorophyll).

COMMENT CCG-10

The analysis conducted made appropriate use of available data, but could go further in acknowledging the limitations imposed by the data. Model 1 includes only a small subset of all CA reservoirs. The chla:MeHg ratio is available for only ~40 reservoirs. The use of unfiltered MeHg data, and of MeHg and chla data that may not have be taken at the same season, depth, or frequency in all reservoirs makes this model more uncertain than it might appear in the formal statistical analysis presented.

RESPONSE TO CCG-10

The reviewer's qualified agreement with the analysis is noted. The reviewer is correct, the ratio of chlorophyll-a to methylmercury (chla:MeHg) is available for 43 reservoirs, see Table 5.1.

Agree particularly that the use of methylmercury and chlorophyll-a data that were not all taken at the same season, depth, or frequency in these 43 reservoirs is one of several components of uncertainty in the model. Uncertainty has its own sub-section in the Staff Report: section 5.5, Linkage Analysis Limitations and Recommendations. The next-to-last sentence of the first paragraph of section 5.5 has been revised as follows: "<u>Additional data are not expected to greatly change the ranking of overall conclusions</u>

about the most important factors influencing methylmercury accumulation in fish in mercury-impaired reservoirs." Also, a new penultimate paragraph has been added to section 5.5 as follows:

> **Fourth, the implementation plan should account for uncertainty in models used in linkage analysis. (This accounting is accomplished in Chapter 7 although it is not described explicitly. For example, the recommendation in section 7.3.7 is for the methylmercury allocation of non-detect to be implemented as a management practice with the goal of achieving the proposed sport fish target—rather than a recommendation to achieve the allocation in every impaired reservoir. This recommendation accounts for the uncertainty in the methylmercury allocation as well as observations from the data set that some non-impaired reservoirs have aqueous methylmercury levels higher than 0.009 ng/L.)**

Moreover, section 5.5 concludes by recommending an improved and expanded data set be collected during Phase 1 and evaluated during Program Review. During Phase 1 in fact, additional data will be collected in reservoirs undergoing pilot tests. See response to CCG-84 for additional reservoir-specific and fish stocking data to be collected in Phase 1 that will be used to support the long-term reservoir management strategy reports.

Conclusion 3.

COMMENT CCG-11

I disagree, based on data limitations in the linkage analysis. See my comments on the linkage analysis in #2 above [*comments CCG-7, CCG-8, and CCG-10*].

RESPONSE TO CCG-11

Responses to reviewer's concerns regarding data limitations are provided in responses to CCG-7, CCG-8, and CCG-10. Staff report sections 5.5 and 9.13.1 will be revised as described in responses to Comments CCG-7 and CCG-8.

Conclusion 4

COMMENT CCG-12

There are reservoirs that will never meet the TMDL targets, including reservoirs w/o mines upstream. See my response to #7 [*comment CCG-15*].

RESPONSE TO CCG-12

The reviewer's assertion that some reservoirs will never meet the TMDL targets is noted. In response, staff report section 9.13.1 Reservoir Technical Review Committee has been revised to ask the Technical Review Committee for their input on which reservoirs will never meet the TMDL targets and what are the lowest fish methylmercury levels that can be achieved. The changes are provided in "[New l*ast bullet*]" in response to CCG-84.

Mercury Source Assessment

Conclusion 5.

COMMENT CCG-13

Agree. The detailed analysis of sources shows there are several sources that contribute to Hg load to CA reservoirs. But mines (and re-emissions from mining areas) are the obvious driver of elevated Hg in most impaired CA reservoirs.

RESPONSE TO CCG-13

The reviewer's agreement with the conclusion is noted.

Conclusion 6.

COMMENT CCG-14

Agree.

RESPONSE TO CCG-14

The reviewer's agreement with the conclusion is noted.

Conclusion 7.

COMMENT CCG-15

Disagree. I think that the linkage model underestimates the benefit of mine site clean-up (source reduction), both in amount and timing. The available data include sediment Hg concentration, but not Hg loading. Critically, Hg in sediments becomes less available for MeHg production over time after deposition to sediments [*Harris et al.*, 2007]. Our estimate of the half-life of Hg bioavailability for methylation in sediments within the METAALICUS study was several months to a few years at most. Mercury becomes unavailable more rapidly that sedimentation, due to sorption into unavailable phases.

Note: Mercury Experiment to Assess Atmospheric Loading in Canada and the United States (METAALICUS study); USGS involvement described here: https://wi.water.usgs.gov/mercury-lab/research/metaalicus.html

RESPONSE TO CCG-15

The reviewer notes that in the METAALICUS study mercury in sediments very quickly became less available for methylmercury production. In contrast to the METAALICUS study that had only a few mercury inputs, episodic large storm events in California continue to transport mercury from mines to reservoirs. In this way, mercury in California reservoirs is replenished periodically. Moreover, the fact that reservoirs downstream of historical mines have highest fish methylmercury levels indicates these reservoirs have bioavailable mercury. Agree with recommendation in comment CCG-20 to do a complete evaluation of effects of one or more mine site cleanups on reservoirs; see response to CCG-20. The reviewer also notes in comment CCG-57 that sediment total mercury *concentration* is a predictor of sediment methylmercury.

COMMENT CCG-16

The relationship between sediment Hg and fish MeHg is significant but weak in the CA data set. But there doesn't seem to be a good measure of loading in the data set - there are data on the number and density of mines in reservoir watersheds, but not flux of Hg off of the sites or into reservoirs (data limitation).

RESPONSE TO CCG-16

Agree that the relationship between sediment mercury and fish methylmercury concentrations is significant—it is the second strongest correlation—but disagree that it is weak; the correlation coefficient ranged from 0.32 to 0.49, see staff report section 5.1.2 and Table B.3. Agree there is not a measure of loading from mines, for reasons previously described in response to CCG- 7.

COMMENT CCG-17

I suspect the relationship between Hg load and fish Hg would be stronger than the sediment Hg;fish MeHg relationship.

RESPONSE TO CCG-17

The reviewer's well-informed ideas are noted. Mercury loading used in linkage analysis is described in response to CCG-7.

Conclusion 8.

COMMENT CCG-18

Not sure. Does the REMSAD model adequately capture re-emissions from contaminated soils in northern CA mining areas?

RESPONSE TO CCG-18

Agree that the REMSAD model does not adequately capture re-emissions of mercury from historical mining. The following staff report sections were revised as follows:

Section 6.4 Atmospheric Deposition, … This evaluation found:

- **About 5,300 kg of atmospheric mercury were deposited in California in 2001 according to USEPA's Regional Modeling System for Aerosols and Deposition (REMSAD). The REMSAD model attributed only about 10% of the 2001 deposition to anthropogenic emissions from California facilities. The model attributed the majority (about 90%) of deposition to natural and global anthropogenic emissions. Note that the REMSAD model does not account for re-emissions of mercury from historical mining.**

Section 6.4.3 Recent Anthropogenic Mercury Emissions

As noted at the beginning of this chapter, atmospheric deposition is considered a nonpoint source discharge into water. Nonetheless, anthropogenic emissions that contribute to atmospheric deposition can be divided into point and nonpoint mercury emissions:

- **Nonpoint emission sources include: on-road motor vehicles (e.g., light- and heavy-duty vehicles) and non-road equipment (e.g., generators). Note that the REMSAD model does not account for re-emissions of mercury from historical mining.**

Section 6.4.4 Atmospheric Deposition in California …

[*third paragraph*] In California, one long-term and several short-term monitoring studies evaluated atmospheric mercury in wet deposition at 13 sites and dry deposition at 7 sites (Figure 6.16, Tables D.3 and D.4 in Appendix D). However, while these monitoring studies provide useful data about specific locations and dates, the data are inadequate to characterize statewide atmospheric deposition patterns, or to account for re-emissions of mercury from historical mining.

…

How much atmospheric mercury is deposited in California and where does it come from?

…

The REMSAD model results in Table 6.5 for California and other United States, Canada, and Mexico sources account only for anthropogenic sources of mercury and do not include atmospheric deposition from natural mercury sources <u>or from re-emissions of mercury from historical mining</u>.

…

What are the emission sources that contribute most to deposition to mercury-impaired reservoirs?

Controlling anthropogenic emissions in California should reduce the amount of mercury deposited in some reservoirs. Specifically, the REMSAD model indicates that 69 of the 74 2010 303(d)-listed reservoirs or their watersheds are within the deposition footprint of California anthropogenic emissions, where deposition attributed to California anthropogenic emissions exceeds 0.5 g/km2/year (Figure 6.17 and Table 6.11). <u>Note that the REMSAD model does not account for re-emissions of mercury from historical mining.</u>

Caption for Figure 6.19:
Global background sources do not include anthropogenic emissions from the United States, Canada, and Mexico in 2001, but may include mercury emitted from anthropogenic sources in these countries in 2000. Re-emission of previously deposited mercury includes mercury from natural and anthropogenic sources <u>but does not include re-emissions of mercury from historical mining.</u>

Appendix D, page D-2:
Tags were assigned to the largest sources in each state as well as a range of source types and potentially important contributors to local and regional mercury deposition in areas with known or suspected mercury water quality programs; not every single source was tagged. In addition, tags were assigned to contributions from global background (“boundary conditions”) and re-emissions of previously deposited mercury to mercury deposition <u>(but not to re-emissions of mercury from historical mining)</u>.

<u>Potentially Controllable Processes and Predictions for Improvement</u>

Conclusion 9.

<u>COMMENT CCG-19</u>

Agree.

<u>RESPONSE TO CCG-19</u>

The reviewer’s agreement with the approach is noted.

Conclusion 10.

COMMENT CCG-20

I'm not sure I agree. But I do think the idea of testing a variety or approaches and evaluating results over the next decade is a good one. However, I'd make sure that several mine site clean ups… with a really complete evaluation of fluxes off of mine sites and into reservoirs during the process… should be part of the pilot testing process. Go slow and low on any nitrate additions and chemical changes other than oxygenation.

RESPONSE TO CCG-20

The reviewer's support for a decade of pilot testing is noted. Agree that it would be informative to have a few thorough and detailed scientific investigations to compare before and after cleanup mass loads (fluxes) of aqueous and atmospheric mercury from mines into reservoirs (and resulting changes in methylmercury and bioaccumulation in reservoirs). Cleanup will reduce erosion and discharge of mercury-contaminated sediments. Non-mine-contaminated sediment will still erode and settle on the bottom the reservoir. We note that a proxy for loads, such as changes in mercury concentrations of reservoir bottom sediments, would likely be very informative and much less expensive to monitor than mass loads.

Moreover, it will likely be difficult to fund such scientific investigations because the Water Boards do not have regulatory authority to require research projects.

Staff report section 9.8.1 Technical adequacy of pilot tests, has been revised to add the following concluding sentences (filterable [dissolved] mercury is included in response to CCG-35; deposition monitoring devices included in response to CCG-37):

> **Additionally, associated studies are recommended to quantify the reductions in mercury loading from mine cleanup, and to determine whether any changes in methylmercury in reservoir water and fish resulted from mine cleanup. Monitoring should occur before and after cleanup. Consideration should be given to monitoring loads of particulate (sediment-bound mercury predominantly transported by stormwater), filterable (dissolved mercury generally transported with stormwater), and gaseous mercury (re-emitted from mining waste that deposits on reservoir water surface). Consideration should also be given to monitoring concentrations and flow to develop rating curves, which have "distinct advantage that they allow all-else-equal comparisons of" before and after mine cleanup (Kirchner et al. 2011). The need for monitoring filterable mercury should be evaluated in light of vast majority of load from mercury mines is in particulate form (see Figure S2 in Kirchner et al. 2011). Consideration should be given to appropriate and cost-effective monitoring devices for wet and dry deposition of gaseous mercury (e.g., consider passive samplers for dry deposition). Reservoir water and fish methylmercury, and other water quality, food web, and weather parameters, should be measured. Proxy measurements should be evaluated, such as reductions in discharges of mercury-contaminated sediments from the mines**

and mercury concentrations in reservoir bottom sediments rather than mercury loads, for validity, accuracy, and cost savings. These associated studies of effects of mine cleanup could be accomplished by a coordinated program between research institutions, mine cleanup responsible parties, and reservoir owners and operators.

For response to comment "Go slow and low on any nitrate additions and chemical changes other than oxygenation," see response to CCG-34 and CCG-35.

Conclusion 11.

COMMENT CCG-21

There will be some reservoirs for which there is no reasonable way to reduce fish MeHg to CA targets. But reductions in fish MeHg should be achievable in the majority of impaired reservoirs. A key question for CA will be whether to try minimally tested interventions like nitrate amendment and fisheries alterations while waiting for clean-up of mine sites.

RESPONSE TO CCG-21

See response to CCG-12 regarding reviewer's assertion that some reservoirs will never meet the TMDL targets. The reviewer's endorsement of predicted widespread reductions in fish methylmercury levels is noted. Agree that a pilot test program is a key question for mercury management in California. The public will have a chance to review and comment on this proposed program, and the State Water Board members will consider this proposed program for adoption in a formal public process.

TMDL and Load Allocations

Conclusion 12.

COMMENT CCG-22

If the loading targets for mining areas can be reached, I suspect that alone would move most reservoirs close to fish Hg targets. But I can't tell how the proposed Reservoir Mercury Control Program will force mine remediation. Appendix I states that the proposed TMDL "will not pose new economic costs or environmental impacts to address discharges from mercury and gold mines." … and further explains that existing regulations already require clean-up. But mine remediation has just barely begun. How will the new TMDL force cleanup without additional spending??

RESPONSE TO CCG-22

The Water Boards enforce mine remediation by issuing orders pursuant to existing California Water Code, for example section 13304 for cleanup and abatement of waste discharges. Upon adoption of this program by the State Water Board, the Water Boards will be committed to prioritize mine sites and issue cleanup and abatement orders for highest priority (Tier 1) mine sites as directed by section IV.D.4 of Reservoir Mercury Provisions.

Recognizing that economic considerations will be included in the next version of the staff report, the following has been deleted from Appendix I, section of I.1:

~~***Environmental Impacts and Costs***~~

~~**Even in the absence of the Reservoir Mercury Control Program, current mine site property owners are responsible for discharges from their property. Many California and federal agencies undertake themselves or require others to undertake cleanup of mine sites (e.g., USEPA superfund; USBLM; California Natural Resources Agency's Department of Conservation; Cal/EPA Department of Toxic Substances Control; and State and Regional Water Boards.) In this context, the Reservoir Mercury Control Program will not pose new economic costs or environmental impacts to address discharges from mercury and gold mines. Therefore, existing requirements for mine site cleanup will be used as baseline conditions in the environmental and cost analysis for the Reservoir Mercury Control Program.**~~

COMMENT CCG-23

I'm also concerned that the loading targets for mine areas are given as Hg concentrations on particles, rather than mass loading to reservoirs. Of course, the former is easier and less expensive to measure. But evaluation of the efficacy of mine clean up will require quantitative measurement of change in reservoir loading.

But overall I'm more concerned with the ability to get mine clean up done than the choice of TMDL targets for clean-up.

RESPONSE TO CCG-23

Comment noted; see also responses to CCG-7, CCG-22, and especially CCG-20.

COMMENT CCG-24

[*With respect to*] other reservoir management tools, I don't think there is enough evidence to be assured that tools other than load reduction, bottom water oxygenation and water level control can reduce fish Hg levels to targets. Data on other controls are sparse. That's not to say that other approaches aren't worth trying in a phased, pilot study approach. But whether these measures along with source control will be adequate to meet fish MeHg goals will have to be evaluated again in a decade. The linkage analysis is a good first step, but its conclusions will have to be tested as remediation proceeds.

RESPONSE TO CCG-24

The reviewer's support for a decade of pilot testing followed by program review is noted.

Conclusion 13.

COMMENT CCG-25

Same answer as #12 [*comments CCG-22, CCG-23, and CCG-24*].

RESPONSE TO CCG-25

See responses to CCG-22, CCG-23, and especially CCG-24: The reviewer's support for a decade of pilot testing followed by program review is noted. Staff report section 9.13.2 provides focusing questions that will be used in program review, including question 4 that asks whether modifications to allocations are appropriate.

Margin of Safety, Seasonal Variations, and Critical Conditions

Conclusion 14.

COMMENT CCG-26

It's too soon to know. See response to #12 [*comments CCG-22, CCG-23, and CCG-24*].

RESPONSE TO CCG-26

Staff plans to return to this question during the first program review. The reservoir program already includes focusing questions (in staff report section 9.13.2) for program review. Question 4.b asks "Should the margin of safety be revisited?"

Implementation and Monitoring

Conclusion 15.

COMMENT CCG-27

See response to #12 [*comments CCG-22, CCG-23, and CCG-24*].

RESPONSE TO CCG-27

See responses to CCG-22, CCG-23, and especially CCG-24: "The reviewer's support for a decade of pilot testing followed by program review is noted." The reservoir program already includes focusing questions (in staff report section 9.13.2) that will be used in program review; several review questions pertain to effectiveness of inorganic mercury controls and what changes if any are needed to the program.

Conclusion 16.

COMMENT CCG-28

As stated above, I don't believe that reservoir management w/o source control will be adequate to achieve target fish MeHg levels in most reservoirs. But other controls may help in the interim, especially bottom water oxygenation in stratified systems.

RESPONSE TO CCG-28

The reviewer's qualified agreement with the approach is noted.

Assessment of Compliance with the Proposed Water Quality Objectives

Conclusion 17.

COMMENT CCG-29

Agree.

RESPONSE TO CCG-29

The reviewer's agreement with the approach is noted.

Conclusion 18.

COMMENT CCG-30

To my knowledge, young of the year sport fish as monitors for MeHg bioaccumulation have been effective in some studies/locals and not others. Consistency in sample timing and location seem important. But year-to-year variability in year class size and growth rate can confound analysis. Monitoring of upper trophic level fish should not be abandoned or reduced if YOY monitoring programs are added.

RESPONSE TO CCG-30

As described in staff report section 9.8.6, biosentinel fish are better indicators of changes in biotic methylmercury than sport fish. Peer reviewer Dr. Mason commented (RPM-47) "Many papers, books and chapters on monitoring have endorsed the approach of using resident, young of the year fish …." Agree that consistency in sample timing and location are important and that year-to-year variability in year class size and growth rate must be evaluated and accounted for in data analysis. Appreciate that monitoring of higher trophic level fish should not be abandoned; California's Surface Water Ambient Monitoring Program Bioaccumulation Oversight Group (SWAMP BOG) program monitors bass in selected lakes and reservoirs every decade.

Comments on Staff Report; Cal Water Boards/Cal EPA; Summary comments

COMMENT CCG-31

The proposed "Mercury TMDL and Implementation Program for Reservoirs" is a highly ambitious program that should reduce MeHg risk to people and ecosystems in impaired California Reservoirs.

I commend the use of fish tissue Hg targets rather than water or sediment.

RESPONSE TO CCG-31

The reviewer's commendation of the approach is noted.

COMMENT CCG-32

I found the distinctions between TMDL under review, the parallel subsistence fishers TMDL, and the separate Water Quality Objectives confusing, no doubt my lack of understanding of California law.

RESPONSE TO CCG-32

This "TMDL under review" is for mercury in reservoirs. The subsistence fishers action was not a TMDL but rather a separate project to establish mercury water quality objectives. Staff report in section 1.1, describes "Separate project: Mercury Objectives Provisions" and described these as proposed water quality objectives. Subsequently, in May 2017, the State Water Board adopted these mercury water quality objectives.

COMMENT CCG-33

The linkage analysis conducted is a statistically appropriate and exhaustive look at available data. However, interpretation of results should go further in acknowledging the limitations imposed by the data, which I discuss in detailed comments below. I am not convinced by the analysis that chla:MeHg ratio is the most important control factor for fish Hg in California lakes.

RESPONSE TO CCG-33

The reviewer's qualified agreement with the analysis is noted; see comment and response CCG-7. The reviewer's question whether the ratio of chlorophyll-a to methylmercury is the most important factor to control methylmercury levels in fish is noted. Additionally, the reviewer expressed agreement that chlorophyll-a is a controllable factor (comment CCG-5) and endorsed the proposed decade-long pilot test program (comment CCG-20).

COMMENT CCG-34

I feel that the major focus of the Mercury Reservoir Provisions TMDL implementation program should be on source reduction. I am concerned that reservoir management approaches other than source reduction will take away resources and attention from mine clean up and monitoring. However, I agree with the idea of a few focused pilot tests of reservoir management actions other than source reduction. I suggest that pilot tests should mainly focus on lower risk approaches (e.g. bottom water oxygenation, sediment hot spot cover or removal) that have already been tested in other lakes. Nutrient additions, nitrate addition for bottom water redox control, or intensive fishing bear especially careful monitoring of food web structure response.

RESPONSE TO CCG-34

See response to CCG-4 regarding agree and that this program incorporates source control. See response to CCG-36 regarding source control is not "prioritized relative" to reservoir management pilot tests.

The reviewer's support for a decade of pilot testing is noted. The Technical Review Committee will evaluate proposals for pilot tests and provide advice on the appropriate locations, types, and how best to conduct pilot tests. The majority of pilot tests will be low biological risk actions such as oxygenation and contaminated sediment management. There will likely be only a few nutrient addition tests, which will require careful design and monitoring and oversight by the Technical Review Committee to prevent unintended water quality or food web consequences. Staff report section 9.13.1 has been revised to incorporate the reviewer's suggestions about monitoring. See response to CCG-84 for the text of the revision in "[*new penultimate bullets*]."

COMMENT CCG-35

All efforts toward remediation should include significant measurement and monitoring programs. For mines, this should include efforts to measure the efficacy of mine clean approaches up in reducing Hg runoff, and careful monitoring of changes in Hg load to reservoirs (particulate and filterable) relative to changes in MeHg in water and fish. For all remediation tests (including water chemistry or fisheries modifications), implementation should include detailed assessment programs of Hg and MeHg in water, sediment and biota through time, and careful monitoring of food web structure and composition especially if nutrient amendments are tried. I am concerned that there will not be enough funding/resources for adequate monitoring of remediation tests, increasing the risk of negative consequences of water chemistry and fisheries modification pilot studies. The work should have external expert panel oversight throughout, including design of proposed management efforts.

<u>RESPONSE TO CCG-35</u>

Agree remediation should include significant measurement and monitoring programs. For mines, agree with recommendation in comment CCG-20 to do a complete evaluation of effects of one or more mine site cleanups on reservoirs; see response to CCG-20.

Agree that all pilot (remediation) tests should each include appropriate monitoring before, during, and after testing of mercury and methylmercury in water and biota and perhaps in sediment, and careful monitoring of food web structure and composition especially if nutrient amendments are tried. The reviewer's endorsement of the Technical Review Committee is noted, and one purpose of this committee is to ensure appropriate monitoring. In response to the previous comment, the staff report was revised to include additional questions for the Technical Review Committee to lessen risk of negative consequences; see response to CCG-34.

The reviewer's concerns with lack of sufficient funding for monitoring pilot tests are noted. The pilot test workplans will specify monitoring and the Technical Review Committee will review and comment on adequacy of monitoring proposed in these plans.

The reviewer's endorsement that the Technical Review Committee have oversight throughout is noted. The Mercury Reservoir Provisions Section IV.F.3, provides that the Technical Review Committee have oversight throughout, as they will advise on the applicability and technical feasibility of potential pilot tests, and review all draft pilot test work plans, final pilot test reports, and long-term reservoir management strategy reports.

In response to CCG-35 concerns regarding potential adverse effects "especially if nutrient amendments are tried," the staff report has been revised to include monitoring for adverse effects, as follows.

Staff Report section 9.8.4 Coordinated pilot test work plan, second paragraph

… Additionally, a work plan must provide detailed descriptions of the following:

…

(3) Which specific actions are proposed to be pilot tested in which specific impaired and non-assessed reservoirs, <u>potential adverse environmental effects of the actions tested,</u> how pilot test reservoirs will be monitored and evaluated <u>including for potential adverse environmental effects</u>, and what associated studies will be conducted in which non-impaired reservoirs;

<u>COMMENT CCG-36</u>

I would have like to seen more emphasis in this report on how source control efforts will be prioritized relative to lake chemistry and fisheries management tools, including how resources and spending will be allocated. Source control from mines is a long-term, expensive fix, with many jurisdictions and stakeholders. Appendix I states that “the Reservoir Mercury Control Program will not pose new economic costs or environmental impacts to address discharges from mercury and gold mines.” … and further explains that existing regulations already require clean-up. But mine remediation has just barely begun. I see a huge disconnect here. If the new TMDL implementation program does not force additional mine clean up through allocation of additional state, federal, local and private funds, the TMDL loading goal will never be met. Again, perhaps I am missing something in the law.

RESPONSE TO CCG-36

Source control is not “prioritized relative” to pilot tests (of water chemistry and fisheries management). Rather, both source control and pilot tests will be undertaken. For these and other reasons, the staff report does not explain (and the Mercury Reservoir Provisions do not prescribe) how resources and spending will be allocated amongst actions 1 (source control), and actions 2 and 3 (pilot tests; see response to CCG-4).

Distinct, separate parties are responsible for source control from parties responsible for pilot tests. For example, the parties responsible for undertaking and paying for:

MERCURY SOURCE CONTROL	RESPONSIBLE PARTIES
Mine cleanup	Current mine site property owners and prior mine owners and/or operators
Urban runoff	Municipal separate storm sewer systems (MS4s) NPDES permittees for the storm drain networks that convey urban runoff into mercury-impaired reservoirs
Discharges from municipal and industrial wastewater treatment facilities	Dischargers named in the NPDES permits for municipal and industrial facilities
Pilot tests	Reservoir owners and operators

Reservoir owners and operators who are not mine site property owners are not responsible for, or have any authority over, cleanup of upstream mine sites, so their financial resources would not be allocated to mine cleanups. Agree that source control for mines is a long-term, expensive fix. The reviewer repeats concerns over sufficient funding for mine cleanup; see response to CCG-34.

In response to CCG-36, the Mercury Reservoir Provisions and staff report have been revised to clarify the phased approach in which mercury source controls are on-going and pilot tests are scheduled to conclude prior to Program Review.

IV.B. Time Schedule and Phased Approach~~ 1 and Phase 2~~

The implementation activities required in Chapter IV shall occur on or after the Effective Date of the MERCURY RESERVOIR PROVISIONS, as provided. Discharges from mines sites and reservoir pilot tests are~~, and may be~~ subject to a two-phased approach (discussed in Chapters .IV.D, IV.H, and V.B)~~, depending on the type of discharger~~. PHASE 1 commences at the Effective Date of the MERCURY RESERVOIR PROVISIONS and ends 10 years thereafter. PHASE 2 will commence after the State Water Board completes its program review of PHASE 1 activities (discussed in Chapter VI).

VI. A. Schedule for Program Review

At the conclusion of PHASE 1, but no later than 12 years after the Effective Date of the MERCURY RESERVOIR PROVISIONS, the State Water Board will evaluate and review the MERCURY RESERVOIR PROVISIONS ("Program Review"). Implementation actions required by Chapters III and IV.D–G will continue during Program Review. Pilot tests required by Chapter IV.H are scheduled to conclude prior to Program Review.

Appendix A: Glossary of Terms

PHASE 1: PHASE 1 generally refers to the first of two phases of the program of implementation for discharges from MINE SITES and RESERVOIR pilot tests (discussed in Chapters IV.D, IV.H, and V.B), and commences at the Effective Date of the MERCURY RESERVOIR PROVISIONS and ends 10 years thereafter.

PHASE 2: PHASE 2 generally refers to the second of two phases of the program of implementation for discharges from MINE SITES and RESERVOIR pilot tests (discussed in Chapters IV.D, IV.H, and V.B)~~IMPAIRED RESERVOIRS~~, and will not begin until the effective date of the State Water Board's amendment to the MERCURY RESERVOIR PROVISIONS, which will occur in accordance with Chapter VI.

COMMENT CCG-37

I recommend more deposition and air monitoring across the state in support of TMDL implementation. Current spatial coverage is relatively poor. Consider using new, much less expensive air Hg passive samplers (Mitchell et al. 2016) for better coverage in urban areas and around impacted reservoirs, and use these as surrogates for dry dep.

RESPONSE TO CCG-37

The reviewer's endorsement is noted for staff report section 9.4.1, Goals and Phasing for Atmospheric Deposition: "The primary goal for Phase 1 is to determine whether there is a trend of increasing or decreasing atmospheric deposition during Phase 1. Not knowing the trend could confound interpretation of reservoir pilot test results." The Mercury

Reservoir Provisions section V.C.2 recommend that California Air Resources Board and U.S. Environmental Protection Agency ensure that mercury deposition is monitored.

Staff Report section 9.4, last paragraph, was revised in response to reviewer's suggestion for better coverage in urban areas and around impaired reservoirs as follows: Alternatively, CARB and USEPA or other organizations may elect to monitor and model atmospheric deposition. <u>Current spatial coverage of atmospheric deposition monitoring in California is poor. Greater spatial coverage can be provided by using new, much less expensive air mercury passive samplers (Mitchell et al. 2016) for better coverage in urban areas and around impaired reservoirs, and use these data as surrogates for dry deposition.</u> The model results could then be assessed ….

The reviewer's suggestion for use of less expensive mercury samplers is also addressed in response to CCG-20 regarding evaluating effectiveness of mine cleanup.

Detailed Comments

<u>COMMENT CCG-38</u>

p 25. The program is very ambitious.

<u>RESPONSE TO CCG-38</u>

The reviewer repeats comment CCG-1, "I commend … ambitious program that should reduce MeHg risk to people and ecosystems in impaired California Reservoirs."

<u>COMMENT CCG-39</u>

Time lines after a decade not clear, but that would be hard.

<u>RESPONSE TO CCG-39</u>

Time lines for after a decade will be developed during program review (upon conclusion of Phase 1 and no later than 12 years after State Board adoption), as provided in Mercury Reservoir Provisions section VI.

<u>COMMENT CCG-40</u>

Resource allocation to reservoir controls vs. mine clean up is not specified and should be.

<u>RESPONSE TO CCG-40</u>

See response to CCG-36 regarding distinct, separate parties are responsible for source control from parties responsible for pilot tests. Consequently, resources allocated to reservoir controls (pilot tests) will not detract from resources needed for cleanup of mine sites and other mercury source control actions.

COMMENT CCG-41

Some of the language in the summary section doesn't match rule or summary in attachment 1 in places.

RESPONSE TO CCG-41

The summary section is deliberately written in plain English and not comprehensive, which can cause it to be perceived as not matching the Reservoir Mercury Provisions. Staff frequently revises the summary based on feedback from interested parties with the intention of improving readability and simple explanations that better match the Reservoir Mercury Provisions.

COMMENT CCG-42

Not clear to me how the water quality objectives (fish MeHg levels) fit in this report – these are part of the TMDL, but are listed in the staff report as a "separate but related project in section S3. "The derivation of and scientific basis for mercury water quality objectives is provided in the Staff Report for Statewide Mercury Water Quality Objectives" – which we are not reviewing I think?

RESPONSE TO CCG-42

Correct, you are not requested to review the Staff Report for Statewide Mercury Water Quality Objectives. The April 2017 reservoir staff report that you did review, in section 1.1, described "Separate project: Mercury Objectives Provisions" and described these as proposed water quality objectives. (Previously, the objectives were submitted for scientific peer review.) Subsequently, in May 2017, the State Water Board adopted these mercury water quality objectives.

COMMENT CCG-43

How will federally-owned reservoirs be managed? What about Bureau of Reclamation reservoirs?

RESPONSE TO CCG-43

Federally-owned mercury-impaired reservoirs, including reservoirs owned by the U.S. Bureau of Reclamation, are listed on Table 3B in Reservoir Mercury Provisions. Section IV.A of the Provisions explains that mercury-impaired reservoirs that are not subject to Federal Energy regulatory Commission hydropower licenses will be required by this program to conduct pilot tests.

COMMENT CCG-44

Commend choice of fish for numeric water quality targets. "Staff proposes numeric targets that are equal to the mercury water quality objectives for COMM, WILD, and RARE beneficial uses because these targets will allow direct assessment of whether beneficial uses are being met." – agree! P. 74

RESPONSE TO CCG-44

The reviewer's commendation of the approach is noted.

COMMENT CCG-45

Appendix L – how to sample fish

Good –

- avg. over whole lake, must include Hg-impacted areas if they exist
- Quantify at total Hg, EPA Method 7473 (thermal)
- 90% UCI of arithmetic mean – good new approach, conservative estimate of risk, smarter faster eval than "binomial" approach with grouped fish

RESPONSE TO CCG-45

The reviewer's agreement with the approach is noted.

COMMENT CCG-46

- Less good –no frequency of sampling required; but frequency of ten years [*or*] less recommended

RESPONSE TO CCG-46

Staff report Appendix L section L.1.3, in last paragraph, explains that lack of reliable resources is the reason for not requiring fish sampling on a particular time schedule. However, as described in text immediately preceding and in Figure L.1, the minimum sample frequency necessary to be able to determine non-impaired is at least three times over no more than 10 years. The last paragraph in section L.1.3 was revised to clarify that, "For reservoirs that were previously determined to be impaired, a minimum of three data sets collected in separate calendar years over a time span no longer than ten years are required to support a determination of non-impaired. For reservoirs that have been determined to be non-impaired, periodic fish sampling is recommended…."

COMMENT CCG-47

Include stocked fish if present and important in creels, but not requirement about what fraction of the fish sampled, or if they should be evaluated separately. Recommend that they [*be*] reported separately even if included in determination of target attainment. p 3

RESPONSE TO CCG-47

Agree that data for stocked fish should be reported separately if stocked fish can be distinguished from resident fish. Hatcheries often but not always mark fish by external fin clip or similar mark that allows for and easy, visual way to distinguish stocked fish from resident fish. For data that support pilot tests, staff report section 9.8.6, Fish selection (age and size), was revised to add a new concluding sentence: <u>The work plan should specify that data for stocked fish should be evaluated both separately and together with data on resident fish, if stocked fish can be distinguished from resident fish.</u> For data that support long-term monitoring, staff report section 10.3.2, Long-Term Fish Monitoring in Impaired Reservoirs, was revised to add a similar, new concluding sentence: <u>The monitoring plan should specify that data for stocked fish should be evaluated both separately and together with data on resident fish, if stocked fish can be distinguished from resident fish.</u>

Regarding the comment about not specifying the fraction of stocked fish to be sampled, agree that this should be considered. However, the data on both fish stocking and relative consumption rates of stocked and resident fish are lacking to support a fraction to apply statewide. Stocked fish are relevant to the sport fish target (and water quality objective) target, not the prey fish targets. Stocked fish are especially relevant to reservoirs in which rainbow trout are stocked and the top trophic level is TL3, because rainbow trout is the most frequently stocked fish. In response, staff report section L.1.1, 1.1Trophic Level and Sizes for the Mercury Water Quality Objectives, second paragraph of Sport Fish Water Quality Objective, was revised as follows: For evaluating compliance with the Sport Fish Objective, monitoring should include representative fish species in TL4 if the objective is for TL4 fish and representative species in TL3 if the objective is in TL3 fish only (no TL4 fish present in the reservoir). "<u>Representative" in reservoirs designated with COMM beneficial use (see Chapter 1) means at least two fish species consumed by humans, one species of which may be stocked fish. "Representative" in reservoirs not designated with COMM beneficial use means at least two fish species consumed by wildlife, one species of which may be stocked fish if wildlife protected by the Sport Fish Objective consume stocked fish (see Table 2.3).</u> A sample is considered either an analytical result from individual fish tissue or a composite of tissue from several fish. Sample sets for comparison with the Sport Fish Objective shall include a range of fish TL3 fish between 150 to 500 millimeters (mm) in total length and TL4 fish between 200 to 500 mm in total length. The objective applies to the wet weight concentration in skinless fillet.

> **TL4 fish are primarily piscivorous and feed at the top of the aquatic food web. TL3 fish consume TL2 organisms (zooplankton, benthic invertebrates, and some small fish). Table 2.1 identifies fish commonly caught in reservoirs and their trophic level (see section 2.2.1).**

Appendix L.1.4, Stocked Fish, states:

Fish that are stocked should be included in sample collection for assessing attainment of the Sport Fish Objective if creel surveys or other information is provided showing that

stocked fish are consumed by people and wildlife species of concern. The rationale for including stocked and consumed fish in compliance evaluations is that methylmercury in stocked fish contributes to the totals of methylmercury intake by people and wildlife. Where stocked fish are important for consumption, methylmercury intakes would be overestimated if stocked fish are not included in assessment of attainment.

COMMENT CCG-48

Wide allowable size range of fish.

RESPONSE TO CCG-48

The size range of fish for assessment of meeting TMDL targets exactly matches size range of fish specified in water quality objectives. The reasoning for TMDL targets to exactly match water quality objectives is to "allow direct assessment of whether beneficial uses are being met" (staff report section 2.4).

COMMENT CCG-49

Min requirement of only 9 fish -too small for good stats, eval thru time, or eval of risk – at least 90% UCI captures some of the inherent variability in small sample size. May allow reservoirs with low fish Hg to avoid expensive sampling, while forcing borderline reservoirs to collect more samples. Why such minimal requirements when the fix can be very expensive??

RESPONSE TO CCG-49

Agree that only 9 fish is a small number, but it is commensurate with the Water Board's sampling program (Surface Water Ambient Monitoring Program, Bioaccumulation Oversight Group) that often collects no more than 11 fish of highest trophic level. Agree that upper 90th confidence limit of the mean provides a more "robust estimate of the true reservoir average" (staff report section L.2.4). Agree that upper 90th confidence limit of the mean induces people to collect more fish mercury data for reservoirs on the borderline to confirm impaired or not impaired before investing in a very expensive fix. Agree that fish sampling and analysis, whether 9 or many more fish, would only be a very small fraction of the cost of pilot studies and full-scale implementation of management practices.

COMMENT CCG-50

90% UCI seems a big improvement on the "binomial" approach that required grouping all fish from one sampling date into a single data point for evaluation

RESPONSE TO CCG-50

The reviewer's agreement with the approach is noted.

COMMENT CCG-51

Chapter 3 – a very comprehensive look at CA reservoirs, and appropriate analysis of available data.

RESPONSE TO CCG-51

The reviewer's commendation of the analysis is noted.

COMMENT CCG-52

Analysis of individual fish and normalizing to standard size is great; also good to see relationship between avg and standardized fish as justification for avg fish target.

RESPONSE TO CCG-52

The reviewer's commendation of the analysis is noted.

COMMENT CCG-53

Chapter 4. Conceptual model

Agree that most CA reservoirs are old [*enough*] that they are steady state [*with respect to*] reservoir construction impacts on methylation.

RESPONSE TO CCG-53

The reviewer's agreement with the analysis is noted.

COMMENT CCG-54

What fraction of CA reservoirs are stratified/anoxic bottoms? This data seems to be missing from the data included in the linkage analysis.

RESPONSE TO CCG-54

Degree of stratification was missing from data set used in the linkage analysis; staff report has been revised to mention this explicitly (see response to CCG-7).

COMMENT CCG-55

In general the references are outdated. Chapter 4 feels like it was taken from an older review, rather than a recent look at the literature. Some of the ideas on Hg complexation are incorrect as a result. Relationships between landscape patterns and watershed chemistry have been strengthened with recent work in the Bay-Delta and the Western Hg Synthesis that isn't cited.

RESPONSE TO CCG-55

Peer reviewer Dr. Benoit opined (comment JMB-40) that “Inferences are drawn from the evaluation of up-to-date, peer-reviewed literature …”. Similar to comment CCG-55, Dr. Mason opined in comment RPM-2, “Overall, I felt that the references seemed skewed to older publications...”

The staff report was prepared methodically and in sequence, so that the literature review (Chapter 4) was completed before the linkage analysis (Chapter 5) was undertaken, and these chapters in turn were completed before TMDL allocations and the implementation plan were devised (Chapters 8 and 9). New mercury research papers were published in the intervening time before the package for peer review was finalized and distributed to reviewers. The Technical Review Committee will help to ensure that pilot tests incorporate current mercury science.

Appreciate the reviewer’s suggestions of additional references provided in the next several comments; see response to CCG-56 through CCG-70. While the new citations provided by the reviewer bring valuable information to the program, we did not find information that changes the basic premises of the program or contradicts the concepts of pilot tests of water chemistry and fisheries management.

In particular, the western North America mercury synthesis effort was completed after Chapters 4 and 5 were completed. This synthesis was led by the U.S. Geological Survey, see [*Link*] and produced many papers. Conclusions of the overarching synthesis paper (Eagles-Smith 2016) correspond to findings and support recommendations in reservoir program staff report, such as:

> **Importantly, inorganic Hg sources and sediment inorganic Hg concentrations are poorly correlated with MeHg concentrations in aquatic sediments. Instead, local biogeochemical conditions appear to be the predominant drivers of MeHg contamination, which is the form of Hg that biomagnifies through food webs and is most toxic to fish, wildlife, and humans. Ecosystem management can have a strong influence on biogeochemical drivers associated with MeHg cycling, and as such is particularly important in the West where a large proportion of land and water resources are publicly managed. For example, reservoirs are dominant features on the western landscape that control large expanses of ecosystem hydrology and food web structure. Management of reservoir water-level fluctuations has a pronounced effect on fish MeHg bioaccumulation that may influence human and wildlife exposure risk. … Effective management … will require looking beyond simply controlling inorganic Hg sources control [*sic*], and will necessitate development of management tools associated with controlling the net production of MeHg, and ultimately its entry into, and bioaccumulation through, food webs.**

COMMENT CCG-56

Anoxic bottom waters and MeHg production - There are several papers on MeHg production in the anoxic hypolimnia of lakes. MeHg may be produced both in the water column, and efflux from sediments when the sediment-water interface in anaerobic. Oxygenation of the water column blocks bottom water methylation and significantly reduced efflux from bottom sediments - including Onondaga Lake papers by Matthews 2013 [*Matthews et al.*, 2013]. See also [*Watras et al.*, 1995] Eckley [*Eckley and Hintelmann*, 2006; *Eckley et al.*, 2005], and the METAALICUS lake [*Harris et al.*, 2007]

RESPONSE TO CCG-56

All but one of these are referenced in Chapter 4; although Eckley and Hintelmann 2006 is not cited, three papers by Eckley are cited (and two of these citations are more recent – 2008).

COMMENT CCG-57

Inorganic Hg in sediment p 90. - Sediment Hg is a predictor of sediment MeHg across ecosystems and should not be discounted (See new synthesis in Hsu-Kim 2017). See [*Fleck et al.*, 2016] – Western Hg synthesis. For the large set of lakes and reservoirs examined, including CA systems, the THg -MeHg relationship was weak (r2=0.25) but significant across the landscape. The results of the linkage analysis should be compared quantitatively to the relationships in Fleck et al.

RESPONSE TO CCG-57

The reviewer's agreement with the approach is noted. Hsu-Kim's 2017 synthesis (also mentioned in comment CCG-69) was not available to cite in staff report, as it was not anticipated to be published until 2018. Data from the linkage analysis are not available to compare quantitatively to the relationships in Fleck et al. (2016) due to lack of reservoir sediment methylmercury data for California reservoirs. The staff report in section 5.5.1, Environmental Data Used in the Linkage Analysis, has been corrected as follows (first bullet): "Reservoir data such as mercury, length, and species of fish; total mercury in reservoir sediment; methylmercury, total mercury, chlorophyll-a, and suspended sediment in reservoir water; and total mercury in upland watershed soils ~~fish, water, sediment, soil total mercury and methylmercury, chlorophyll a, organic carbon, sulfate, and suspended sediment~~ compiled from …."

COMMENT CCG-58

Hg bioavailability: discussion on page 91 says that Hg0 may be more readily oxidized and available than HgS. I don't think that's supported by real world data. The Bloom 2003 sequential extraction study of different Hg forms was never linked to bioavailability to microbes for methylation, and the extractions don't represent how Hg behaves in the anoxic conditions of sediments. Agree overall that that cinnabar has low availability however.

RESPONSE TO CCG-58

The reviewer's qualified agreement with the approach is noted. Regarding the Bloom 2003 sequential extraction study of different Hg forms, the staff report does not include sequential mercury extraction as a parameter to include in any monitoring program.

COMMENT CCG-59

Also the availability of Hg in atmospheric deposition depends on the path and timing to sites of methylation – reactions in the watershed can make Hg much less available (sorption to particles prior to transport for example). Atmospherically-deposited Hg may have the same availability as mine waste after moving thru watersheds – it could react for form sulfides. The science of Hg source availability is NOT settled.

RESPONSE TO CCG-59

The reviewer's agreement with the approach is noted.

COMMENT CCG-60

The neutrally-charged sulfide hypothesis has been updated. What's really going on is the formation of HgS nanoparticles that pass filters and appear "dissolved." Hg in the presences of just about any measurable concentration of bisulfide precipitates as HgS, however particles interact with DOM to form colloids that reduce the growth of particles. DOM helps keep HgS particles small and bioavailable to microbes for methylation [*Andrew M. Graham et al.*, 2012; 2013; *A. M. Graham et al.*, In review; *Zhang et al.*, 2012]. The practice upshot is that Hg can be highly bioavailable in sulfidic settings if DOM is present to reduce the rate of HgS precipitation. See a discussion of the process in Aiken [*Aiken et al.*, 2011] and in Hsu- Kim 2017. HgS can be "dissolved" in the presence of DOM as well (Ravichandran papers).

RESPONSE TO CCG-60

Firstly, appreciate the reviewer's verification that passing filter is not truly chemically "dissolved" form of mercury but rather an operationally defined "dissolved" that includes very small particles that pass through filters. In response to the comment, staff report section 4.1.1, Bioavailability of Inorganic Mercury, fourth paragraph on page 4-5, has been revised to incorporate this information, as follows:

> **… Wallschläger et al. 1998; Ravichandran et al. 1998). Mercury in the presence of nearly any measurable concentration of bisulfide precipitates as mercuric sulfide, however these particles interact with dissolved organic matter to form colloids that reduce the growth of particles. In this way, dissolved organic matter help to keep mercuric sulfide particles small and bioavailable to microbes for methylation (Graham et al. 2012, 2013; Zhang et al. 2012; and Aiken et al. 2011) ~~In addition, once ionic inorganic mercury reaches the anoxic hypolimnion, sulfide can dissolve it, resulting in dissolved mercury-sulfide complexes (Watras 2009). These neutrally-~~**

~~**charged mercury-sulfide complexes are more bioavailable than ionic inorganic mercury, and can be passively transported across the membranes of sulfate-reducing bacteria.**~~ **At very high levels of sulfide, however, mercury-polysulfide complexes can be formed, which are negatively charged and less bioavailable for microbial uptake (Benoit et al. 2003).**

<u>COMMENT CCG-61</u>

P 92 **Wetlands** – Foundational references for the importance of freshwater wetlands in MeHg production in watersheds are [*Driscoll et al.*, 2007; *Hurley et al.*, 1995; *Mitchell et al.*, 2008; *St. Louis et al.*, 1994; [Lee, Y.H.] *et al.*, 1995]. Several recent papers on MeHg production in Bay Delta wetlands by Marvin-DiPasquale and Windham Meyers are important, missing citations.

<u>RESPONSE TO CCG-61</u>

Staff report section 4.1.2, Wetlands and Other Land Uses, cites Driscoll et al. 2007. The first paragraph of this section has been revised to provide these additional citations to interested readers at end of first paragraph, as follows: <u>(For more information, foundational references for the importance of freshwater wetlands to production of methylmercury in watersheds include: Hurley et al. 1995[2]; Mitchell et al. 2008[3]; St. Louis et al. 1994[4]; Lee et al. 1995[5].)</u>

<u>COMMENT CCG-62</u>

DOC p 93. Two key points to be made in this section: DOC is a carrier for Hg and MeHg from watersheds to reservoirs; DOC may enhance methylation rates in reservoirs. These are the mechanisms by which MeHg is related to DOC in surface waters.

Some of the strongest refs for MeHg export on DOC are local ones: [*B. A. Bergamaschi et al.*, 2011; *Brian A. Bergamaschi et al.*, 2012]

[2] Hurley, J. P., J. M. Benoit, C. L. Babiarz, M. M. Shafer, A. W. Andren, J. R. Sullivan, R. Hammond, and D. A. Webb (1995), Influences of watershed characteristics on mercury levels in Wisconsin rivers, Environ. Sci. Technol., 29(7), 1867-1875.

[3] Mitchell, C. P. J., B. A. Branfireun, and R. K. Kolka (2008), Spatial characteristics of net methylmercury production hot spots in peatlands, Environ. Sci. Technol., 42(4), 1010-1016, doi: 10.1021/es0704986.

[4] St. Louis, V. L., J. W. Rudd, C. A. Kelly, K. G. Beaty, N. S. Bloom, and R. J. Flett (1994), Importance of wetlands as sources of methyl mercury to boreal forest ecosystems, Canadian Journal of fisheries and aquatic sciences, 51(5), 1065-1076.

[5] Yee, Y. H., K. Bishop, C. Pettersson, A. Iverfeldt, and B. Allard (1995), Subcatchment output of mercury and methylmercury at Svartberget in Northern Sweden, Water Air Soil Pollut., 80(1-4), 455-465.

RESPONSE TO CCG-62

The staff report in section 4.1.2, Dissolved Organic Carbon, focuses on in-reservoir conditions rather than on transport from watershed to reservoirs. The focus on in-reservoir conditions is appropriate because dissolved organic carbon is intrinsic to a watershed and not controllable (see response to CCG-7).

The first paragraph of section 4.1.2 describes that dissolved organic carbon was the key factor controlling aqueous methylmercury concentrations. However, in contrast to comment CCG-62, the literature cited indicated that DOC was not a facilitator of methylation but instead was likely a principal transport vector or photodemethylation inhibitor. The Bergamaschi citations were not added to the staff report because they relate to tidal wetlands not reservoirs. The definition of reservoirs was revised in both staff report section 1.5 and glossary in Mercury Reservoir Provisions to exclude tidally-influenced waters, as follows: "6. Ponds created to impound saline waters, e.g., salt evaporation ponds<u>; and ponds open to tidal exchange of water with estuary</u>."

<u>COMMENT CCG-63</u>

The mechanism of DOC dissolution of HgS is not it's weak acid character, but the strong binding of thiols in DOC with Hg [*Aiken et al.*, 2011; *Deonarine and Hsu-Kim*, 2009]

RESPONSE TO CCG-63

Staff report section 4.1.2, Dissolved Organic Carbon, has been revised as follows: "~~DOC is a weak acid and will dissolve cinnabar and other complexed forms of mercury.~~ <u>Thiols (sulfur groups) in DOC dissolves cinnabar by strongly binding with mercury (Aiken et al. 2011; Deonarine and Hsu-Kim 2009)."</u>

<u>COMMENT CCG-64</u>

The key message for reservoir management is that high DOC systems (and systems with high DOC in inflows) are much more likely to have high Hg and MeHg levels. Perhaps high DOC/high Hg watersheds should be ones for early attention for remediation. DOC was not one of the parameters included in the linkage study, but should be included in ongoing data collection for reservoirs.

RESPONSE TO CCG-64

See response to CCG-7 regarding that dissolved organic carbon itself is not controllable. Nonetheless, staff report section 9.8.1, Phase 1 pilot tests, in list "Additionally, the locations of pilot tests could be selected for the following attributes" has been revised to add following:

- **<u>Locate tests in reservoirs located in watersheds high in both dissolved organic carbon and mercury.</u>**

Additionally, staff report section 9.13.1 has been revised to include dissolved organic carbon. See response to CCG-84 for the text of the revision in "[*New first bullet*]."

COMMENT CCG-65

Fig 4.2 doesn't distinguish between Hg-contaminated systems and others. Suggest marking them, or noting that the orange arrows are locally-contaminated systems. It's a incomplete graph of the very large literature, but it makes the point that wetlands and reservoirs can be sources of MeHg production.

RESPONSE TO CCG-65

Agree that overall Figure 4.2 does not distinguish between mercury contaminated systems and others. Appreciate the reviewer's suggestion to note that the arrows are locally-contaminated systems. The reviewer's agreement that Figure 4.2 makes the point that wetlands and reservoirs can be sources of methylmercury production is noted.

In response, the caption of Figure 4.2A has been revised to describe that "Red arrows point to high, off-the-chart, values and are all for locations highly-contaminated by local industries or mines."

COMMENT CCG-66

P 94 MeHg loss. Photodemethylation is probably the major loss term in lit surface waters. However, MeHg degradation in sediments causes larger mass losses of MeHg in reservoirs. The mechanism for this loss is still being sorted out. It may be microbial [*Oremland et al.*, 1995] or more likely abiotic [*Jonsson et al.*, 2016]

RESPONSE TO CCG-66

Mercury commonly cycles in the aquatic environment between inorganic and organic forms and methylmercury builds up to environmentally relevant levels when formation exceeds demethylation. However, photodemethylation of methylmercury results in permanent loss of methylmercury from the reservoir through evasion as described (on page 94 in section 4.1.3, Demethylation and Evasion.) In contrast, methylmercury degradation in sediments results in inorganic mercury that is available to again be methylated and discharged into reservoir water.

COMMENT CCG-67

Biomass removal. Removal of aquatic plants is a potential mechanism for reduction of MeHg production am [*Windham-Myers et al.*, 2009].

RESPONSE TO CCG-67

Agree that Windham-Myers and others (2009) found that plant rhizosphere enhances production of methylmercury in wetland sediment. However, aquatic plants provide

valuable habitat, and aquatic habitat is a beneficial use that the Water Boards protect. Therefore, the staff report has not been revised to consider pilot tests of plant removal.

COMMENT CCG-68

Sweden has tried many MeHg remediation techniques for lakes including intensive fishing, liming for pH [*Lindqvist et al.*, 1991]. It would be wise to review their real-life experience over several decades in evaluating options for CA. See [*Bishop et al.*, 2009; *Hultberg et al.*, 1995; *Munthe et al.*, 2007; *Verta et al.*, 2010]

RESPONSE TO CCG-68

Appreciate this constructive comment. Staff report section 9.9.1, Technical adequacy of pilot tests, was revised to incorporate additional references regarding intensive fishing (add to end of first paragraph), as follows: The Technical Review Committee's advice should incorporate Sweden's long-term experience with liming for pH control and intensive fishing (Lindqvist et al. 1991). Staff report section 9.6.1, last paragraph, was revised to incorporate a recommended reference relating to forestry, as follows: "However, scientists around the world are actively studying mercury discharges and cycling from lands used for forestry and timber harvest, e.g., Bishop et al. 2009.

Note that the Hultberg et al. (1995) and Munthe et al. (2007) references relate to comment CCG-4 ("Only reductions in Hg deposition to Sweden really improved the problem across large spatial scales.") rather than liming or intensive fishing. The Verta et al. (2010) reference relates to climate change. Several older publications regarding intensive fishing and liming for pH control in Swedish lakes were referenced in the staff report, as follows:

- **Gothberg (1983) Intensive Fishing: A Way to Reduce the Mercury Level in Fish**
- **Lindestrom (2001) Mercury in sediment and fish communities of Lake Vanern, Sweden: recovery from contamination**
- **Sonesten (2003) Catchment area composition and water chemistry heavily affects mercury levels in perch (Perca Fluviatilis L.) in circumneutral lakes**
- **Verta (1990) Changes in fish mercury concentrations in an intensively fished lake**

COMMENT CCG-69

P 99 Reservoirs. See a new summary of reservoir effects/literature in Hsu-Kim 2017 (ICMGP synthesis paper, posted on ICMGP website).

RESPONSE TO CCG-69

Hsu-Kim's 2017 synthesis was too new to cite in staff report, as it was not yet published at time of reviewer's letter. The website referenced by reviewer is: http://mercury2017.com/ The paper is open access, and the citation is: Hsu-Kim, H., Eckley, C.S., Achá, D. et al. Ambio (2018) 47: 141. https://doi.org/10.1007/s13280-017-1006-7**. See response to JMB-5 for revisions to staff report from Hsu-Kim's 2017 synthesis.**

COMMENT CCG-70

The Western Hg Synthesis [*Fleck et al.*, 2016; *Willacker et al.*, 2016] provides quantitative relationships between reservoir characteristics and MeHg risk that should be cited and used in CA reservoir management planning.

RESPONSE TO CCG-70

The reviewer cites the western North America mercury synthesis effort, which is described in response to CCG-55; see response especially regarding conclusions from the synthesis effort that correspond to findings and recommendations in reservoir program staff report.

Willacker et al. (2016) is more relevant to reservoir management planning and therefore is addressed first. The title is, "Reservoirs and water management influence fish mercury concentrations in the western United States and Canada." This corresponds to a finding in linkage analysis (staff report section 5.1) that water level fluctuation is one of the important factors that explain fish methylmercury concentrations in California reservoirs. Nonetheless, Willacker et al. (2016) recognizes in the introduction that, "The modern development of western North America was made possible by impounding waterways to create reservoirs for water storage, irrigation, flood control, and hydropower." Similarly, the reservoir program recognizes that reservoirs are vital to California and therefore does not suggest pilot tests on water level fluctuations. The staff report in section 9.1 states this as, "[*T*]this mercury program addresses controllable water quality factors and does not impose any restrictions on water supply."

Willacker et al. (2016) evaluated an extensive dataset of mercury concentrations in fish from reservoirs and non-impounded lakes and assessed the influence of reservoir age and water management practices on fish mercury concentrations. Quantitative relationships include the following:

- **Fish mercury concentrations in Mediterranean California were 2.6-fold higher in reservoirs than in lakes, and 1.5-fold higher in North American Deserts (an area that includes a portion of southern California);**
- **50% of fish from reservoirs in Mediterranean California and North American Deserts exceeded the U.S. EPA benchmark for safe consumption (0.3 µg/g ww) compared to only 20% of fish from natural lakes in these regions. This is similar to findings from Finland where 66% of fish sampled from reservoirs exceeded the Finnish consumption benchmark (0.5 µg/g ww) compared to 35% of fish from natural lakes;**
- **The between-year change in maximum water storage had a strong impact on fish mercury concentrations (statistically significant $p < 0.001$), whereas within-year changes between minimum and maximum water level were not correlated with fish mercury concentrations (not significant $p = 0.26$). Predicted (modeled) fish mercury concentrations were as much as 3.2-fold higher due to between-year change in maximum water storage but did not vary over the range of within-year changes in water storage;**

- **The month in which reservoirs reached minimum water storage was a significant predictor of fish mercury concentrations in North American Deserts such that reservoirs with minimum water storage occurring during July had fish mercury concentrations 13.6-fold higher than reservoirs with minimum water storage occurring in January;**
- **Mean fish mercury concentrations in Mediterranean California were not different among reservoirs with water storage minimums that occurred in different months; there was no apparent pattern in fish mercury concentrations among months; and there was no effect of between-year difference in maximum water storage;**
- **Mediterranean California is subject to one of the most intensive water storage and diversion systems in the world. Because of the high density of reservoirs and prevalence of inter-basin water movements, nearly every reservoir in the region is situated downstream of other reservoirs. This "downstream effect" can have substantial impacts on fish mercury concentrations, with upstream reservoir conditions explaining >75% of the variation in downstream reservoirs, and often more than in-reservoir processes;**
- **Fish mercury concentrations in reservoirs are shown to change dramatically with reservoir age, and the authors suggest management techniques from such as pre-flooding biomass reduction and extending filling over longer time-frames from Mailman and others (2006), that are considered in staff report section 7.6.1.**

We conclude from Willacker and others' (2016) quantitative analysis that it is appropriate to develop a statewide mercury control program for reservoirs because in California fish methylmercury levels are commonly higher in reservoirs than in lakes. Next, we consider the other synthesis paper recommended by the reviewer.

Fleck et al. (2016) evaluated aquatic bed sediment total mercury and methylmercury concentrations from a wide array of aquatic habitats across western North America, including lakes and reservoirs, but did not evaluate fish mercury concentrations. Relevant findings include the following. Fleck et al. (2016) in section 3.1, total mercury, discusses of importance of sieving due to grain-size effect on mercury concentration. Importance of grain-size effect further supports particulate mercury concentrations selected for load allocations, e.g., staff report section 7.2.1, load applications applicable to runoff from mine sites. Fleck et al. (2016) in section 3.2, methylmercury, discusses important findings that some of the highest sediment methylmercury concentrations occurred in areas with relatively low mercury concentrations, and that lakes and canals had sediment methylmercury concentrations twice as high as estuaries and streams.

We conclude that Fleck and others' (2016) quantitative analysis provides additional support for efforts to address methylation in California reservoirs, i.e., support to pilot test water chemistry management practices.

Moreover, Fleck et al. (2016) contradicts the reviewer's "interpretation of the extensive literature on [*mercury*] remediation is that [*mercury*] source control should always be the first approach to reducing [*methylmercury*] risk." (See comment CCG-4.) Fleck and others' (2016) state in section 3.4, Implications, "The extensive landscape and water

management activities that are commonplace in western North America present a potential opportunity to minimize the threats posed by mercury contamination. Because [*mercury*] is a poor predictor of [*methylmercury*] across the habitats in this vast region, management approaches focused on [*mercury*] concentration as the means to reduce risk are likely to have limited effects." Nonetheless, we agree that mercury source control should be the first approach (see responses to CCG-4).

COMMENT CCG-71

Chapter 5. Linkage analysis. Very good statistical analysis of available data. But the available data have substantial limitations. The linkage analysis did not include several parameters that may be strongly related to MeHg production and MeHg in water or fish, including the degree of stratification or anoxia, the organic content of sediments, growth of submerged aquatic vegetation (the last two enhance microbial activity and MeHg production), DOC, and critically the loading rate of Hg to reservoirs.

RESPONSE TO CCG-71

The reviewer repeats comment CCG-7; see response to CCG-7.

COMMENT CCG-72

I assume that Hg loading wasn't used because data aren't available. But sediment Hg concentration may not be a good surrogate for loading. Relationship between sed Hg and fish Hg doesn't consider the idea that Hg in sediments becomes less available for methylation over time (faster than burial). This is why source reduction is so [*important*]. I suspect the linkage analysis is underestimating the efficacy of source control in reducing fish MeHg; because the model is based on sediment Hg concentrations rather than Hg load.

RESPONSE TO CCG-72

Mercury loading used in linkage analysis is described in response to CCG-7. Regarding the comment that mercury in sediments becomes less available for methylation over time, the reviewer repeats comment CCG-15; see response to CCG-15. Regarding the last comment that linkage is based on sediment mercury concentrations rather than load, the reviewer repeats comment CCG-17; see response to CCG-17.

Regarding importance of source reduction, in response staff considered how mercury load data could be used to prioritize mine sites for cleanup. Staff proposes five characteristics of Tier 1 (highest priority) mine sites for cleanup (see staff report section 9.2.1, Tiers for mine site prioritization). Combining the first and fourth characteristics of Tier 1 equates to mercury loads. The first characteristic of Tier 1 is elevated mercury levels in reservoir bottom sediment. The fourth characteristic of Tier 1 is significant discharges of mercury from mine site (meaning both elevated [>10x] particulate mercury concentration compared to modern background mercury levels in soils surrounding the mine site and significant active erosion [mass wasting]) (see staff report section 9.2.1,

Tiers for mine site prioritization). Mercury loads could be substituted for the combination of these two characteristics.

However, it is much, much more expensive to collect mercury load rather than concentration data, especially loads from mines that are dependent on infrequent, large storm events (Kirchner et al. 2011). Staff concludes that the benefits to prioritize mine sites for cleanup based on mercury load data rather than Tier 1 characteristics are minimal and not cost effective. Additionally, staff concludes that opportunities to prioritize mine sites for cleanup based on mercury load data are limited due to lack of loading data.

COMMENT CCG-73

The use of unfiltered (and often spatially and temporally scarce) water MeHg data may be problematic. Unfiltered MeHg would include MeHg on particles including phytoplankton. [*It*] isn't really the amount of MeHg available to enter the base of the food web but may represent MeHg in the base of the food web itself.

RESPONSE TO CCG-73

The reviewer repeats comment CCG-8 regarding scarce methylmercury data; see response to CCG-8. Agree that methylmercury on phytoplankton is methylmercury in the base of the food web itself.

COMMENT CCG-74

I couldn't tell if MeHg data for the reservoirs included in the linkage analysis were averages that included hypolimnia or not – and this could make a big difference in the outcome of the analysis.

RESPONSE TO CCG-74

Yes, hypolimnia aqueous methylmercury data were used in the linkage analysis. The staff report in section 5.1.1., Water Data, describes aqueous methylmercury data used in the linkage analysis, as follows:

> **Aqueous methylmercury concentration data are available for 53 reservoirs, though generally there are few measurements for each site. Much more information is available for near-surface, unfiltered water samples than for lower (hypolimnion) in the water column or for filtered samples. Consequently, the linkage analysis uses results for unfiltered samples collected throughout the water column and throughout the year."**

Although agree that it would have been optimum to have frequently-collected, near-surface, below oxycline, and hypolimnia aqueous methylmercury concentration data to use in linkage analysis, insufficient data were available. The results of the linkage analysis were used to develop the methylmercury allocation to reservoirs, but allocations are not static. The program allows for allocations to be modified in the future after a

decade of pilot testing; see response to CCG-79 regarding implementing methylmercury allocation as a management practice and not as a cleanup standard.

COMMENT CCG-75

Unfiltered MeHg concentrations can by driven by particulate concentrations – which can vary enormously with season and depth.

RESPONSE TO CCG-75

Typically, particulate concentrations are determined by measuring suspended sediment concentrations, although other measurements may be used instead, e.g., turbidity. In response, staff report section 9.13.1 Reservoir Technical Review Committee has been revised to include suspended sediment concentration. See response to CCG-84 for the text of the revision in "[*New first bullet*]."

Note to readers:
Dissolved and total aqueous methylmercury sediment concentrations were included in response to CCG-8; unfiltered means total.

COMMENT CCG-76

The chla:MeHg ratio was available for only ~40 reservoirs. MeHg and chla data may not have be taken at the same season, depth, or frequency in all lakes. The multiple regression model that includes the chla:MeHg ratio uses a subset of only 26 reservoirs.

RESPONSE TO CCG-76

This comment is also provided in CCG-10; see response to CCG-10. Staff report section 5.2.1 describes that Models 2 and 3 were used to develop the aqueous methylmercury allocation. These two models included more reservoirs in their development: 35 and 43 reservoirs for Models 2 and 3 respectively, compared to 26 reservoirs for Model 1.

COMMENT CCG-77

The linkage analysis only included data from Hg-impaired reservoirs. An analysis that included all reservoirs may have shown stronger relationships between total Hg, MeHg and MeHg in fish.

RESPONSE TO CCG-77

The reviewer repeats comment CCG-10; see response to CCG-10.

COMMENT CCG-78

The analysis conducted made appropriate use of available data, but could go further in acknowledging the limitations imposed by the data. Model 1 includes only a small subset of all CA reservoirs. The use of unfiltered MeHg data reservoirs makes this model more uncertain than it might appear in the formal statistical analysis presented.

RESPONSE TO CCG-78

The reviewer repeats comment CCG-10; see response to CCG-10.

COMMENT CCG-79

Goal of no detectable water column MeHg (at a 0.009 ng/L DL) is a great goal, but may be unachievable in some reservoirs.

RESPONSE TO CCG-79

The reviewer's qualified endorsement of the goal is noted. This goal is used as a TMDL allocation that is being implemented as a management practice with the goal of achieving all TMDL targets (fish methylmercury levels) applicable to each reservoir. The methylmercury allocation is not being implemented as a cleanup standard or a numeric effluent limitation (staff report section 9.8.1). See response to CCG-74, which describes that allocations can be modified in the future.

COMMENT CCG-80

Hg loading rates from mines – don't have a good measure of this – using number or density of mines in the watershed as a proxy? Is there any data to suggest this is a good proxy?

RESPONSE TO CCG-80

We are aware of one paper that suggests mine density is indeed a good proxy for mercury loading rates from mines. This paper is from the western North America mercury synthesis effort (described in response to CCG-55) and is titled, "Comparison of mercury mass loading in streams to atmospheric deposition in watersheds of Western North America: Evidence for non-atmospheric mercury sources" (Domalgalski et al. 2016). A highlighted conclusion from this paper is that: "Abandoned mines increased annual stream load relative to deposition."

Mercury loading rates from mines is scarce in the literature; one of the few excellent loading studies that was fortuitously conducted during infrequent, extreme storm events is available for a California mercury mine although it does not drain to any reservoirs; it was cited in staff report Chapters 6 and 7 (Kirchner et al. 2011). Another excellent loading study that unfortunately was conducted during small storm events is available for the Cache Creek watershed and was cited in staff report Chapter 6 (Domagalski et al. 2004). However, neither of these loading studies accounts for mine density.

Staff report section 6.3.3, Location of Historic Mining Activities, states, "Past and present discharges from historic gold and mercury mines may be particularly important sources to reservoirs with a high number of mine sites, high watershed mine density, or high mine production (and associated mercury loss) amounts (Shilling et al. 2002; Scudder et al. 2009; Alpers, 2016). We reviewed these citations to confirm they did not also contain mercury loading rates, as described in next paragraph. The staff report was revised to correct the citation to Alpers to: <u>Alpers et al. 2016</u>.

Shilling and others' (2002) work covered the Sacramento River Watershed and Bay-Delta, used mine density, used ratio of total mercury to total suspended solids, but did not use loading rates. Scudder and others' (2009) work covered the United Stated and they noted their "study was not designed specifically to address impacts of mining, so there may be areas of intense gold and [*mercury*] mining that were not represented." Scudder and others (2009) also used particulate mercury fraction, but not loading rates. Alpers and others' (2016) work covered western North America and used streambed sediment mercury data, fish mercury data, landscape metrics of anthropogenic disturbance in watersheds including mine locations, but not loading rates.

<u>COMMENT CCG-81</u>

I don't see a measure of stratification or bottom water anoxia in the data set. – does dam height capture this? Is chla related to anoxia?

<u>**RESPONSE TO CCG-81**</u>

Regarding stratification or bottom water anoxia, the reviewer repeats comment CCG-7; see response to CCG-7. Dam height is not a proxy for stratification or bottom water anoxia but is a proxy for maximum water depth, as explained in staff report section 5.1.1, Other Reservoir Data., Chlorophyll-a data are not a robust proxy for anoxia, even though chlorophyll-a is a proxy for algae. When algae blooms die, they often sink to the bottom and cause bottom water anoxia. Consequently, chlorophyll-a data alone without corresponding bloom and die-off measurements do not provide a proxy for bottom water anoxia.

<u>COMMENT CCG-82</u>

Despite the linkage analysis, I remain skeptical of the conclusion that "mercury source control alone cannot achieve the sport fish target" - because of the limitations of the linkage analysis.

<u>**RESPONSE TO CCG-82**</u>

The reviewer repeats concerns expressed in comments CCG-3 through CCG-11; see responses to CCG-3 through CCG-11.

<u>COMMENT CCG-83</u>

What does "goals lower than natural background" mean – are these sediment concentration or loading targets?

<u>**RESPONSE TO CCG-83**</u>

These goals are for reservoir sediment mercury concentration not mercury loading to reservoirs. This comment refers to overview of Chapter 5, Implications, second bullet: "Calculation of goals for total mercury source reduction should take into account technical feasibility to avoid having goals that are lower than natural background.

Chapter 6 provides an assessment of mercury sources and Chapter 7 estimates how much these sources can be reduced.”

These goals are for concentration not loading, as explained in Chapter 7, Overview, *Key Points from This Chapter*:

Predictions for mercury source control include the following:

1. **The lowest reservoir sediment mercury concentration that can be achieved in the foreseeable future (i.e., within the next several decades) is modern background soil mercury concentrations, versus natural (pre-industrial) background conditions.**

COMMENT CCG-84

Recommendations for sampling/monitoring in reservoirs undergoing TMDL implementation:

- switch to filterable and particulate MeHg for the water column
- conduct more detailed temporal and spatial sampling of MeHg and chla in the water column, especially in stratified lakes
- collect data on the volume and duration of anoxia.
- MeHg in sediments.

RESPONSE TO CCG-84

In response, staff report section 9.13.1 Reservoir Technical Review Committee has been revised to include all of these suggestions. For readability, the following changes “[*new first bullet*]” also show responses to CCG-8, CCG-64, CCG-75, and CCG-86. The following changes “[*new last bullet*]” show response to CCG-12. The following changes “[*new penultimate bullets*]” show response to CCG-34 (including response to RPM-22 regarding appropriate mix of major and minor nutrients).

Staff report section 9.13.1 Reservoir Technical Review Committee has been revised to include new questions, as follows:

Examples of questions regarding pilot tests of water chemistry that could be put to the Technical Review Committee are the following:

- **[New f*irst bullet*] Where and when should dissolved, particulate, and/or total aqueous methylmercury; dissolved organic carbon; and suspended sediment concentrations be monitored (for pilot tests and associated studies, and for reservoirs not undergoing pilot tests)? Where and when should more detailed (temporal and spatial) sampling of aqueous methylmercury and chlorophyll a be conducted, especially in stratified reservoirs? How best should data be collected for volume, areal extent, and duration of anoxia? Where and when should**

reservoir sediment mercury, methylmercury, grain size, organic content, and other parameter data be collected?

- **[*New penultimate bullets*] For nitrate addition for bottom water redox control, does the monitoring program provide sufficient measures of food web structure response to determine if adverse impacts have occurred?**

- **[*New penultimate bullets*] For nutrient additions, were limiting nutrients assessed and does the initial amendment contain an appropriate mix of major and minor nutrients? Does the work plan include adequate monitoring to inform adjustments in the amendment formulation to avoid stimulating undesirable species (e.g., cyanobacteria or the diatom *Rhizosolenia*)? For nutrient additions or intensive fishing, does the monitoring program provide sufficient measures of food web structure response to determine if adverse impacts have occurred?**

- **[*New last bullet*] Based on completed pilot tests, in your opinion which reservoirs will never meet the TMDL targets and what are the lowest fish methylmercury levels that can be achieved in these and similar reservoirs? If unable to answer now, what more is needed to determine the lowest fish methylmercury levels)?**

Additionally, comment CCG-84 together with comment RPM-33 caused staff to recognize the need for additional reservoir-specific data. Comment RPM-33 states, "…it appears to me that in most cases each [*reservoir*] will have to be dealt with as an individual case with little ability to extrapolate from 'case studies'…". As noted in response to CCG-10, during Phase 1 additional data will be collected in reservoirs undergoing pilot tests to support selection of reservoir management practices (and development of long-term reservoir management strategy report). However, many of the coordinated reservoirs will not undergo pilot tests but will need additional data to support selection of reservoir management practices. Moreover, fish stocking information is needed to support selection of fisheries management practices. In response, both the Provisions and Staff Report have been revised as follows to require at least two years of monitoring and to recommend that all fish stocking of reservoirs and lakes be reported to a central, on-line database.

Add to Mercury Reservoir Provisions:
IV.H.3. Monitoring in Coordinated Reservoirs Not Undergoing Pilot Testing

An owner or operator that elects to develop and implement coordinated plans and reports described in Chapter IV.H.1 shall additionally comply with the following requirements for IMPAIRED RESERVOIRS not undergoing pilot testing, to support development of the Long-term Reservoir Management Strategy Report:

d. Monitoring Plan. The monitoring plan shall include the following elements.

i. A description of the monitoring activities and methods, expected types of data, data quality assurance, and data analysis methods that will be used to characterize (a) mercury and methylmercury inputs, outputs, cycling,

and bioaccumulation; and (b) reservoir limnology and water quality; in sufficient detail to support development of a reservoir-specific long-term reservoir management strategy report.

ii. A description of the monitoring timing and frequency. Monitoring should occur in calendar years, if applicable, before and after changes in reservoir operations or management made for reasons other than mercury, or before and after re-fill after prolonged drawdown due to drought or reservoir management. Where applicable, reservoir monitoring must be coordinated with and occur in same calendar year(s) as methylmercury discharge monitoring required by Chapters IV.F.3 and IV.G.1. If not specified otherwise in the monitoring plan, monitoring shall occur in the fourth and seventh calendar years after the Effective Date. Monitoring frequency is no less than quarterly during two calendars years.

iii. Time schedules for the following, at a minimum: (a) projected calendar years of monitoring; and (b) reporting dates in accordance with Chapter IV.H.5.

e. Monitoring Progress Report. Monitoring progress reports shall describe the progress made to date on the monitoring, any preliminary findings or results, and any recommendations to revise the monitoring work plan including changing.

f. Monitoring Final Report. Monitoring final reports shall describe results of the monitoring and how this information will be incorporated (in conjunction with results from the coordinated pilot tests) in each long-term reservoir management strategy report.

IV.H~~F~~.4. Time Schedule Requirements for Reservoir Owners and Operators:

e. Implement Pilot Tests and Monitoring. Beginning not later than six months after WATER BOARDS approval of each pilot test and monitoring work plan, the owner and operator shall implement the approved individual ~~or coordinated~~ pilot test work plan or coordinated pilot test and monitoring work plan.

V.B.6 CDFW require all fish stocking of RESERVOIRS and lakes be reported to a central, on-line database. Stocking information to include date, permit number if applicable, hatchery, species, sizes (length and weight ranges of size classes), and count and total weight by size classes.

VI.B.3. Review each long-term reservoir management strategy report submitted in accordance with Chapters IV.~~F~~H.1.d, IV.~~F~~ H.4.h, and IV.~~F~~H.5, and, if approved by the State Water Board, direct each owner and operator ~~on whose behalf the long-term reservoir management strategies were submitted~~ to implement actions informed by the PHASE 1 pilot tests and monitoring during PHASE 2.

Add to Mercury Reservoir Provisions:

IV.F~~G~~.3 Within one year of the Effective Date of the MERCURY RESERVOIR PROVISIONS, for any permittee with a direct discharge of mercury to an IMPAIRED RESERVOIR or a surface water that is tributary to an IMPAIRED RESERVOIR (including those identified in

Table 5) that uses one or more treatment pond systems (e.g., oxidation, facilitative, settling, or stabilization ponds), the WATER BOARD will either issue an order pursuant to Water Code sections 13267 or 13383, or modify, re-issue, or adopt the applicable NPDES permit to require effluent methylmercury monitoring. The effluent methylmercury monitoring shall occur at a minimum on a quarterly basis for two calendar years and shall occur in the same calendar years in which monitoring in reservoirs listed in Tables 3A and 3B occurs as required by Chapter IV.H~~F~~.4.e [Implement Pilot Tests and Monitoring**], and the monitoring results may be submitted in an annual report. If all methylmercury sample results in the first calendar year are below the detection limit of 0.02 ng/L, then the permittee may discontinue the monitoring.**

Add to Mercury Reservoir Provisions:
IV.G~~H~~.1.b. The WATER BOARD will either issue an order pursuant to Water Code sections 13267 or 13383, or modify, re-issue, or adopt the applicable NPDES permit to require methylmercury monitoring in representative urban runoff discharges to the reservoir or its tributaries at least twice during each of one dry season and one wet season and to submit the monitoring results to the WATER BOARD within eight years of the Effective Date of the MERCURY RESERVOIR PROVISIONS. The methylmercury monitoring shall occur in the same calendar year in which monitoring in reservoirs listed in Tables 3A and 3B as required by Chapter IV.H~~F~~.4.e [Implement Pilot Tests and Monitoring**].**

Staff Report Summary, S-5 Key Actions in Phase 1, Reservoirs: Pilot tests

> **Owners and operators of mercury-impaired reservoirs (see Table S-2) would conduct pilot tests of methods to reduce methylmercury concentrations in reservoir fish. Hydroelectric power reservoirs (i.e., licensed by Federal Energy Regulatory Commission) would be excluded from mercury pilot test requirements in Phase 1. Coordinated pilot tests could be conducted in fewer, targeted reservoirs rather than in all impaired reservoirs, and monitoring would be conducted in impaired reservoirs not undergoing pilot testing. Reservoir owners and operators would convene a third-party independent Technical Review Committee to advise on pilot tests.**
>
> **Reservoir owners and operators would use lessons learned from pilot tests and monitoring data to develop long-term reservoir and fisheries management plans. In program review after Phase 1, the Technical Review Committee and the State Water Board would evaluate results of pilot tests and monitoring and review the long-term reservoir and fisheries management plans.**

Staff Report section 9.1, Overview of Implementation Plan, second paragraph

> **In the first decade, reservoir owners and operators would test feasible reservoir management actions. The Water Boards encourage a coordinated approach for fewer, focused tests rather than tests in all mercury-impaired reservoirs. Monitoring would be conducted in impaired reservoirs not undergoing pilot testing. The test and monitoring results will be evaluated by an independent, third-**

party Technical Review Committee before the Water Boards would develop long term requirements for all mercury-impaired reservoirs.

Staff Report section 9.1.1, Key Actions in Phase 1, Reservoirs: pilot tests

Owners and operators of mercury-impaired reservoirs (see Table 9.1) would conduct pilot tests of methods to reduce methylmercury concentrations in reservoir fish. FERC-licensed reservoirs would be excluded from mercury pilot test requirements in Phase 1. Owners and operators could coordinate the development of pilot tests such that the tests are conducted in fewer, targeted reservoirs rather than each of the owner's or operator's reservoir. <u>Monitoring would be conducted in impaired reservoirs not undergoing pilot testing.</u> Reservoir owners and operators would convene a third-party independent Technical Review Committee to advise on pilot tests.

Reservoir owners and operators would use lessons learned from pilot tests <u>and monitoring</u> to develop long-term reservoir and fisheries management plans. The Technical Review Committee and the Water Boards would evaluate results of pilot tests <u>and monitoring</u> and <u>review the</u> proposed long-term reservoir and fisheries management plans.

Staff Report section 9.8.3, Coordinated Approach

…

Coordinated Approach

Key features of a coordinated approach acceptable to the Water Boards are the following:

- **Preferably one statewide work plan that addresses pilot tests for both reservoir water chemistry and fisheries management, but up to three work plans for reservoir management and three work plans for fisheries management are acceptable.**
- **Reservoirs included in a coordinated approach must be representative of all of the reservoirs of those entities participating in the coordinated effort.**
- **<u>Monitoring would be conducted in impaired reservoirs not undergoing pilot testing and be coordinated with and occur in same calendar year(s) as methylmercury discharge monitoring for urban runoff and municipal and industrial wastewater facilities (see sections 9.5.5 and 9.7.5).</u> Where practicable, pilot tests and associated studies could be coordinated with other mercury and methylmercury monitoring efforts.**

Pilot tests conducted in representative reservoirs <u>and monitoring conducted in reservoirs not undergoing pilot testing</u> must provide information to help answer management questions 1 and 2 in section 9.13.2. …

…

Staff Report section 9.8.4, Work and Monitoring Plans and Reports

The following new section will be placed after "Coordinated pilot test work plan" and before "Individual pilot test work plans."

Coordinated pilot test monitoring plan

Monitoring must occur in reservoirs that are part of the coordinated approach but *not* **undergoing pilot testing to provide information necessary to develop each long-term reservoir management strategy report and to help answer management questions 1 and 2 in section 9.13.2. The monitoring plan must provide detailed descriptions of the following, individually for each reservoir:**

(a) A detailed description of the reservoir and its watershed, including at least the following: currently known general limnological characteristics, available water quality data, current monitoring program, current water quality and fisheries management practices, and anticipated changes for reasons other than mercury in monitoring program and water quality and fisheries management practices. A description of the most likely feasible water chemistry and fisheries management practices, and the limnological and water quality characteristics needed to support selection (or elimination) of these management practices.

(b) Description of the proposed mercury monitoring activities and methods, expected types of data, and data quality assurance. Expected data include but are not limited to:

- **Water: unfiltered total mercury and methylmercury; ancillary water quality parameters; water quality field measurements; water mercury samples must be collected from at least three depths during stratified periods (epilimnion, below thermocline, and from deep in hypolimnion); water mercury samples may be collected from only epilimnion when the reservoir is well-mixed; additionally for reservoirs with known or suspected cyanobacteria, monitor for chlorophyll-a, phycocyanin, and algal species identification to inform bioaccumulation and fish growth rates;**

- **Biota methylmercury: plankton;**

- **Biota methylmercury: prey fish and sport fish (may be analyzed as total mercury); and**

- **General limnological measurements such as: (i) depth profiles (T, DO, Chl-a, and SC; and others on reservoir-specific basis such as phycocyanin and redox potential); (ii) nutrient data to support calculating trophic status (e.g., Carlson's Trophic State Index); and (iii) data to support calculating stratification metrics (e.g., Richardson number, Anoxic Factor, Schmidt stability, and others).**

(c) A description of the data analysis methods and how the monitoring data will be evaluated to support development of each long-term reservoir management strategy report. The analyses and evaluations are expected to include but are not limited to:

- **Characterize mercury and methylmercury inputs, outputs, cycling, and bioaccumulation; and in-reservoir methylmercury production;**
- **Mass balances on mercury and methylmercury (order-of-magnitude estimate);**
- **Reservoir limnological and water quality characteristics, especially characteristics needed to support selection (or elimination) of specific management practices.**

(d) A description of the monitoring timing and frequency. Monitoring should occur in calendar years, if applicable, before and after changes in reservoir operations or management made for reasons other than mercury, or before and after re-fill after prolonged drawdown due to drought or reservoir management. Where applicable, reservoir monitoring must be coordinated with and occur in same calendar year as methylmercury discharge monitoring for urban runoff and municipal and industrial wastewater facilities (see sections 9.5.5 and 9.7.5). If not specified otherwise in the monitoring plan, monitoring shall occur in the fourth and eighth calendar years after the effective date of the Mercury Reservoir Provisions. The frequency of water sampling and measurements of general limnological characteristics is no less than quarterly during two calendar years. Other data may be collected less frequently if the monitoring plan provides technical justification acceptable to the Technical Review Committee.

(e) Time schedules for the following, at a minimum: (a) projected calendar years of monitoring; and (b) reporting dates in accordance with section 9.8.5.

Staff Report section 9.8.4, Pilot test and monitoring progress reports

Pilot test and monitoring progress reports are needed to keep the Water Boards and interested parties informed of progress and challenges to progress that require a revision to the work plan. Accordingly, pilot test and monitoring progress reports should describe the progress made to date on the pilot tested management practice(s) or monitoring, any preliminary findings or results, and any recommendations to revise pilot test work plans or monitoring plans.

Staff Report section 9.8.4, Pilot test and monitoring draft and final reports

Pilot test and monitoring draft reports must describe results of the pilot test(s) or monitoring and recommendations for long-term reservoir water chemistry (and if applicable fisheries management, see section 9.9) practices to achieve all applicable targets in each impaired reservoir. Draft reports must be submitted for review to the Technical Review Committee and to the Water Boards. Owners and operators must revise these reports to account for the Technical Review

Committee's conclusions and recommendations and the Water Boards direction prior to submitting the final pilot test and monitoring reports to the Water Board. The final pilot test and monitoring reports must assess effectiveness in reducing fish methylmercury levels, economic costs, potential public and environmental benefits of lower fish methylmercury levels, and potential negative impacts of long-term operations of mercury controls.

Staff Report section 9.8.5, Schedule for Phase I Pilot Tests and Monitoring

For readability and brevity, this response describes the edits made to staff report section 9.8.5 rather than providing them in underline, because the same edits are made multiple times. The time schedule for monitoring is generally the first and last calendar years that coincide with pilot tests, which are the fourth and eighth years after the effective date of the Mercury Reservoir Provisions. If applicable on a reservoir-specific basis, monitoring should occur in calendar years before and after changes in reservoir operations or management made for reasons other than mercury, or before and after re-fill after prolonged drawdown due to drought or reservoir management. Also if applicable on a reservoir-specific basis, monitoring must be coordinated with and occur in same calendar year as methylmercury discharge monitoring for urban runoff and municipal and industrial wastewater facilities.

The time schedule for monitoring plans and reports is the same time schedule as for pilot tests. Hence, draft monitoring plans are due on same date as draft coordinated pilot test work plan(s); and similarly, final monitoring plans are due on the same date as final pilot test work plan(s); monitoring progress reports are due on the same date as pilot test progress reports; and draft and final monitoring reports are due on the same dates as pilot test draft and final reports.

Staff Report section 9.8.1, Phase 1 pilot tests, new final paragraph, and Staff Report section 9.9.1, Phase I Actions for Fisheries Management, new penultimate paragraph:

Data interpretation for the long-term reservoir management strategy should be informed by fish stocking, particularly because if stocking of large amounts of low-mercury hatchery fish occurs, it will skew the fish mercury data collected during pilot tests. Stocking is often undertaken by multiple parties, e.g., by both California Department of Fish and Wildlife and private sportfishing concessionaires. Although fish stocking is subject to regulation by the California Department of Fish and Wildlife, currently this agency does not require reporting of all fish stocking. Therefore, to ensure that complete data are available on stocking in impaired reservoirs during pilot tests, the California Department of Fish and Wildlife should require that all stocking be reported. For simplicity, it is recommended that California Department of Fish and Wildlife require reporting of all stocking in all reservoirs and lakes, rather than only in mercury-impaired reservoirs. These data for non-impaired reservoirs will be evaluated to determine whether stocking is the reason for very low methylmercury levels in largemouth bass in some reservoirs (e.g., Toluca Lake, Lake of the Pines, Lake Calabasas, Prado Lake, Lake Evans, Dixon Lake, Lake Poway, and Lake Wohlford; see footnotes for Table 9.3). For ease of reporting and data retrieval, it is

<u>recommended to use a centralized, on-line form or database. At a minimum, the stocking information should include date, permit number if applicable, hatchery, species, sizes (length and weight ranges of size classes), and count and total weight by size classes.</u>

<u>COMMENT CCG-85</u>

Sediment goal: Sediment Hg concentrations and assessment of background values: would these be more informative if normalized to sediment organic content? What is the avg organic content of reservoir sediments? Either target on p 125 – 2 or 20 ug/kg – are low values in the context of available data for the US (See Fleck 2016 for example). The Western Hg synthesis found an avg on 29 ug/kg for lakes, near the Water Boards suggested target.

Suggest putting the CA data into context with the Fleck synthesis.

<u>RESPONSE TO CCG-85</u>

The reviewer expands upon comment CCG-83. See response to CCG-83 for context.

<u>Regarding: normalize to sediment organic content</u>
Agree that normalizing to sediment organic content could be informative for linkage analysis. However, normalizing to sediment organic content would not be more informative for determining feasible reservoir sediment mercury concentrations that might be achieved by cleanup of upstream mining wastes and contaminated soil. These feasible concentrations were used to develop TMDL load allocations for mining waste and soil. The goal for TMDL load allocations, as described in section 8.2.1, is to "is to reduce to the extent feasible inputs of mercury to mercury-impaired reservoirs caused by anthropogenic activities."

Response to CCG-84 includes new questions to put to the Technical Review Committee, and includes a question regarding where and when to collect reservoir sediment organic content data.

The reviewer is comparing calculations to support TMDL load allocations (in staff report Chapter 6) with modeling undertaken in linkage analysis (in staff report Chapter 5). Nonetheless, the reservoir program anticipates re-visiting the linkage analysis in the future, after a decade of pilot testing, during program review. See responses to CCG-25 and CCG-74: staff report section 9.13.2 provides focusing questions that will be used in program review, including question 4 that asks whether modifications to allocations are appropriate. Question 4 also asks whether modifications to linkage analysis (i.e., modifications to models) are appropriate. If in the future modifications are made to models, analysts may consider evaluating sediment mercury normalized to sediment organic content, if data are available.

<u>Regarding: put the California data into context</u>
Fleck and others (2016) in the western North America mercury synthesis effort evaluated aquatic habitat sediment mercury and methylmercury. Of the various aquatic habitats

that Fleck and others (2016) evaluated, stream sediment data are most comparable to landscape soil data evaluated in staff report Chapter 6. (Therefore, this response considers stream and not lake data as suggested in the comment.) Mean mercury was 0.021 mg/kg +/- 0.005 mg/kg in mining- and non-mining-impacted stream mercury bulk sediment (Fleck et al. 2016). This mean concentration for all of western North America is slightly lower than that calculated for California modern background levels in trace mercury areas that typically range from 0.05 to 0.1 mg/kg as described in staff report Chapter 6. It is reasonable that mean mercury concentration for all of western North America would be lower than in California due to mercury enrichment from historical atmospheric deposition from California's legacy mercury and gold mines.

COMMENT CCG-86

Recommend collecting grain size and/or organic content for reservoir samples collected going forward, and incorporate Hg:LOI ratios into models going forward.

RESPONSE TO CCG-86

In response, staff report section 9.13.1 Reservoir Technical Review Committee has been revised to include grain size and organic content. See response to CCG-84 for the text of the revision in "[*New first bullet*]."

The reviewer's suggestion that ratio of mercury and methylmercury to organic content (measured by loss on ignition [LOI] or measured by other means) for use in models are noted. See responses to CCG-25 and CCG-74: staff report section 9.13.2 provides focusing questions that will be used in program review. Focusing question 4 also asks whether modifications to linkage analysis (i.e., modifications to models) are appropriate. If in the future modifications are made to models, analysts may consider evaluating various ratios of sediment mercury to sediment organic content, if data are available.

COMMENT CCG-87

Chapter 7 – Source remediation.

The report noted (p 183) that "it could take decades to centuries for industrial-era mercury in watershed soils to be depleted" – meaning that contaminated soils could be contributing to high Hg in fish for a very long time. It's certainly true that reservoir fish in mining areas are impaired more than 100 years after the CA gold rush.

RESPONSE TO CCG-87

The reviewer's agreement with the approach is noted.

COMMENT CCG-88

Clean up should focus on flow paths to reservoirs, to reduce continued erosion of contaminated sediments that leads directly to reservoir Hg loads. In soils disconnected from main flow paths in the watershed, Hg may become immobile to leaching and transport over time. Solute transport of Hg from soils in these areas may be effectively zero (Oswald, 2016?)

<u>RESPONSE TO CCG-88</u>

The reviewer's agreement with the approach is noted. The staff report discusses concerns with erosion off the landscape and consequent transport of particulate-bound mercury implicitly via flow paths, which is supported by the scientific literature (see section 6.1.2). The reviewer confirms that cleanup should carefully evaluate where mercury is subject to erosion and transport via flow paths to reservoirs. The reviewer appears to cite Oswald and others (2014), who studied atmospheric deposition on to forested upland soils. They found that mercury can be effectively sequestered in depressional areas disconnected from flowpaths.

Regarding consideration of flow paths in cleanup, the staff report considers transport of mining waste to reservoirs in section 6.3.2, and considers other human activities that erode contaminated sediments that are transported to reservoirs in section 6.7.5. However, section 7.2.1, Potentially controllable processes, describes that at, "many sites, mining waste has moved offsite and is deposited along tens or hundreds of miles of downstream streams and rivers. … bank stabilization (erosion control) or removal of contaminated sediment followed by creek restoration can reduce mercury and sediment discharges." Rationale and recommendations for prioritization for cleanup of mine sites is provided in section 7.2.1.

Moreover, disagree that cleanup should first focus on flow paths to reservoirs. Instead, upstream mine sites should be remediated prior to remediating downstream flow paths (creeks and rivers) to avoid re-contaminating downstream stretches from upstream mercury sources (as described in section 9.3.1). It is expected that the State Water Board will evaluate the timing for cleanup of downstream sites in program review, as consideration for timing of cleanup of mining waste downstream of mine sites is included in "Issue #8" to be considered in first program review (see section 9.13.2).

<u>COMMENT CCG-89</u>

Did staff consider that concentration-based TMDL load allocations for suspended sediments (instead of mass loading to reservoirs) could be a problem for watersheds with large suspended solid loads, or a high fraction of upstream soils that are contaminated. I understand that a concentration-based allocation is easier to measure and enforce.

<u>RESPONSE TO CCG-89</u>

Yes, staff considered various watershed configurations with respect to concentration-based TMDL load allocations. In the first case presented of watersheds with large suspended solid loads, this is one of the scenarios considered in staff report section 7.2.1, Potentially controllable processes, as follows:

> **After [*cleanup upstream of reservoirs is*] completed, natural soil erosion will provide new, non-mine impacted sediment to the reservoir. These new sediments will have lower (background) mercury concentrations and will dilute and bury the mining waste as they settle on the reservoir bottom. Such gradual burial can be effective at reducing mercury concentrations in the active methylation zone of a reservoir. Burial, however, is not a quick process. The length of time for burial is dependent on the erosion rate and relative size of the watershed compared to the reservoir. More erosive geology, more frequent and larger storm events, and relatively large watersheds all speed burial.**

In the second case presented of watersheds with a high fraction of upstream soils that are contaminated, this scenario was considered using elevated, moderate, and high mine density as a proxy for fraction of upstream soils that are contaminated (see sections 6.3.3 and 7.2.1, (1) Comparison of reservoir sediment mercury concentrations and watershed mining density). On the one hand, 14 of 17 reservoirs with elevated sediment mercury had moderate to high mine density. On the other hand, 17 of 30 reservoirs have background sediment mercury despite having elevated mine density. A key point from Chapter 7 regarding upstream cleanup is sobering and applies regardless of mass or concentration based allocations: "Source control alone is expected to achieve measurable and relatively quick fish methylmercury reductions in only about 10% of the mercury-impaired reservoirs due to control of nearby mines and local atmospheric emissions."

Therefore, we conclude that concentration-based TMDL load allocations are not problematic for either of the scenarios the reviewer posed, and are appropriate for the reasons provided in Chapter 7.

Agree that concentration-based allocations are easier to measure and enforce; and monitoring them is less expensive (see response to CCG-72).

<u>COMMENT CCG-90</u>

Nevertheless…

In any case, implementation of Hg load allocations as "management practices" and not clean-up standards will need to be evaluated once data become available for more reservoirs after remediation. The only available study data listed is for one mine (Gambonini) and no mention is made of resulting Hg load reductions to a downstream reservoir.

<u>RESPONSE TO CCG-90</u>

The reservoir program already includes the recommended evaluation, which will be undertaken in program review. Staff report section 9.13.2 provides focusing questions that will be used in program review, including question 2 regarding assessing results of source reduction actions for mercury.

Although there are no reservoirs downstream of the Gambonini mercury mine, there are several sediment deposition areas in Walker Creek downstream of the Gambonini mercury mine where Water Board staff are monitoring mercury concentrations in newly deposited sediment. Reservoirs are comparable because they too are efficient sediment traps, and the reservoir program anticipates monitoring reservoir sediment mercury concentrations downstream of mine cleanup (see response to CCG-20).

COMMENT CCG-91

P 185. Mine site density may or may not relate to reservoir Hg loads. While no other data relating to reservoir Hg loadings may be available, the Water Boards should recognize that mine site density may be a very weak predictor of Hg loads from mine sites and mine waste in stream channels.

RESPONSE TO CCG-91

The reviewer repeats comment CCG-80; see response to CCG-80.

COMMENT CCG-92

P 186 Lake San Antonio, Lake Nacimiento comparison. Here's an obvious case of mines in the watershed impacting Hg in fish. Yet the discussion centers around the fact that the reservoir w/o mines has fish levels of 0.27, which is somewhat above the sportfish target. The state of California CA will be lucky to reduce Hg in the most impaired reservoirs given the number of impaired reservoirs and available resources. I find it unlikely that CA will be able to focus management tools on reservoirs like Lake San Antonio where fish Hg is only slightly higher than the sport fish target. The discussion also includes other factors that might result in differences in fish MeHg… when the obvious remediation approach is mine clean up.

RESPONSE TO CCG-92

The reviewer refers to section 7.2.1, Effectiveness of controlling mining waste to reduce reservoir sediment mercury and fish methylmercury levels. Several scenarios are evaluated; the reviewer refers to scenario (3) Comparison of neighboring reservoirs. San Antonio has no record of mines whereas Nacimiento has numerous upstream historical mercury mines; fish methylmercury levels are four times higher in Nacimiento than in San Antonio.

There are many reservoirs in California that, like San Antonio, have fish methylmercury levels only slightly above the sport fish target. Disagree with implication of this comment to ignore these exceedances of the target; the Clean Water Act requires the Water Boards to establish a TMDL to address these exceedances. This reservoir program is both a "TMDL" to control sources and a "control program" to address methylation and bioaccumulation.

Agree that the obvious remediation approach for Nacimiento is mine cleanup.

<u>COMMENT CCG-93</u>

Chapter 9. Implementation Plan.

P 262. I agree with this approach: "The Water Boards encourage a coordinated approach for fewer, focused tests rather than tests in all mercury-impaired reservoirs." Testing in more than a few reservoirs would be very expensive and incurs more risk of unknown consequences.

<u>RESPONSE TO CCG-93</u>

The reviewer largely repeats comment CCG-20. The reviewer's support for a decade of pilot testing is noted. The risk of unknown consequences was addressed in staff report section 7.8. Additionally, the implementation plan includes "avoidance of adverse consequences" in pilot tests of oxidant addition (Chapter 9), and the first program review may consider negative impacts resulting from implementation (bottom of page 9-53).

<u>COMMENT CCG-94</u>

Pilot management testing will require a high level of measurement and monitoring. This should be more explicitly built into this TMDL implementation plan, so that resources for that monitoring can be built into planning and cost estimates. There is danger in implementing too many strategies in too many lakes w/o a hard look a results along the way.

<u>RESPONSE TO CCG-94</u>

The reservoir program already incorporates an appropriate level of measurement and monitoring for pilot tests through use of a Technical Review Committee, as described in staff report section 9.13.1. The reviewer has helped to improve use of a Technical Review Committee (for example, see response to CCG-84).

<u>COMMENT CCG-95</u>

A outside technical review panel should be involved in design of [*pilot test*] plans, not just evaluation of results.

<u>RESPONSE TO CCG-95</u>

The reviewer's endorsement of an outside (third-party, independent) Technical Review Committee to review designs and results of pilot tests (see sections 9.8.8 and 9.13.1) is noted.

<u>COMMENT CCG-96</u>

P 264. Pilot tests should explicitly include mine site (and stream channel) remediation, along with detailed monitoring of results.

<u>RESPONSE TO CCG-96</u>

The reviewer repeats comment CCG-20; see response to CCG-20.

<u>COMMENT CCG-97</u>

Potential water chemistry pilot tests: Is the TMDL implementation program open to options other than those listed here? There are several other potential approaches, including:

- Approaches to reduce loading, like sedimentation basins
- Addition of clean sediment to lakes by eroding clean soils
- *In-situ* mercury sorption technologies
- Decrease in nutrient loading to increase light penetration (demethylation) and reduce organic load to sediments (decrease methylation)
- Reduction in sulfate load in systems with [*municipal wastewater discharges*], industrial, or mining sources of sulfur

<u>RESPONSE TO CCG-97</u>

Greatly appreciate this constructive comment. In response to this comment (and in response to JMB-12 on manganese oxides), the staff report and Mercury Reservoir Provisions were revised to include some of these additional management options. The following bullet points describe the changes (or why not changed in response to CCG-97), and then text changes follow. Additionally, staff notes that manganese oxides are another developing technology intended to reduce methylation.

- **"Approaches to reduce loading, like sedimentation basins" – revised Mercury Reservoir Provisions section IV.D.1.c and staff report sections 7.2.1 and 9.2.4.**
- **"Addition of clean sediment to lakes** *by eroding clean soils*" **[***emphasis added***] – sediment capping is already considered in section 7.3.3. This suggestion is not considered further because we understand it to mean deliberate erosion of clean watershed soils. The Water Boards undertake significant effort to reduce anthropogenic erosion because it often impairs water quality and fisheries habitat by increasing turbidity, phosphorus, and metals.**
- ***In-situ* mercury sorption technologies – revised staff report section 7.3.4 to add a subsection on this topic, and revised staff report section 9.13.2 to add a focusing question for program review.**
- **Decrease in nutrient loading to increase light penetration (demethylation) and reduce organic load to sediments (decrease methylation) – revised staff report section 7.3.4, Increase photodemethylation.**

- **Reduction in sulfate load [*discharged by municipal wastewater*], industrial, or mining sources of sulfur – revised staff report section 7.3.4 to add a subsection ("Reduce sulfate discharges"), and revised staff report section 9.13.2 to add a focusing question for program review.**

- **Use of manganese oxides as oxidant in epilimnetic and hypolimnetic sediments – revised Mercury Reservoir Provisions section IV.F.1.a.i.a and staff report sections 7.3.2 and 9.8.1.**

REVISIONS TO MERCURY RESERVOIR PROVISIONS SECTION IV.D.1.c. MINE SITE CLEANUP PLAN:

New last sentence: <u>If applicable, such as because more than seven years to complete cleanup, the plans shall also describe construction and maintenance of interim measures to collect mercury before it discharges from their property, e.g., sedimentation basins.</u>

REVISIONS TO MERCURY RESERVOIR PROVISIONS SECTION IV.F.1.a.i. PILOT TEST WORK PLAN:

a. **Oxidant addition to reservoir bottom waters (near the sediment-water interface) to reduce anoxia or adjust redox potential when reservoirs are stratified to suppress methylation of mercury. <u>Oxidant addition directly to reservoir sediments, such as solid manganese oxides, to suppress methylation of mercury.</u> Evaluate various oxidants (e.g., dissolved oxygen, ozone, nitrate, <u>manganese oxides,</u> others) for (a) efficacy for methylmercury reduction, (b) multiple benefits (e.g., drinking water quality, algal controls), and (c) avoidance of adverse consequences (e.g., application <u>of nitrate</u> only when a reservoir is stratified and not discharging bottom waters from the dam, with monitoring to ensure that added oxidant does not increase nutrient levels in the reservoir or downstream;**

REVISIONS TO STAFF REPORT SECTION 7.2.1 MINE SITES AND MINING WASTE IN DOWNSTREAM CREEKS:

Mines (not atmospheric deposition) are the source of California's highest fish methylmercury concentrations, as illustrated by comparing graphs A and B in Figure 7.2. Consequently, the Regional Water Boards have already completed mercury TMDLs for many of the worst problems, e.g., Clear Lake and Guadalupe River watershed. However, mines are upstream of only 48 of the 74 303(d)-listed reservoirs. Even where there are mines upstream, the reservoirs may not have elevated sediment mercury. This section accounts for these factors and proposes allocations and implementation actions for mercury discharged from mines.

Potentially controllable processes

<u>This section starts at the top of the watershed by discussing erosion from mine sites, then moves downstream to discuss sedimentation basins and erosion from creeks. Reservoirs at the bottom of the watershed are discussed in section 7.3.3.</u>

Erosion of mining waste from historical mining… (no changes to this paragraph).

Mine site remediation and erosion control… (no changes to this paragraph).

Sedimentation basins could be built to collect mercury-contaminated sediments before they enter reservoirs. Sedimentation basins located upstream of reservoirs and downstream of mine sites that discharge mercury may be an effective means to keep mercury-contaminated sediments out of reservoirs. Sedimentation basins are commonly employed at construction sites (see State Water Board's Construction Storm Water Program [*Link*]). However, sedimentation basins perform poorly in the largest storm events that transport the greatest amount of sediment and mercury from mines (Kirchner et. al 2011). Therefore, sedimentation basins could be best used as an interim measure before mine site cleanup is undertaken.

From a mercury perspective, the most advantageous location for sedimentation basins would be near toe of slope and/or the most upstream portion of mine drainages, because these locations collect minimal drainage and sediment from non-mined or process areas. Therefore, these locations would have the highest likelihood of capturing highly-mercury enriched sediments as compared to locations farther downstream. These locations are more likely to be on land owned by the mine responsible parties as compared to locations farther downstream.

However, from a hydraulic and geomorphic perspective, the most logical location for sedimentation basins is at a natural break in hillslope where the creek enters the valley floor. Unfortunately, these downstream locations are not likely to be on land owned by either mine responsible parties or reservoir owners, which would complicate access for construction and maintenance.

Sedimentation basins necessarily involve construction within a creek and therefore require detailed engineering and agency approvals and permits. Sedimentation basins require periodic dredging of collected sediments for continued basin effectiveness. Consequently, arrangements for disposal of dredge material must be accounted for in the basin design process.

At many sites, mining waste has moved offsite… (no changes to this paragraph or to remainder of section).

REVISIONS TO STAFF REPORT SECTION 9.2.4 *Requirements and Implementation Actions for Mine Sites*:

Implementation (cleanup) actions

Actions to be undertaken … provided in Appendix I.) It may be appropriate to install interim measures, such as sedimentation basins (see section 7.2.1), if the time to design, permit, and construct full-scale cleanup will be longer than seven

years. Mine site cleanup may also need to address other goals not related to mercury in reservoirs, such as reducing on-site risks from inhalation of mercury vapors; addressing discharge of acid mine drainage or elemental mercury; or meeting a site-specific cleanup goal (i.e., mercury concentration in surface soil).

REVISIONS TO STAFF REPORT SECTION 7.3.4 *Other Potentially Controllable Methylation Factors*:

In-situ mercury sorption technologies

In-situ mercury sorption technologies are an emerging technology. Consequently, staff recommends time be allowed for the research to develop further. The implementation plan should incorporate an adaptive approach that includes, during program review, performing a review and analysis of scientific literature on this topic with a focus on effects on methylation and fish methylmercury levels in downstream reservoirs and lakes. The literature review should include evaluation whether to wait for additional studies to be completed, or that the technology is ripe for pilot-testing in one or more mercury-impaired California reservoir(s).

Increase photodemethylation

Photodemethylation can be a major loss pathway of methylmercury in water bodies. Photodemethylation is dependent on ultraviolet light intensity, residence time, and methylmercury concentration. In turn, increasing light penetration in reservoirs could help reduce methylmercury concentrations in water. Possible ways to increase light penetration include reducing turbidity, reducing DOC, and decreasing nutrient loading or take other measures to reduce~~ing~~ algae in eutrophic reservoirs. Likewise, increasing the residence time (water retention) of reservoirs can possibly reduce aqueous methylmercury concentrations by exposing methylmercury to sunlight longer.

Raise pH of acidic reservoirs – no changes

Reduce sulfate discharges

Sulfate is necessary for sulfate-reducing bacteria to produce methylmercury. Hence, reducing sulfate discharges to reservoirs could reduce methylmercury production, if sulfate is not abundant naturally. Controllable sources of sulfate discharges include wastewater (NPDES-permitted municipal and industrial wastewater facilities), and acid-mine drainage discharges from mine sites.

Reduce emissions of sulfur dioxide – no changes

REVISIONS TO STAFF REPORT SECTION 9.13.2 *Focusing questions for use in program review*:

New, last focusing questions for use in program review:

(4) d. Based on a literature review, is there new *in-situ* mercury sorption technology that should be pilot tested?

(4) e. Is there evidence from an evaluation of California discharge data (from NPDES-permitted municipal and industrial wastewater facilities, or data on acid-mine drainage) that sulfate from wastewater is contributing to methylation within reservoirs?

REVISIONS TO STAFF REPORT SECTION 7.3.2 *Redox Potential*

Potentially controllable processes – Nitrate as oxidant

[*No changes to 5 paragraphs on nitrate*]

Potentially controllable processes – Manganese oxides as oxidant

[*Add a new section prior to "Predictions for improvements"*]

Manganese oxides are a developing technology for *in situ* methylation control[6]. These are oxidants intended to suppress methylation. Their main advantage over oxygen is that they are solid, which facilitates application to bottom of reservoir. At this time, manganese oxides have not been field-tested, so the next section does not discuss predictions for improvements from addition of manganese oxides.

REVISIONS TO STAFF REPORT SECTION 9.8.1 *Phase 1 Actions for Reservoir Water Chemistry Management*:

Sixth paragraph: The scope of reservoir water chemistry management actions to be evaluated include the following (from Chapter 7):

- **Oxidant addition to reservoir bottom waters (near the sediment-water interface) to reduce anoxia or adjust redox potential when reservoirs are stratified to suppress methylation of mercury. Oxidant addition directly to reservoir sediments in either or both the epilimnion or hypolimnion, such as solid manganese oxides, to suppress methylation of mercury. Evaluate various oxidants (e.g., dissolved oxygen, ozone, nitrate, manganese oxides, others) for (a) efficacy for methylmercury reduction, (b) multiple benefits (e.g., drinking water quality, algal controls), and (c) avoidance of adverse consequences (e.g., application of nitrate only when a reservoir is stratified and not discharging bottom waters from the dam, with monitoring to ensure that added oxidant does not increase nutrient levels in the reservoir or downstream; see section 7.3.2);**

[6] For example, May 2016 presentation to Delta Tributaries Mercury Council [*Link*]

COMMENT CCG-98

Per Table 9.1 there are 74 reservoirs in Phase I TMDL implementation. This 303(d) impaired doesn't include the reservoirs that might be designated impaired based on fish sampling in the last few years. How would those reservoirs be staged for implementation?

RESPONSE TO CCG-98

Staff report section 1.6.1 describes how the list of impaired reservoirs will be updated to include recent fish data. At that time, the update was expected to add about 70 reservoirs for a total of about 150 impaired reservoirs. Staff report section 1.6 explains that this list of impaired reservoirs is static for the duration of Phase 1, during which a decade-long pilot test program will be conducted.

COMMENT CCG-99

Section 9.1 Mine clean-up

There is no mention of potential available funding for mine clean up that will have to be paid for by state or local governments. It's hard to judge the potential time frame of efficacy of even Tier 1 clean up without some estimate of resources and cost. But it seems that this undertaking could be hugely (billions) expensive and take decades. Have the number of Tier 1 mine sites (or reservoirs) been identified?

RESPONSE TO CCG-99

The reviewer repeats concerns over lack of funding for mine cleanup; see responses to CCG-34 regarding lack of funding; CCG-36 regarding who pays for mine cleanup; and CCG-22 regarding economic considerations to be included in the next version of the staff report.

A preliminary identification of Tier 1 mine sites and corresponding reservoirs for which sediment mercury data are available is provided in staff report section 7.2.7, Mining sources; Table 7.1; and Appendix H Table H.1 Notes. These mines and reservoirs are (a) Reid Mine and Davis Creek Reservoir; (b) Mount Diablo Mine and Marsh Creek Reservoir; and (c) Klau/Buena Vista and other mines in the Las Tablas Creek Watershed, and Nacimiento Reservoir. Coincidentally, responsible parties are already taking some actions toward mine cleanup for these mine sites, so they could be the first mine cleanups that are monitored intensively for improvements in downstream reservoirs (see comment and response to CCG-20). During Phase 1, additional Tier 1 mine sites will be identified, and one or more of these could instead be monitored intensively for improvements in downstream reservoirs.

COMMENT CCG-100

Appendix I, p 4. "…the Reservoir Mercury Control Program will not pose new economic costs or environmental impacts to address discharges from mercury and gold mines." … because existing regulations already require clean-up. But mine remediation has just barely begun –

there is a huge disconnect here. If the new TMDL implementation program does not force additional clean up through allocation of additional state, federal and local funds, the TMDL loading goal will never be met.

RESPONSE TO CCG-100

The reviewer repeats comment CCG-22; see response to CCG-22.

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Responses to the next reviewer begin on the following page.

S.4 Daniel A. Jaffe (DAJ)

Dr. Jaffe first commented on The Big Picture, then commented on conclusions by number, and lastly provided some detailed comments on the staff report. Dr. Jaffe focused on Conclusions 3–8 (and provided some comments on Conclusions 1 and 2). Reviewers are not obligated to address all conclusions[7], and Dr. Jaffe did not address Conclusions 9–18.

COMMENT DAJ-1

As requested I have reviewed The Scientific Basis of the Proposed Plan Amendment to Establish the Statewide Implementation Program for Mercury in Reservoirs and the associated supporting documents that were supplied to me via the Water Boards FTP site. As discussed in our earlier correspondence, my review focused on conclusions 3,4,5,6,7 and 8, but also touched on conclusions 1 and 2. These are the areas where I have the most scientific expertise.

My detailed review is given below. Please let me know if you need further information or if there are questions about my review.

RESPONSE TO DAJ -1

The reviewer's focus is noted.

Summary and "big picture"

COMMENT DAJ-2

In general the staff report is a remarkable review of mercury biogeochemistry. While I do have significant comments, and a few concerns over the modeling component, I think the staff should be congratulated for producing such a high quality scientific report.

RESPONSE TO DAJ -2

The reviewer's commendation of the approach and high quality of the staff report is appreciated.

COMMENT DAJ-3

Mercury is a complex problem and there are many scientific uncertainties. I appreciate that the State has conducted a detailed and comprehensive review of the fish mercury problem and

[7] Reviewers are not obligated to address all conclusions. See top of page 2 of August 7, 2017 transmittal letter from Bowes to Mumley: "Each reviewer was asked to address each topic, as expertise allows, in the order given." Each of the transmittal letters to reviewers also states this.

proposed some workable solutions. In general terms, I am in agreement with many of the conclusions that form the scientific basis for the mercury provisions, but have some significant comments/concerns on the atmospheric deposition modeling that was conducted to do source apportionment. This will be discussed in the section on conclusions 6, 7 and 8 (sources).

RESPONSE TO DAJ -3

The reviewer's qualified agreement with the approach is noted.

Other "big picture" comments:

COMMENT DAJ-4

1. The program proposes to use "adaptive management" (including modest fertilization) and continued research on Hg to guide future policy decisions. This is a very important step as there is much we do not understand about the sources and biogeochemical cycling of mercury. I strongly recommend that the state reinvest a fraction of the implementation costs on research to improve the scientific basis of these actions.

RESPONSE TO DAJ-4

The Mercury Reservoir Provisions in section IV.F.3 relies on a Technical Review Committee for advice on applicability and technical feasibility of implementing reservoir management and fisheries management practices to address elevated levels of methylmercury in reservoir fish.

COMMENT DAJ-5

2. The documents use a variety of terms involving "background" (e.g. "natural background", "modern background", "global background", or just "background"). As near as I could tell, these were never defined and there is a great deal of ambiguity in the documents over their meaning. I recommend that the report include some over-arching definitions of all of these terms and stick to these definitions throughout the report.

RESPONSE TO DAJ-5

These terms are defined in the staff report and used consistently. Section 6.2 defines "natural and modern background mercury concentrations in soils and sediments. Natural background (pre-industrial) conditions reflect naturally-occurring mercury from native geologic formations. In contrast, modern background conditions include not only natural background but also contributions from atmospheric deposition resulting from industrial-era emissions."

Section 6.4 defines natural and anthropogenic mercury emissions (see beginning paragraphs in sections 6.4.1, 6.4.2, and 6.4.3). Global background is first used in the staff report in reference to Figure 6.19. The caption of Figure 6.19 defines global background as follows, "Global background sources do not include anthropogenic emissions from the United States, Canada, and Mexico in 2001, but may include mercury emitted from anthropogenic sources in these countries in 2000."

COMMENT DAJ-6

3. The conclusions use the term "many reservoirs" several times, but without providing specific %. It would be helpful to provide a % for each conclusion in these statements.

RESPONSE TO DAJ-6

Whereas the conclusions use the term "many reservoirs," the staff report uses specific numbers and percentages, for example, see section 6.8.

COMMENT DAJ-7

4. The fact that the land area around many reservoirs (half) have naturally occurring mercury is an important and supported conclusion (pg 6-5 and conclusion #4). In these cases it is the presence of the reservoir (or its management) that enhances fish methylmercury. I suggest that conclusion #4 be restated to clarify this (see suggestion below).

RESPONSE TO DAJ-7

The reviewer's support for conclusion 4 is noted. Additionally, the reviewer provides support for conclusions 7 and 10.

COMMENT DAJ-8

5. While I did not review in detail conclusions beyond #8, I did review section 7.2.2 concerning future global sources contributing to deposition in Chapter 7.2.2. While it seems reasonable to expect that California emission sources will continue to decrease, I was surprised at the level of reduction assumed for global sources. On page 7-19, the report states "…anthropogenic sources outside of California incorporate a 50% reduction from the 2001 baseline…" This is a highly optimistic conclusion based on a 2008 AMAP study. It is not clear what time frame is relevant here. More recent and much more carefully done studies indicate a reduction in deposition over the continental US from global sources suggest that for the year 2050 global non-US anthropogenic emissions may decrease deposition by a few percent or as much as 10% by the year 2050. These same studies also suggest that global emissions could continue to increase as countries like India develop. There is much uncertainty around future global emissions, but a 50% reduction in deposition from global sources seems highly optimistic and inconsistent with the most recent published studies. See for example:

Corbitt et al. Global Source–Receptor Relationships for Mercury Deposition Under Present-Day and 2050 Emissions Scenarios. Environ. Sci. Technol., 2011, 45 (24), pp 10477–10484. DOI: 10.1021/es202496y.

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RESPONSE TO DAJ-8

Agree there is uncertainty around future global emissions. The basis for the 50% reduction from anthropogenic sources outside of California is provided in staff report section 7.2.2, Recent and anticipated changes in anthropogenic emissions, and in Appendix H.2.

Specific comments on conclusions 1-8

Conclusion 1:

COMMENT DAJ-9

I concur with this conclusion.

RESPONSE TO DAJ-9

The reviewer's support for conclusion 1 is noted.

Conclusion 2:

COMMENT DAJ-10

I would agree that the first two factors are clearly important in controlling fish methylmercury. The evidence for the third factor, water level fluctuations, is much weaker. On page 5-11, the report states that this factor is weakly, and negatively associated with aqueous methylmercury. Only by including this factor in the multiple linear regression model does it show up as "significant". I would argue that this demonstrates an overall weak controlling influence and, as such, its inclusion in conclusion 2 is probably over-stated. In addition, due to uncertainties in the atmospheric deposition and modeling of deposition, I would argue that we do not currently know how important deposition is in directly controlling fish mercury concentrations.

RESPONSE TO DAJ-10

The reviewer's qualified support for conclusion 2 is noted.

The reviewer conflates associations between environmental factors and *aqueous* **and** *fish* **methylmercury. The reviewer's comment regarding water level fluctuations relates to**

aqueous **methylmercury. However, most of the linkage analysis is focused on** *fish* **methylmercury. Water level fluctuation is significantly correlated to fish methylmercury (see section 5.1.2 and Table B.3).**

Agree that there are uncertainties about atmospheric deposition. However, Section 7.2.7, Predictions for Improvement Based on Source Control, Atmospheric deposition, identifies 3 reservoirs that are expected to have relatively quick reductions in fish methylmercury levels from controlling local air emissions. In 1 of these 3, Puddingstone Reservoir, fish methylmercury already meets the sportfish target (see Appendix I.3.b).

Conclusion 3:

<u>COMMENT DAJ-11</u>

I agree with the general sense of conclusion 3, but there are problems with several parts. First, the term “primary” is problematic. Certainly sources of inorganic mercury are a necessary ingredient in mercury impairments. Are these “primary” or not? Judgement call, what do we mean. I would suggest wording such as “Inorganic sources of mercury, by themselves, do not determine mercury impairments in California reservoirs.” Next the term “amount of mercury” is too vague. Are you referring to the concentration in the reservoir or a flux into the system? Is this THg or something else.

<u>RESPONSE TO DAJ-11</u>

The reviewer’s support for conclusion 3 is noted.

Indeed, “primary” was a deliberate word choice because Total Maximum Daily Loads (TMDLs) exclusively rely on source control to solve a pollution problem. The reviewer’s re-wording expresses support for the scope of this mercury control program to include not only mercury source control but also pilot tests for reservoir water chemistry and fisheries management.

Amount of mercury refers to total mercury concentration.

Conclusion 4:

<u>COMMENT DAJ-12</u>

I find the wording here confusing. What is natural background? What % of reservoirs fall into this category? As worded, it sounds like the goal is to reduce fish mercury to levels that are lower than a “natural background”. Is this really the intent? The conclusion might be reworded to something like “Many reservoirs (%) have inorganic sources or fluxes in that are near background/natural levels (define). However the presence of the reservoir and/or reservoir management have resulted in increased mobilization of that mercury and increased the concentration of methylmercury in fish."

RESPONSE TO DAJ-12

"Natural background" is the term for pre-industrial (i.e., pre-1850) naturally-occurring mercury concentrations in soils (see staff report section 6.2). Section 6.2.4 describes that 15 of 44 reservoirs have sediment mercury concentrations within the range of natural background levels.

The reviewer is correct that the intent is *not* to reduce fish mercury to levels that are lower than "natural background." Moreover (and relating to Conclusion 4), it is *not* the intent to reduce reservoir sediment mercury to levels that are lower than "natural background."

Natural erosion transports watershed soils downstream where they accumulate ("reservoir bottom sediments"). Regressions of reservoir bottom sediment total mercury to fish methylmercury are presented in staff report section 5.3.1. These regressions indicate that mercury concentrations lower than natural background would be needed in many reservoirs to achieve the TMDL targets. Clearly, reducing sediment concentrations below a watershed's natural background mercury level is not feasible. Therefore, other factors (i.e., methylation and bioaccumulation) must be addressed. For these reasons, re-wording of Conclusion 4 is not warranted.

Conclusion 5:

COMMENT DAJ-13

This is certainly true. I agree with this conclusion.

RESPONSE TO DAJ-13

The reviewer's support for conclusion 5 is noted.

Conclusion 6:

COMMENT DAJ-14

This is a broad conclusion and covers the three primary sources. As such the statement is largely correct. However I have significant concerns on the atmospheric deposition modeling, discussed below.

RESPONSE TO DAJ-14

The reviewer's qualified support for conclusion 6 is noted.

Conclusion 7:

COMMENT DAJ-15

Suggest minor edit to "Reducing watershed mercury sources alone is not expected…" Might add an additional sentence "Source reductions combined with management actions are needed to reduce fish methylmercury in many reservoirs."

RESPONSE TO DAJ-15

The reviewer's support for conclusion 7 is noted.

Conclusion 8:

COMMENT DAJ-16

This conclusion depends heavily on the atmospheric deposition modeling, which is problematic. See below.

RESPONSE TO DAJ-16

In comments DAJ-16 through DAJ-24 the reviewer has called out atmospheric deposition modeling for focused review. Staff report section 6.4.4 explains that, "Staff used the REMSAD model to characterize atmospheric deposition in California because it was designed specifically to support TMDL development and implementation and because its simulated spatial distribution of mercury deposition is consistent with observed deposition patterns." Appendix D provides a section on "Peer Review and Comparison to Empirical Results" that describes several strong and a few weak indicators for validity of the REMSAD model. As described in the staff report in Appendix D, Peer Review and Comparison to Empirical Results, U.S. EPA staff used a different model for a southern California reservoir, but that model had lower accuracy than REMSAD compared to local monitoring data.

While mercury from atmospheric deposition impacts water quality, the Water Boards have no jurisdiction over emissions to air (see staff report section 7.2.2, Authority to regulate local and global industrial emissions). Hence, the Mercury Reservoir Provisions in section V.C provide recommendations to the California Air Resources Board and U.S. EPA to continue to enforce emission regulations, track progress in emissions reductions, and if necessary identify and implement additional mercury emissions controls.

Atmospheric deposition modeling:

COMMENT DAJ-17

Modeling can provide a useful tool to estimate source-receptors relationships, transport processes and deposition. Models are also very useful to identify sensitivities to key processes. However models are not a panacea for all environmental analyses, their underlying assumptions must be stated and evaluated and the results must be evaluated with observations. Even in cases where the modeled result and observations agree, it is possible to get the right answer for the wrong reason. However in this case, the model appears to have little skill in reproducing the observations.

RESPONSE TO DAJ-17

Agree with the reviewer's cautions about models in general. However, it is not possible to validate rigorously any model of atmospheric deposition to California because of the paucity of monitoring data. (See response to DAJ-19 regarding underlying assumptions.) As noted in response to DAJ-16, the staff report in section 6.4.4 explains that REMSAD's "… simulated spatial distribution of mercury deposition is consistent with observed deposition patterns."

COMMENT DAJ-18

For this analysis, the REMSAD model used was used. Based on the citations, it appears that the most recent model evaluation took place in 2008 (Bullock et al 2008). However it is important to note that the Bullock analysis actually made no comparisons with observations (in contrast to what is implied in Appendix D ("the model was found to be reasonable."). In fact the three models differed by up to a factor of 10 for some parameters. Dry deposition showed strong disagreements between the three models and this is particularly problematic since dry deposition is thought to be a large fraction of the deposition over California (Figure 6.17). So it is not clear what is meant by the statement in Appendix D "the model was found to be reasonable".

RESPONSE TO DAJ-18

The staff report in Appendix D, Peer Review and Comparison to Empirical Results, has been revised as follows.

> **The REMSAD model was peer reviewed in 1999 (Seigneur et al. 1999) and the modeling in the Devils Lake TMDL Pilot (including the tagging application) was subjected to an external peer review (USEPA 2008a). REMSAD was included in the North American Mercury Model Intercomparison Study for mercury ~~and the performance and response of the model was found to be reasonable~~ (Bullock et al. 2008). <u>The intercomparison study found that simulated dry deposition of varied by nearly a factor of 10 in some locations. However, the intercomparison study did not determine which of the regional-scale models tested is the most accurate reflection of nature. The authors urged far more monitoring of mercury.</u>**

COMMENT DAJ-19

It appears the model has not been updated since 2008 despite some significant progress in our understanding of mercury cycling. For example the REMSAD uses ozone and OH as the sole oxidants for elemental mercury, yet we now know that these oxidants are almost certainly not relevant and that halogens are probably the dominant oxidant. See:

1. Gratz, L. E., et al., Oxidation of mercury by bromine in the subtropical Pacific free troposphere, Geophys. Res. Lett., 42, oi:10.1002/2015GL066645, 2015.
2. Shah, V., et al., Origin of oxidized mercury in the summertime free troposphere over the southeastern US, Atmos. Chem. Phys., 16, 1511-1530, doi:10.5194/acp-16-1511-2016, 2016.
3. Horowitz, H.M., D.J. Jacob, Y. Zhang, T.S. Dibble, F. Slemr, H.M. Amos, J.A. Schmidt, E.S. Corbitt, E.A. Marais, and E.M. Sunderland, A new mechanism for atmospheric mercury redox chemistry: implications for the global mercury budget, Atmos. Chem. Phys., 17, 6353-6371, 2017.

RESPONSE TO DAJ-19

In response, the Mercury Reservoir Provisions and staff report have been revised. The staff report has been revised as follows:

Section 6.4.4 of the staff report (fifth paragraph) has been revised as follows:

Staff used the REMSAD model to characterize atmospheric deposition in California because it was designed specifically to support TMDL development and implementation and because its simulated spatial distribution of mercury deposition is consistent with observed deposition patterns. Additional description of the REMSAD model and comparison of its output to deposition rates observed at different locations in California is in Appendix D. The REMSAD model is outdated and it should be revised to reflect current scientific understanding, such as (a) that halogens are the dominant oxidants of elemental mercury rather than ozone or hydroxyl ions; and (b) to provide source profiles with respect to mercury speciation and local deposition in California (Jaffe 2017). After revision, the REMSAD model should be validated with extensive, new wet and dry deposition data for California.

Section 9.4 of the staff report (last paragraph) has been revised as follows:

Alternatively, CARB and USEPA or other organizations may elect to monitor and model atmospheric deposition. USEPA (alone or in partnership with others) should revise and validate its outdated REMSAD model (see section 6.4.4). The model results could then be assessed particularly during the first program review (see section 9.13.2) as to whether allocations for atmospheric deposition attributed to anthropogenic sources are or are not likely to be attained. More information is provided in Appendix I.

The Mercury Reservoir Provisions have been revised to add a new "V.C.2.a." as follows:

V.C.2.a. Which agencies will revise and validate the REMSAD model by nine years after the Effective Date;

COMMENT DAJ-20

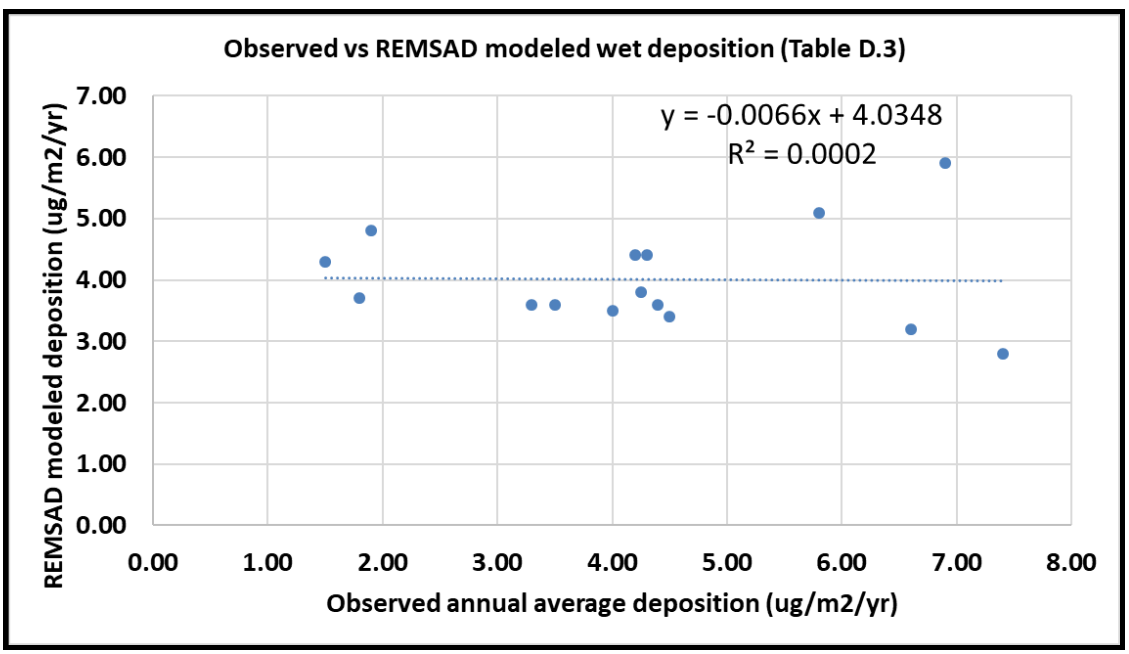
In addition, I was surprised at the lack of discussion on source profiles with respect to mercury speciation. It is known that industrial sources that emit mercury in the Hg(II) form will have much greater local deposition, compared to Hg(0). What is know about the California emissions and how well is this speciation understood? While the total mercury from these facilities is probably reasonably known (+/- 30%), the speciation will have much higher degree of uncertainty. What is the speciation, what is the uncertainty and how important is this?

RESPONSE TO DAJ-20

See response to DAJ-19, which recommends the REMSAD model be revised to reflect current scientific understanding.

COMMENT DAJ-21

Finally, in terms of model evaluation, Table D.3 provides a possible look at the model's ability to reasonably reproduce observations. This was not done for the report, so I made the graph myself. The graph below shows the annual wet deposition from observations in California vs the REMSAD modeled value. Two sites, which had multiple observed values, were averaged in this analysis. The observed values range from about 1.5 ug/m2/yr to 7.4 ug/m2/yr, whereas the modeled values range from 2.8 to 5.9. Some of the sites with the highest observed mercury wet deposition have the lowest modeled values. The graph below shows that the REMSAD model has essentially no skill at reproducing wet deposition fluxes in California.



RESPONSE TO DAJ-21

See response to DAJ-19, which recommends the REMSAD model be revised to reflect current scientific understanding.

COMMENT DAJ-22

However as mentioned above, dry deposition is even more important that wet for most of California. Unfortunately there are few or no observations of dry deposition in California. But given the large uncertainties and model disagreements in Bullock et al (2008) this is certainly a large uncertainty in the analysis.

RESPONSE TO DAJ-22

See response to DAJ-19, which recommends the REMSAD model be revised to reflect current scientific understanding.

COMMENT DAJ-23

So in summary, the largest uncertainties associated with the REMSAD source attribution modeling arise from:

1. Incorrect oxidation mechanism for Hg(0).
2. Unknown accuracy of emission inventories and speciation of emissions.
3. Model failure to reasonably reproduce observed wet deposition fluxes in California.
4. Inadequate data to evaluate model dry deposition.

RESPONSE TO DAJ-23

See response to DAJ-19, which recommends the REMSAD model be revised to reflect current scientific understanding.

COMMENT DAJ-24

A good summary of model uncertainties relevant to policy are given in:
Kwon, S.Y. & Selin, N.E. Curr Pollution Rep (2016) 2: 103. https://doi.org/10.1007/s40726- 016-0030-8.

RESPONSE TO DAJ-24

See response to DAJ-19, which recommends the REMSAD model be revised to reflect current scientific understanding.

Other comments:

COMMENT DAJ-25

Pg. 5-3: I do not understand the last sentence in the first paragraph "Consequently, staff proposes a goal for reservoir…".

RESPONSE TO DAJ-25

Chapter 5 of the staff report has been revised to clarify "modern background," as follows:

***Overview, continued* (top of page 5–3)**

- **The model results indicate many reservoirs will require sediment mercury concentrations lower than both natural (pre-industrial) and modern (industrial-age) background concentrations to achieve the sport fish target. However, it is not feasible to reduce reservoir sediment mercury concentrations to levels lower than modern background mercury concentrations. Consequently, staff proposes a goal for reservoir sediment total mercury concentrations to meet modern background watershed soil total mercury concentrations.**

COMMENT DAJ-26

Pg 5-3, next to last bullet point: Natural background is unclear here. A natural background would be much lower than a present day background….

RESPONSE TO DAJ-26

Chapter 5 of the staff report has been revised to clarify "modern background," as follows (page 5-3, next to last bullet point):

- **Calculation of goals for total mercury source reduction should take into account technical feasibility to avoid having goals that are lower than ~~natural~~ modern background. Chapter 6 provides an assessment of mercury sources and Chapter 7 estimates how much these sources can be reduced.**

COMMENT DAJ-27

Pg 5-9, second paragraph: the R value of 0.2 is very weak, despite the P value. Given the challenges with the modeling, what do we really infer from this?

RESPONSE TO DAJ-27

The staff report provides this information. The paragraphs following the second paragraph on page 5-9 discuss the weakness of the associations (low R values), implication that "a combination of factors influence fish methylmercury concentrations,"

and provide rationale for a multiple-variable analysis that is presented in the subsequent section.

COMMENT DAJ-28

Pg 5-20, next to last paragraph: This introduces several new variables (methyl mercury production, food web transfers). I don't recall seeing these anywhere in the document up to this point (possibly in an appendix?). How are these defined and measured?

RESPONSE TO DAJ-28

The terms methylmercury production, transfer of methylmercury through the food web, and food web transfer are described in Chapter 4.

COMMENT DAJ-29

Pg 6-6, second bullet: I assume this is for soil or sediment?

RESPONSE TO DAJ-29

Yes. The staff report has been revised for clarity in section 6.2, second bullet top of page 6–6, as follows:

- **Modern background mercury levels in soils and sediments typically range from 0.05 to 0.1 milligrams per kilogram (mg/kg) in trace mercury areas, and 0.1 to 0.3 mg/kg in the mercury-enriched region. Reservoirs with average sediment mercury concentrations that exceed these ranges are likely significantly affected by discharges from local (watershed) anthropogenic mercury sources (e.g., mine sites) in addition to industrial-era mercury in atmospheric deposition from California and global sources.**

COMMENT DAJ-30

Pg 6-10, recommendations: I assume there should be a "<" (less than) symbol in front of these values (e.g. <0.1 mg/kg).

RESPONSE TO DAJ-30

The "<" (less than) symbol is not needed in Chapter 6 for mercury levels that characterize regions of California. The less than symbol corresponds to a ceiling, but these characterizations are more similar to central tendency than to a ceiling level.

COMMENT DAJ-31

Pg 6-11, second thru fourth bullets: There are large uncertainties here. I agree that these definitions are useful, but you should point out that these ranges overlap.

<u>RESPONSE TO DAJ-31</u>

Each of these bulleted statements builds from the previous several pages and corresponding figures and tables that illustrate overlap in ranges in mercury concentrations. Each statement contains the modifier "likely" and focuses on mercury sources more than ranges in mercury concentrations, so there is no need further to point out that these ranges overlap.

<u>COMMENT DAJ-32</u>

Pg 6-24, second bullet: I assume these are direct anthropogenic emissions and exclude re-emission. Suggest to clarify this.

<u>RESPONSE TO DAJ-32</u>

The introductory paragraph of staff report section 6.4.3 has been revised as follows:

As noted at the beginning of this chapter, atmospheric deposition is considered a nonpoint source discharge into water. Nonetheless, <u>direct</u> anthropogenic emissions <u>(not re-emissions)</u> that contribute to atmospheric deposition can be divided into point and nonpoint mercury emissions:

<u>COMMENT DAJ-33</u>

Pg 6-27, third line from bottom: I did not see any comparisons between the model and observations in any part of the report. The comparison I showed above indicates very poor model performance for wet deposition.

<u>RESPONSE TO DAJ-33</u>

See response to DAJ-19, which recommends the REMSAD model be revised to reflect current scientific understanding.

Appendix D provides a section on "Peer Review and Comparison to Empirical Results" that describes several strong and a few weak indicators for validity of the REMSAD model. For wet deposition, this section states, "The REMSAD simulation results tend to overestimate wet deposition of mercury, as compared to the MDN monitoring data. … The model results are very similar to empirical (monitoring) wet and dry deposition rates throughout California and eastern Nevada. The similarities are remarkable given: there is a broad range of deposition rates across California; the periods of the precipitation data used in the deposition calculations were different from the wet deposition concentration monitoring periods; and the wet and dry deposition monitoring periods are different from the REMSAD simulation period. Tables D.3 and D.4 provide a qualitative comparison of wet and dry deposition rates observed at different sites in California compared to the REMSAD 2001 deposition values and Figure D.1 shows the study locations."

COMMENT DAJ-34

Pg 6-28, second bullet: The discussion of “global background emissions and “re-emissions” is confusing. What are global background emissions? Why are re-emissions only considered for one year when it is the net accumulated deposition that causes these emissions?

RESPONSE TO DAJ-34

The reviewer refers to the second bullet:

- **Anthropogenic emissions in 2001 from California, other United States, Canada, and Mexico (Figure 6.18)**
- **Global background emissions in 2000 and re-emissions in 2001 from land and water surfaces of previously deposited mercury, which include both natural and anthropogenic sources from California and elsewhere in the world (Figure 6.19).**

The title and caption for Figure 6.19 provide clarification of the REMSAD model output, as follows:

Title: Figure 6.19: Statewide maps of REMSAD 2001 model output for atmospheric deposition of mercury in California attributed to 2000 emissions from global background sources and re-emission of previously deposited mercury (from a combination of natural and anthropogenic sources)

Caption: Global background sources do not include anthropogenic emissions from the United States, Canada, and Mexico in 2001, but may include mercury emitted from anthropogenic sources in these countries in 2000. Re-emission of previously deposited mercury includes mercury from natural and anthropogenic sources.

COMMENT DAJ-35

Pg 7-16, first factor: The linkage analysis found a minor relationship between modeled deposition and fish methylmercury, but given the uncertainties in modeled deposition, I find this result rather inconclusive.

RESPONSE TO DAJ-35

The reviewer repeats comment DAJ-27.

COMMENT DAJ-36

Pg 7-18, bottom: No timelines are given for these allocation. The 66% reduction factor for California sources seems reasonable.

RESPONSE TO DAJ-36

Comment noted.

COMMENT DAJ-37

Pg 7-19, top: The 50% reduction factor for global sources is highly optimistic and inconsistent with recent published studies.

RESPONSE TO DAJ-37

The reviewer repeats comment DAJ-8.

S.5 Robert P. Mason (RPM)

Dr. Mason's letter repeats the conclusions to be evaluated; for compactness, the conclusions are not repeated in this section but rather are available at the beginning of this document. For clarity, some of his comments have been renumbered to indicate to which conclusion they relate (e.g., from 1 and 2 to 4-1 and 4-2). Although Dr. Mason (similar to Dr. Gilmour) did not explicitly comment on The Big Picture, some of his comments address Big Picture issues.

Response to Assumptions, Findings, and Conclusions:

Note: As the conclusions were answered mostly in order there is much more comment and discussion earlier in the document as many concerns and comments are provided in the first instance. Therefore, much of what is commented on in the earlier statements is pertinent to other sections of this document, and I have attempted to indicate this where applicable.

Conclusion 1.

COMMENT RPM-1

The statement is entirely true that the amount of total mercury (Hg) in a system does not often provide a good prediction of the concentration of methylmercury (MeHg) in fish. Chapter 4 provides a detailed overview of the many factors that can influence the concentrations of MeHg in water and sediment, and therefore in fish, and has accurately covered most of the important variables in sufficient detail to provide a suitable conceptual model of the factors that influence fish MeHg.

RESPONSE TO RPM-1

The reviewer's qualified support for conclusion 1 is noted.

COMMENT RPM-2

Overall, I felt that the references seemed skewed to older publications and I am sure there are more recent studies that should be cited.

RESPONSE TO RPM-2

Peer reviewer Dr. Benoit commented (JMB-40) that "Inferences are drawn from the evaluation of up-to-date, peer-reviewed literature…".. Similar to comment RPM-2, peer reviewer Dr. Gilmour commented (CCG-55), "In general the references are outdated." In response to Dr. Gilmour's comment, the staff report was revised; see responses to CCG-55 through CCG-70.

COMMENT RPM-3

There are some missing details and more information on some aspects would improve this discussion and the development of the conceptual model:

1-1. The report indicates that methylation in the epilimnion is important but the implication is that this methylation is still in the sediment. Recent studies have highlighted the potential for methylation in periphyton and in biofilms on surfaces, and within settling particles, and this should be discussed.

RESPONSE TO RPM-3

Agree that recent studies have shown that methylation occurs in periphyton and in biofilms. Agree that recent studies by Gascón Díez and others (2016) in Lake Geneva, Switzerland, have shown that methylation occurs in settling particles. In response to JMB-5, section 4.1.1 was revised to include: "Methylating organisms are prevalent in … microenvironments with steep redox gradients (e.g., periphyton, biofilms, microbial flocs)." However, staff are not aware of studies of control measures to reduce methylation in these microenvironments. Therefore, the reservoir program's focus on anoxia (i.e., water chemistry pilot tests) remains appropriate. If control measures are developed in the near future, they can be evaluated in pilot test work plans in accordance with Mercury Reservoir Provisions Chapter IV.~~F~~H.1.a.i.c "Other management practices to reduce methylation, including enhancing demethylation;".

Moreover, it is appropriate to include methylation in the metalimnion in the conceptual model in Chapter 4. This is needed to support section 9.13.2, Management Question 1a, "…Additionally, reservoirs produce some methylmercury in the metalimnion…."

In response to RPM-3, the staff report and Mercury Reservoir Provisions have been revised as follows. The staff report in section 4.1.1, The Mercury Methylation Process: Inorganic Mercury Transforms to Aqueous Methylmercury, has been revised to add the following new fourth paragraph.

> **Methylation can also occur in the metalimnion. Researchers have observed accumulation of decaying algae in the metalimnion of thermally stratified reservoirs. Oxygen is consumed as algae decay, and algae serve as the carbon source for methylating microbes. In California reservoirs, Negrey and Stephenson (2010) indicated that, "There is some evidence to suggest buildup of aqueous methyl mercury may be occurring in the thermocline in some lakes which could be associated with low oxygen levels."**

In response to RPM-3, the staff report in section 7.3.1, Anoxia, Potentially controllable processes, has been revised as follows to include oxygenation of metalimnion to reduce methylation. In contrast, no changes are proposed to section 7.3.2 that describes nitrate application to the hypolimnion. Although nitrate application to the metalimnion may reduce methylation, it may also contribute to undesirable eutrophication, and so is not considered further.

> **[*First paragraph*] Anoxic conditions in the aquatic environment can stimulate methylmercury production as well as affect other water quality parameters. Reducing the degree, extent, or duration of anoxia in the hypolimnion of stratified~~waters of a~~ reservoirs may suppress mercury methylation and discharge to the hypolimnion in some reservoirs. Similarly, reducing anoxia in the epilimnion of a stratified reservoir may suppress mercury methylation and bioaccumulation in the metalimnion. Management practices to increase oxygen levels in reservoirs include artificial circulation, hypolimnetic aeration, and hypolimnetic oxygenation (Beutel and Horne 1999; Cooke et al. 1986). Oxygenation of the metalimnion without breaking stratification can be accomplished either by bubblers (placed so that bubbles travel up to metalimnion) or Speece cones (that discharges oxygenated, equal-density and equal-temperature water to metalimnion).**
>
> **[*Last paragraph*] In summary, it is possible that multiple water quality impairments could be addressed by reservoir oxygenation management practices. Evidence suggests that reducing anoxic conditions in the hypolimnion or metalimnion of stratified~~some~~ reservoirs could reduce methylmercury production; however, concomitant methylmercury reductions in biota have yet to be observed from oxygenation.**

In response to RPM-3, the staff report in sections S-5 [Key Actions in Phase 1, Reservoirs: pilot tests]; 9.1.1 [Key Actions in Phase 1, Reservoirs: pilot tests]; and 9.8.1 [Phase 1 Actions for Reservoir Water Chemistry Management, Phase 1 pilot tests]; has been revised as follows.

> **(1) Oxidant addition to reservoir (near the sediment-water interface) to reduce anoxia or adjust redox potential when reservoirs are stratified to suppress methylation of mercury. Oxygen addition to reservoir mid-depth waters (near the thermocline) to reduce anoxia when reservoirs are stratified to suppress methylation of mercury. …**

In response to RPM-3, the Mercury Reservoir Provisions have been revised as follows:

> **IV.F.1.A.i.a Oxidant addition to reservoir bottom waters (near the sediment-water interface) to reduce anoxia or adjust redox potential when reservoirs are stratified to suppress methylation of mercury. Oxygen addition to reservoir mid-depth waters (near the thermocline) to reduce anoxia when reservoirs are stratified to suppress methylation of mercury. …**

COMMENT RPM-4

1-2. The role of reduced sulfur in binding Hg in sediments and influencing methylation was not really discussed. While this is less important in freshwaters than in saline systems it is worth some discussion.

RESPONSE TO RPM-4

The staff report focuses on freshwater reservoirs, which is why it does not address this topic. In response to CCG-62, the definition of reservoir was revised to exclude tidally-influenced waters, to make clear the focus on freshwater not saline systems. (Reduced sulfur is "sulfide." Regarding sulfide increasing methylation, see comment CCG-60).

COMMENT RPM-5

1-3. There have been recent studies indicating the potential for the formation of colloidal Hg in the environment and that colloidal Hg can be available to methylating bacteria. Again, this may not be a big issue for reservoirs and I don't know if there are any studies examining this but it may be worth mentioning when discussing bioavailability to methylating organisms.

RESPONSE TO RPM-5

Comment noted. This is potentially useful information that the Technical Review Committee may consider when they are advising on selection of pilot tests.

COMMENT RPM-6

1-4. There is very little discussion in Chapter 4 of the potential importance of demethylation in sediments, and in the water column, which is both abiotic and biotic, and how this may impact net MeHg in fish, and the factors that may influence this demethylation should be discussed, even though there is likely no strong specific information about the controlling mechanisms for this process in the literature. There is some reference to demethylation and its potential impact on water MeHg in Ch 7 but it could also be mentioned here.

RESPONSE TO RPM-6

Section 4.1.2, Factors Affecting Aqueous Methylmercury Concentrations, considers demethylation. Demethylation in epilimnetic (shallow) sediments is discussed in section 4.1.2 (Seasonality), but not whether it is an abiotic or biotic process. Demethylation in the water column is discussed in sections 4.1.2 (Dissolved Organic Carbon – mentions photodemethylation [an abiotic process]) and 4.1.3 (Demethylation and Evasion – mentions that it could be either an abiotic or biotic process).

Section 4.2.2, Factors Affecting Bioaccumulation of Methylmercury in Fish, discusses the positive correlations between aqueous or sediment methylmercury and fish methylmercury concentrations. The implication is that demethylation lowers aqueous or sediment methylmercury and the impact is lower fish methylmercury concentrations.

COMMENT RPM-7

1-5. It is stated that the fish concentration correlates strongly with aqeous MeHg and Fig. 4.4 is given as an example. Again, while the data may not be for reservoirs, there are studies in the literature that indicate that the relationship to aqueous MeHg is not always that strong, especially for studies that compare across systems. Within one ecosystem the relationship may be strong but across many it may be weak. The assumption that aqueous MeHg is the key is that the partitioning into the particulate phase is constant across ecosystems and that may be reasonable for systems where most of the biomass is algae and where suspended solids levels are similar, but this may not be so across all the reservoirs. The concept of biodilution is discussed and this could be important in confounding the relationship between water column MeHg and fish MeHg.

RESPONSE TO RPM-7

Appreciate the reviewer's insights into the scientific literature; this is a helpful introduction to the linkage analysis for California reservoirs discussed in the subsequent chapter (Ch. 5).

COMMENT RPM-8

1-6. Fig. [*4.6*] is given to support the idea that MeHg in fish correlates with MeHg in sediment. Again, for reservoirs of similar size and depth this may be so but there are likely to be other variables that impact this relationship in many reservoirs. Some discussion of the effect of physical conditions (size, depth etc) on this relationship would be useful.

RESPONSE TO RPM-8

Figure 4.6 provides data collected from different arms of California's second-largest reservoir, Lake Oroville. (The different arms are comparable in size to many other reservoirs.) Agree that there are other factors that impact the relationship between methylmercury in sediment and in fish. The staff report in Chapter 4 discusses many of the factors (variables) identified in the scientific literature and in Chapter 5 evaluates the importance of factors for which data were available. The factors evaluated are listed in Table 5.1 and include several factors related to size (e.g., Reservoir Surface Area, and Reservoir Maximum Capacity), and depth (e.g., Reservoir Dam Height).

The staff report in section 4.2.1, Methylmercury and Total Mercury Concentration in Sediment, describes Figure 4.6 as follows: "For example, sediment methylmercury and spotted bass were collected from different arms of Lake Oroville. Sediment methylmercury concentrations explained approximately 95% of the variability in length-standardized mercury concentrations in spotted bass (Figure 4.6)." For clarity, the caption of Figure 4.6 has been revised as follows:

<u>This plot shows co-located sediment methylmercury and spotted bass mercury data from different arms of Lake Oroville.</u> A strong positive correlation was found between natural logarithm transformed sediment methylmercury concentrations and length normalized (MeHg mg/kg/mm) spotted bass methylmercury concentrations ~~collected from the same arms of Lake Oroville~~<u>reported</u> in a California Department of Water Resources fish and sediment contaminant study (DWR 2006). The correlation

suggests that Lake Oroville food web methylmercury bioaccumulation is highly influenced by in-lake production of methylmercury.

COMMENT RPM-9

1-7. While there is discussion of the role of anoxia there appeared to be little discussion of the effect of eutrophication on the MeHg in fish in Chapter 4. Again, maybe this is not a big problem in CA reservoirs but some discussion of the link between eutrophication and fish MeHg in Chapter 4 is needed. In Appendix A, there is discussion of the potential impact of increasing nutrient levels as a mitigation strategy but the potential impact of too many nutrients needs to be highlighted. It is clear that the problem of nutrient limitation is more important than the opposite of excessive nutrients. There is some more discussion of the impact of nutrients in Ch 7. In discussing the impact of nutrient levels, most of the impacts are highlighted but there appears little mention of the potential for longer food chains in more oligotrophic systems which would lead to higher fish MeHg. Also, the sequestration of phosphorous (P) in sediments can be altered by anoxia or low oxygen conditions which could lead to its release from sediment. This should be discussed as its sequestration in sediments could change with changes in nutrients and ecosystem status.

RESPONSE TO RPM-9

The effect of eutrophication and fish methylmercury is discussed in Appendix A, Part 2, Primary Production and Mercury Bioaccumulation. "Multiple studies have demonstrated that water bodies with higher chlorophyll levels [*i.e., more eutrophic*] have lower biotic mercury concentrations. These observations come from both descriptive field studies and from nutrient amendments to whole lakes and laboratory mesocosms. The purpose of [*Part 2*] is to summarize the results of these studies and to identify the responsible biological mechanisms."

The potential impact of too many nutrients is discussed in Appendix A, Part 6, Nutrient Criteria Program. "The USEPA established the National Nutrient Criteria Program because about half of the Nation's waters are impaired by excess nutrients and cultural eutrophication (USEPA 2000b). … For more information about State Water Board efforts to develop nutrient objectives and a control program …, see: http://www.swrcb.ca.gov/plans_policies/nutrients.shtml)."

Importantly, Part 6 includes the following: "Tetra Tech (2006) recommended chlorophyll criteria to protect California reservoirs from the negative effects of cultural eutrophication. The recommended chlorophyll criteria should not conflict with an experimental fertilization program to reduce fish methylmercury concentrations, which should focus on oligotrophic reservoirs with chlorophyll concentrations less than 3 µg/L. Nonetheless, reservoirs with drinking water intakes should not be included in the fertilization program to eliminate the possibility that nutrient additions might contribute to a blue-green algal bloom in a potable water supply."

Appreciate the reviewer's confirmation that "the problem of nutrient limitation is more important than the opposite of excessive nutrients."

Regarding "the potential for longer food chains in more oligotrophic systems," the reviewer has not provided citations for and staff are not aware of citations that support this statement. The staff report in section 4.2.2, Food Web, cites Kelly and others (2006) finding that a forest fire *increased* nutrient loading, restructured the food web, and resulted in a longer food chain. Oligotrophication is not a biological mechanism that produces longer food chains; cultural oligotrophication is discussed in Appendix A. Citations regarding food web structure and its influence on fish methylmercury levels are provided in section 4.2.1. (Data on reservoir food chain length was not available for evaluation in Linkage Analysis in Chapter 5, which pertains to Conclusions 2–3.)

Agree that "the sequestration of phosphorous (P) in sediments can be altered by anoxia or low oxygen conditions which could lead to its release from sediment." Phosphorus release is mentioned several times in the staff report, e.g., section 4.3.2, Anoxia.

COMMENT RPM-10

1-8. The dissolved MeHg/chlorophyll ratio also takes into account the likely impact of higher biomass on influencing dissolved organic carbon (DOC) levels and therefore the bioavailability of MeHg to the base of the food chain. Some more discussion of the complexity of the role of DOC may be useful – it is not always the case that higher DOC leads to lower bioaccumulation and the type of DOC plays a role. There are studies that suggest for example that Hg bound to DOC may be more available for methylation that Hg bound to other ligands. The complex role of DOC in Hg and MeHg cycling could be further highlighted in Ch 4, and discussed further in Ch 7. The role of DOC and higher plankton levels on light penetration and therefore photochemical demethylation and the likely impact of this is not mentioned in Ch 4, although it is discussed in Ch 7.

RESPONSE TO RPM-10

Discussion of the complex role of dissolved organic carbon has been added to the staff report in response to CCG-7, CCG-62, and CCG-63. The role of dissolved organic carbon on light penetration is discussed in staff report section 4.1.2, Dissolved Organic Carbon. The role of dissolved organic carbon in reducing plankton methylmercury levels is discussed in Appendix A, Part 2, Dissolved organic carbon.

COMMENT RPM-11

While biotic methylation is not well understood there is increasing evidence that it can occur in the water column and maybe there is some manner in which this could be enhanced in some reservoirs over others. This could be worth mentioning.

RESPONSE TO RPM-11

See response to RPM-3.

COMMENT RPM-12

1-9. Also, there is little discussion of the potential for removal of Hg from the reservoirs by Hg reduction and evasion. As with MeHg photodemethylation, this is likely related to DOC levels and TSS, but there could be the potential for enhancing net reduction and evasion of Hg from the reservoir. There is essentially no discussion of this pathway and its potential importance in the cycling of Hg within the reservoirs. For the ocean and large lakes (e.g. Great lakes), evasion is the most important Hg sink and its importance has also been shown for smaller lakes, and could be more important for oligotrophic reservoirs.

RESPONSE TO RPM-12

Agree the staff report has a brief discussion of photodemethylation and evasion of mercury in section 4.1.3 Potential Loss Pathways for Inorganic Mercury and Methylmercury. Yet, the potential importance of this mercury sink is recognized in the implementation plan, which includes pilot tests of "Other potentially controllable methylation factors, including methods to enhance demethylation, described in Chapters 4 and 7 or which may be described in scientific literature …" (section 9.8.1).

Agree that enhancing net reduction and evasion of mercury might be a controllable action to consider for pilot tests. Staff proposes to include this in early discussions with the Technical Review Committee.

COMMENT RPM-13

1-10. The implication in much of the discussion is that sulfate reducing bacteria (SRB) are the principal methylators in reservoirs. Given recent research about methylating genes and the role of other organisms, this may not be completely correct. Some discussion of the role of other organisms in methylation in CA reservoirs is needed.

RESPONSE TO RPM-13

See response to JMB-5.

COMMENT RPM-14

1-11. The correlation model in Appendix A appears to capture most of the important variables, and as indicated, the ratio of dissolved MeHg to chl-a includes the impacts of many of the other variables that can influence MeHg production, fate and transport, and bioaccumulation.

RESPONSE TO RPM-14

The reviewer's support for the correlation model in Appendix A is noted.

Conclusion 2.

COMMENT RPM-15

2-1. This conclusion is based on the evaluation of the available data for reservoirs which does not include all reservoirs and is therefore the best empirical evaluation of the controlling factors given the data. However, the variables that are important make scientific sense and are reasonable and indicate that it is the trophic dynamics that have more control over the fish MeHg levels than the relative differences in net production of MeHg across the reservoirs. This is likely the result of similarity in the conditions across the reservoirs and the fact they are mostly oligotrophic and therefore differences such as degree of anoxia in bottom waters in summer, sediment organic content and its redox chemistry, and other factors that are more important in other ecosystems are of less importance for CA reservoirs.

RESPONSE TO RPM-15

The reviewer's qualified support for Conclusion 2 is noted.

The range and differences—not similarity—of reservoir conditions evaluated in the linkage analysis is illustrated on Figure B.1. For example, the reservoirs ranged from oligotrophic (count of 27), mesotrophic (16), and included 6 eutrophic reservoirs (Table B.1, based on chlorophyll *a* ranges in ug/L of up to 2.6 for oligotrophic, 2.6 to 20 for mesotrophic, and above 20 for eutrophic).

COMMENT RPM-16

2-2. While the model includes four variables (two as a ratio) there are other variables of some importance that have been found in other systems that clearly do not have as much importance for the CA reservoirs because of their likely similarity in the reservoirs from where the data was available. However, the importance of these variables may become more apparent as more data is collected on other reservoirs. Many of these other variables are discussed in more detail in Ch 7.

RESPONSE TO RPM-16

The reviewer's support for Chapters 5 and 7 is noted.

COMMENT RPM-17

2-3. The targets [*allocations*] that are derived from the analysis are reasonable based on the data but it is not clear that these are easily attainable and so this is of course the major problem. As noted for the total Hg in sediment criteria the derived value is lower than background levels and therefore the criteria are set for a reservoir based on the background value in the region. That levels have to be at background makes this very difficult to achieve as there still may be a small "reservoir effect" in many locations which would likely make the reservoir exceed the criteria.

RESPONSE TO RPM-17

The reviewer's support for the mercury allocations to mining waste and soils is noted. These are allocations to mercury sources and not allocations to reservoir bottom sediments. Eventually, when sources meet these allocations, cleaner sediment will be transported into reservoirs where it will settle on the bottom and bury sediment with elevated mercury levels.

COMMENT RPM-18

One issue that should be mentioned is the potential impact of stimulating algal production - a suggested remedy - on the concentration of Hg in sediments. Increased algal biomass has the potential to lead to more deposition of organic material to the sediment and this may lead to a higher concentration of Hg being stored in the sediment over time, and therefore changing primary productivity may lead to the reservoir exceeding the criteria. There is some mention of these links in Ch 7.

RESPONSE TO RPM-18

The staff report considers an exceptionally modest stimulation of algal production, and appreciate the reviewer has acknowledged text in Chapter 7. A recent paper on the full-scale nutrient amendment program in Idaho's Dworshak Reservoir found chlorophyll *a* levels were unchanged (Wilson et al. 2018). Consequently, there is little possibility that minimal nutrient addition will increase mercury in sediments.

COMMENT RPM-19

In many ecosystems there is a relationship between sediment Hg and organic content especially at low organic matter levels, which is likely representative of the reservoirs given that they are oligotropic – the sediment organic content and its potential impact is not really discussed in the report. Was this one of the variables that was considered in Ch 5? Perhaps some consideration should be given to normalizing the reservoir sediment Hg to OC when comparing it to the content of the background Hg in the watershed as differences in OC likely will be important – for example a watershed with high forest coverage probably has higher Hg and OC levels than one that is not.

RESPONSE TO RPM-19

See response to CCG-85.

COMMENT RPM-20

Overall, throughout the report there is discussion of a potential controllable variable as if its impact is in isolation, but most of the factors that can be manipulated to influence MeHg concentrations could easily result in other changes that could lead to an increase in MeHg in the longer term. The overall timescale of these interactions will differ and this should be discussed and acknowledged in the report.

RESPONSE TO RPM-20

On the one hand, the staff report considers multiple variables together. The obvious examples are the multivariate analysis in Chapter 5, and section 7.5.1, Competing factors. Regarding the potential for nutrient amendment to have multiple impacts, the reviewer repeats comment RPM-18.

On the other hand, the staff report considers source controls individually, because mercury sources are not evenly distributed across the state (see section 6.8). Also, the staff report considers hypolimnetic oxygenation to reduce methylation as if its impact is in isolation. In fact, this intervention would also reduce phosphorus releases and hence reduce chlorophyll-*a* and thereby increase fish methylmercury levels. However, there would be less algae that die and fuel methylation in the hypolimnion. Less phosphorus could also change the relative abundance of algae and cyanobacteria species. Staff report section 9.13.2, *Focusing questions for use in program review*, has been revised as follows:

(1) a. Are reservoir aqueous methylmercury levels decreasing and other bioaccumulation factors (e.g., chlorophyll-a, relative abundance and nutritional value of phytoplankton) changing as expected? Are reservoir aqueous methylmercury concentrations, or the ratio of methylmercury to chlorophyll-a, useful to predict where or whether TMDL targets will be attained in Phase 2?

Timescale is considered in the staff report. See responses to RPM-23 and RPM-28 regarding timescales for nutrient amendment. See response to RPM-31 regarding timescales for mine remediation and controlling local air emissions.

COMMENT RPM-21

2-4. The dissolved MeHg level of 0.009 ng/L is the concluded level for protection given the specific fish concentration of 0.03 [*0.2*] mg/kg. One issue is whether such low levels can be measured on a relatively routine basis and it is indicated that this should be possible. Indeed, such low levels are found in ocean waters and routinely measured by investigators in these waters although intercalibration studies show that there can be high variability in the reported levels at lower concentrations. Therefore, if this low level is to be used then there needs to be an excellent QA plan associated with the reservoir TMDL to ensure that the values reported are accurate and precise, either by having one accredited lab doing the analysis or having the labs participate in regular low level intercalibration studies. This issue needs to be discussed in the report as this is not a trivial undertaking.

RESPONSE TO RPM-21

Appreciate confirmation that very low levels of aqueous methylmercury are measured on a routine basis in studies of ocean waters. The staff report in section 7.3.7, Recommendations, has been revised as follows.

Finally, staff recommends a study take place to develop an analytical protocol that consistently achieves an MDL of 0.009 ng/L or lower for methylmercury in water. This study requires a quality assurance (QA) plan to ensure accuracy and precision. The QA plan may be fulfilled by having an accredited laboratory experienced with ultra-low methylmercury detection performing all of the analysis. Alternatively, the QA plan may be fulfilled by having all of the laboratories who are performing the analyses participate in regular low-level intercalibration studies. Results of the study, and future data collected using lower MDL analytical methods, can be used to revise the allocation for in-reservoir methylmercury production as needed, using an adaptive implementation approach.

COMMENT RPM-22

2-5. The idea of trying to stimulate algal growth and biodilution is put forward and based on the information put forward from the literature and the current oligotrophic status of the reservoirs this appears to have merit but it needs obviously to be carefully controlled. It may also however be that it is not just the major nutrients that are limiting in the reservoirs. While there has been less study in freshwaters, there is definitely evidence that trace metals (e.g. Fe, Mo) may be limiting productivity in lakes, and so if this is the case, then adding major nutrients could lead to a shift in the species composition rather than a stimulating of the existing algal species in the system. While this may not be a major issue, it should be considered. Iron limitation may be important if the systems have oxic sediments.

RESPONSE TO RPM-22

Agree that oligotrophic status may result from lack of trace metals as well as lack of major nutrients. See response to CCG-84 that responds to this reviewer's suggestions about minor nutrients (i.e., trace metals). The text added to section 9.13.1 in response to comment RPM-22 is the following: "For nutrient additions, were limiting nutrients assessed and does the initial amendment contain an appropriate mix of major and minor nutrients? Does the work plan include adequate monitoring to inform adjustments in the amendment formulation to avoid stimulating undesirable species (e.g., cyanobacteria or the diatom *Rhizosolenia*)?"

COMMENT RPM-23

Another issue that is not really discussed is whether the change in primary productivity would leave to a shift in zooplankton and other secondary consumers, or how if may affect the relative amount of benthic to pelagic production. As noted in the report, benthic production is an important component of system productivity. The timescale over which studies that have been done to examine the impact of adding nutrients is not detailed in the report, as it may be that changes associated with changing nutrient dynamics could be slow.

RESPONSE TO RPM-23

The staff report in Appendix A, Importance of Primary and Secondary Production in Controlling Fish Methylmercury Concentrations, considers changes in abundance and

methylmercury concentration of secondary consumers. Part 3 of Appendix A discusses how large annual fluctuations in water levels change the physical characteristics of reservoir margins in ways that reduce benthic primary production along the margins. Benthic primary production along the margins, or in deeper areas below the photic zone, is not expected to be changed by nutrient amendments and therefore is not discussed in the staff report. However, agree that the staff report does not consider shifts in secondary species.

The staff report in Appendix A does provide the timescales—*from years to decades***— over which many of the cited studies or nutrient amendment programs were conducted. Notably from page A-2, Part 4 "is included because 'lessons learned' from** *decades* **of fertilization work elsewhere may be of interest to the State of California." Importantly from page A-25, "There did not appear to be any long term build up in nutrients because fertilization was light. The lakes returned to background conditions** *several years* **after the addition of nutrients ceased…." Also see response to RPM-18 that describes quick (within a year or two) response to fertilization in an Idaho reservoir.**

COMMENT RPM-24

2-6. Other things that could be manipulated that are not mentioned here but are touched on later in the report is whether it may be possible to alter the seasonality of the water level drawdown as this may lessen its impact.

RESPONSE TO RPM-24

This mercury program addresses controllable water *quality* **factors and does not propose to alter water level drawdown or other water** *supply* **factors; see response to CCG-70.**

COMMENT RPM-25

Also, in the systems that do have low oxygen bottom waters in summer, water column oxygenation may be useful. Some discussion of these may be warranted to indicate that they were considered but not found to be appropriate. While it may not be of use for the reservoirs, there has been success in the addition of nitrate to bottom waters in Onadaga Lake in NY. While this is likely a completely different system, some mention of this would be appropriate here – it is mentioned somewhat in Ch. 7.

<u>RESPONSE TO RPM-25</u>

The reviewer diverges from Conclusion 2, for which reviewers were directed to staff report Chapters 2 and 5[8]. Comment RPM-25 is relevant to Chapters 7 and 9; oxygenation and nitrated addition are discussed in both of these chapters.

Conclusion 3.

<u>COMMENT RPM-26</u>

This statement is valid and the reasons have been well outlined and any additional information needed is described in the comments above.

<u>RESPONSE TO RPM-26</u>

The reviewer's qualified support for conclusion 3 is noted.

Conclusion 4.

<u>COMMENT RPM-27</u>

4-1. I am assuming this statement refers to Hg in sediments. This statement is the logical conclusion of the analysis in Ch 5 and elsewhere and is the basis for the conclusions for 2 and 3 above that other factors need to be addressed besides Hg inputs. The implications of this conclusion are that, for example, sediment levels should not be lower than the "modern" background at the reservoir locations, as discussed above. This does raise the concern that the criteria are not attainable and the obvious implication of this is that if levels have to be reduced below modern background concentrations then the organism that this level is designed to protect may have been exposed for a long period – of course, the reservoirs are not natural but it is likely that lakes in the region would behaved similarly historically. The fish level values that are determined for the protection of humans and wildlife will have uncertainty associated with their calculation and perhaps this needs to be further considered in evaluating how this statement is possible. There is likely a large error range in the exposure estimate. This may be discussed in the report somewhere but I might have missed it but perhaps some measure of the uncertainty in the wildlife and human estimates needs to be incorporated into the evaluation. As a simple example, most exposure estimates use a single value for human assimilation of MeHg from food, but recent studies suggest there is actually a much wider range in this value. Can the uncertainty be incorporated into the choice of the sediment levels associated with the various risks?

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[8] **See letter dated April 10, 2017 from Dr. Mumley to Dr. Bowes with subject line "Request for External Scientific Peer Review of Draft Proposed Rule for the Mercury Reservoir Provisions to Establish a Mercury TMDL and Implementation Program for Reservoirs."**

<u>RESPONSE TO RPM-27</u>

The reviewer's support for conclusion 4 is noted. The reviewer is correct that conclusion 4 addresses mercury allocations to mining waste and soils. The reviewer repeats some previous comments including about attainability; see response to RPM-17.

Uncertainty in exposure estimates and consequently in fish methylmercury levels for the protection of humans and wildlife were considered by the State Water Board as it developed mercury water quality objectives. Chapters 1 and 2 of the April 2017 reservoir mercury staff report described these as "proposed" mercury water quality objectives. These objectives were adopted by the State Water Board in May 2017 and subsequently approved by U.S. EPA. Future revisions to the staff report will describe these as "adopted" objectives. The uncertainty in exposure estimates cannot be incorporated into the choice of mercury allocations to mining waste and soils because these choices were made based on measured soil and sediment mercury concentrations and not based on risk calculations.

<u>COMMENT RPM-28</u>

4-2. Manipulation of environmental conditions to try and achieve goals, and to reduce one effect by perturbing the system in another way, has always the potential for unknown adverse effects and there are many historical examples of this. The report states that the reservoirs would revert back to the pre-perturbed state if nutrient addition is stopped and claims evidence to support this but it is not clear over what timescale the experimental perturbation was enacted, and the recovery monitored. Further, over what timescale would the interventions be considered as it appears that there may need to continue such interventions indefinitely.

<u>RESPONSE TO RPM-28</u>

Agree that monitoring is needed to determine if adverse impacts have occurred, see response to CCG-34. See response to RPM-23 regarding "lakes returned to background conditions *several years* **after the addition of nutrients ceased…." Appendix A states, "A nutrient fertilization program should only be considered as a** *temporary* **solution until a permanent mercury fix is developed."**

Conclusion 5.

<u>COMMENT RPM-29</u>

This is a relatively obvious statement given that mining and other point source inputs are not evenly distributed around the state, and that external inputs such as atmospheric deposition do not dominate the inputs for many of the reservoirs.

<u>RESPONSE TO RPM-29</u>

The reviewer's support for conclusion 5 is noted.

Conclusion 6.

COMMENT RPM-30

This statement is reasonable because the location of other potential point sources and other anthropogenic inputs (urban runoff (this is however primarily derived from atmospheric deposition), wastewater treatment plants effluent etc) are in locations relatively far removed from the location of most of the reservoirs in the state. However, this is not entirely true and so in a way the statement is too definite – maybe it would be better to add: "…to the majority of the impaired reservoirs…". Also, modeling indicates that a small fraction of the Hg in atmospheric deposition in CA comes from anthropogenic emissions within the state, and further that a small fraction of the reservoirs are impacted by these CA-based anthropogenic emissions. Therefore, the inclusion of the local (CA) emissions in the statement seems to indicate that these sources may be more important than they are. Overall, regulation of emissions in CA would have a small impact on Hg inputs to the reservoirs. In total, the statement is supported by the presented information and analysis of the distributions of sources in the state and the locations of the reservoirs but could be altered to focus on the most important sources to the majority of the reservoirs.

RESPONSE TO RPM-30

The reviewer's qualified support for conclusion 6 is noted. (Note that Staff Report 6.8 provides a mercury source comparison.)

Conclusion 7.

COMMENT RPM-31

7-1. This statement appears to contradict the Statement 6 above and some of the others statements. Above, it is concluded that historic mining sites are an important source. Is this statement referring to the natural and background sources in the watersheds or all sources in the watersheds? This needs to be clarified and better supported in the document. Perhaps this background information for this statement could be better presented – there is little detail in Ch. 6. Is there some subset of reservoirs where this could be true, based on reservoir size, watershed area, watershed Hg levels, water depth, trophic state etc as one could envision factors that could make this true for some locations – e.g. very low sedimentation rates, larger watershed and a small number of mining sites, naturally Hg- enriched soils in the watershed etc. If this statement is correct, then why is there a proposed outcome and an effort in some of the statements below to reduce inputs from historic sites. Surely this will always have an impact? Additionally, the timescale needs to be considered and this is not discussed. While I have no idea of the sedimentation rates, they could be less than a cm per year, and therefore with sediment mixing due to benthic organisms, it would take many years for the sediment concentrations to change. There is no discussion of the timescale or the expected response time of the reservoirs to changes in watershed inputs. I would expect this response time to be many years to decades and perhaps this is the reason why this conclusion has been reached.

While water bodies will respond reasonably rapidly to changes in atmospheric inputs the timescale of response to changes in watershed loading are much slower. This has been examined in a number of modeling papers and these should be detailed and discussed in the report.

RESPONSE TO RPM-31

Conclusion 7 builds on and does not contradict conclusions 5 and 6 or other conclusions. Support for conclusion 7 is provided in staff report section 6.8, which demonstrates that many reservoirs have few and/or comparatively small watershed mercury sources. The reviewer supported both conclusions 5 and 6.

Dr. Mason is correct, there is a subset of reservoirs where addressing mine sites *or* **local emissions would be effective. This topic is discussed in the next chapter—in section 7.2.7, Predictions for Improvement Based on Source Control. Section 7.2.7 considers timescale of response. Staff predicts relatively quick improvements may occur from remediation of mining waste in 3 reservoirs, though the reviewer is correct that timing depends on sedimentation rates, mixing, initial mercury concentrations, etc., so staff are not able to provide more precise time estimates. Coincidentally, staff predicts fish methylmercury levels could decline in approximately a decade in 3 other reservoirs from controlling local air emissions; of these 3, fish methylmercury already meets the sportfish target in Puddingstone Reservoir (see Appendix I.3.b).**

COMMENT RPM-32

7-2. There could be a further categorization of the reservoirs. As noted in the report in various places, the watershed/reservoir area ratio varies by many orders of magnitude so combining the data for large reservoirs with small watersheds with small reservoirs with large watersheds will lead to confusion in the driving factors as these would be different – atmospheric deposition in the first case and therefore changing watershed inputs would have little effect, while the opposite would be true in the latter case. Overall, the major differences in the sources to the different reservoirs, and the complexity of issues such as water transfer between systems, which is outlined in section 6.8, is not properly conveyed in this statement and the others, and a better effort is needed to do so.

RESPONSE TO RPM-32

Agree. Moreover, staff is working with owners and operators of reservoirs and anticipates working with the Technical Review Committee on further categorization of reservoirs for pilot tests. Note that coordinated reservoirs are not proposed to be grouped (or "binned") into categories *strictly* **by similar** *reservoir* **characteristics. Instead, this program allows for reservoirs to be binned by** *applicable* **management practices, and any binning will be subject to review by and advice from the Technical Review Committee. Staff considered the complexity of issues for each reservoir—on an individual basis—in developing Table 7.1: Potential fish methylmercury reduction methods predicted for each 303(d)-listed reservoir.**

COMMENT RPM-33

7-3. While many statements are put forward in a general way there appears to be little generality in terms of the actual reservoirs, their sources and it appears to me that in most cases each will have to be dealt with as an individual case with little ability to extrapolate from "case studies" as is proposed.

RESPONSE TO RPM-33

On the one hand, agree that each reservoir is an individual case (see staff report section 7.5, Need for Reservoir-Specific Strategies). On the other hand, do not agree there is little ability to extrapolate from pilot tests of water chemistry and fisheries management to other reservoirs.

Similar to mercury, reservoir managers commonly address algal-related problems ranging from taste and odor in drinking water to fish kills from hyper-eutrophic conditions. To address algae, each reservoir is assessed on an individual basis, but management practice(s) are selected based on pilot tests from other reservoirs.

The coordinated pilot test program relies on

> **"'representative reservoirs,' meaning that the management practices pilot tested at a specific reservoir or reservoirs are expected to be effective to aid in achieving the applicable targets in each similar reservoir included in the coordinated approach. This aspect of representativeness should be verified with the Technical Review Committee…" (section 9.8.3).**

Note the wording about management practices to, "*aid* **in achieving," which allows for extrapolation to other reservoirs more than if the wording were, "***achieve* **the TMDL targets." This wording was selected because in some cases more than one management practice maybe be needed to achieve the TMDL target.**

Chapter IV.F.2.a of the Mercury Reservoir Provisions was revised to correct a typographical error, as follows:

> **A coordinated approach may only encompass "representative reservoirs." "Representative reservoirs" means that each reservoir proposed to be coordinated must be sufficiently similar to other reservoirs such that the management practices pilot tested at a specific reservoir or reservoirs are expected to be effective to ~~achieve or~~ aid in achieving the mercury water quality objectives in each similar reservoir included in the coordinated approach, and …"**

In response to RPM-33, the Mercury Reservoir Provisions have been revised in recognition of potential challenges to find perfectly "representative reservoirs." The revision is to allow for an additional round of pilot testing during Phase 2 in impaired reservoirs addressed in Phase 1 coordinated pilot tests. The revisions to Chapter IV.B and Chapter VI.A are the following:

IV.B. Time Schedule and Phased Approach ~~1 and Phase 2~~

VI.A.5 Consider whether to require any owner and operator to conduct a new or an additional pilot test in any of their IMPAIRED RESERVOIRS.

The last paragraph of staff report section 9.1, Reservoirs and mercury control actions, already considers that additional pilot tests may be needed during Phase 2 for newly identified mercury-impaired reservoirs. This section of the staff report has been revised in response to RPM-33, to consider the need for additional pilot tests during Phase 2 for reservoirs addressed in Phase 1 coordinated pilot tests, as follows.

Staff Report section 9.1, Reservoirs and mercury control actions, last paragraph

In addition, during program review the State Water Board could determine whether and when to require additional pilot tests, i.e., pilot tests in reservoirs newly determined to be impaired. For example, to resolve operational issues for an expensive best management practice proven in pilot tests for other reservoirs, by conducting a pilot test in a localized portion of a reservoir newly determined to be impaired. Favorably, if pilot tests are needed after Phase 1, the duration and cost of pilot tests are expected to decrease with each successive wave of mercury-impaired reservoirs incorporated into the Statewide Mercury Control Program for Reservoirs.

Additionally, some reservoirs included in Phase 1 coordinated pilot tests might need additional pilot tests, rather than proceeding directly to full-scale implementation ~~for some reservoirs, might be needed for different reasons~~. ~~Another~~For example, ~~would be to use~~ a site-specific pilot test might be necessary to scale up a best management practice for full-scale implementation. ~~Favorably, if pilot tests are needed after Phase 1, the duration and cost of pilot tests are expected to decrease with each successive wave of mercury-impaired reservoirs incorporated into the Statewide Mercury Control Program for Reservoirs.~~

Also in response to RPM-33, an additional focusing question is provided for use in program review, as follows.

Staff Report section 9.13.2, Focusing questions for use in program review

(1) f. Where are additional pilot tests needed, whether for reservoirs newly determined to be impaired, or for reservoirs included in Phase 1 coordinated pilot tests?

Further, the Mercury Reservoir Provisions were revised (see response to CCG-84) to ensure that monitoring data will be collected from reservoirs not undergoing pilot testing. Such monitoring data ensures that reservoir-specific information will be available to support selection of reservoir management practices (and for development of the long-term reservoir management strategy report).

Note that coordinated reservoirs are not proposed to be grouped (or "binned") into categories ***strictly*** **by similar** ***reservoir*** **characteristics. Instead, this program allows for reservoirs to be binned by** ***applicable management practices*****, and any binning will be subject to review by and advice from the Technical Review Committee.**

Conclusion 8.

COMMENT RPM-34

This statement is entirely based on the computer modeling results and therefore is valid if there is confidence in the ability of the computer model to reflect reality. There is no other way with the current understanding and information available to evaluate this in another manner – mercury isotopes could help perhaps but this approach is still being developed and likely would not be sufficient to provide a conclusive answer. There are other computer models in the literature and it would be useful perhaps to compare the REMSAD results with other models if possible.

RESPONSE TO RPM-34

See responses to DAJ-16 through DAJ 24.

Conclusion 9.

COMMENT RPM-35

This is true and the determination of which will be the most effective will require an evaluation for each reservoir as it is likely that each will have a unique set of inputs, and factors influencing in situ net methylation, that will need to be considered. It is not clear to me given the large difference in the reservoir characteristics, their locations, the size relative to the watershed etc that it will be easy to extrapolate results from one reservoir to the next, or even to identify without further study and sample collections which approach may be the best for a particular reservoir.

RESPONSE TO RPM-35

The reviewer's support for conclusion 9 is noted. Regarding unique characteristics, see response to RPM-33.

Conclusion 10.

COMMENT RPM-36

This appears a valid statement based on the information provided and discussion in the report.

RESPONSE TO RPM-36

The reviewer's support for conclusion 10 is noted.

Conclusion 11.

COMMENT RPM-37

This leads on from the previous statement however I am not sure that the final sentence is entirely valid. This is a hope rather than an expectation, I would conclude, as it is indicated that there could be a limit to which strategies could be invoked and therefore there is no a priori reason why success is guaranteed. Also, what is the timescale of expectation here.

RESPONSE TO RPM-37

The reviewer's qualified support for conclusion 11 is noted. Regarding the final sentence, in contrast Dr. Benoit opined in the last sentence of comment JMB-38, "Given the multiple options available for most reservoirs, it is reasonable to conclude that there will be a feasible strategy for every reservoir." Taking the middle-of-the-road position, Dr. Gilmour opined in the opening of comment CCG-21, "There will be some reservoirs for which there is no reasonable way to reduce fish MeHg to CA targets. But reductions in fish MeHg should be achievable in the majority of impaired reservoirs."

The timescale of expectations is several decades or sooner, which pilot tests will help to inform.

Conclusion 12.

COMMENT RPM-38

12-1. The load allocation approach seems confusing as there is allocation for external sources of inorganic Hg as well as an allocation for the in situ formation of MeHg. The relative impact of these loadings may not be adequately taken into account because of the reliance on concentrations rather than actual loads. For example, a small reservoir with a large watershed with mining contamination would have a very different source allocation (high inputs from the watershed of contaminated sediments compared to a small in situ net production of MeHg for a specific concentration because of reservoir size) than a large reservoir with a small watershed. Maybe these extremes don't exist but the reservoirs are not relatively similar in size and in relative watershed/lake area. Therefore, it is easy to imagine that the allocation approach may lead to the disproportionate allocation to one source over the other, and therefore the result would be incorrect assignment of the necessary source reduction. The information in Tables 3.2 & 5.1 indicate that the watershed/lake area ratio varies by many orders of magnitude, and the dam height by a factor of about 200, so there is the need to take these concerns into account when assigning inputs on the basis of concentrations in particulate load and MeHg concentration in water. This needs to be discussed in more detail in the report.

RESPONSE TO RPM-38

Yes, there are load allocations to both external sources of inorganic mercury and in-reservoir methylmercury production. Regarding concentrations rather than loads, see response to CCG-7.

Dr. Mason is familiar with and referring to TMDLs that assign allocations based on *necessary source reduction* **and apportion different reductions to different sources. In contrast, these reservoir inorganic mercury allocations to mining waste and soil were developed that account for** *technical feasibility* **(i.e., estimates of how much these sources can be reduced; see response to CCG-83). Consequently, the allocations do not consider relative impact to small and large reservoirs and watersheds (and various combinations thereof). Furthermore, the concept of "disproportionate allocation to one source over the other" does not apply as these allocations were each developed for technical feasibility.**

COMMENT RPM-39

12-2. The [*assignment*] of a site to a particular region may be easily assessed but this is not clear on reading the document but it is of substantial importance given the differences in allocation for "mineralized" versus "enriched" areas in particular. I would have liked to have seen a better justification of the choice for these values. This was not adequately described in the document.

RESPONSE TO RPM-39

Staff report section 6.2.1 describes at length the "Three Mercury Regions in California" and includes "Maps of Mercury-Enriched Region and Mercury Mineralized Zones" (see Figure 6.1).

COMMENT RPM-40

12-3. It was not clear to me how the atmospheric loading would be allocated – based on the reservoir surface area relative to the total area of CA, or on the watershed ratio? Whichever it is will have an important impact of the allocated importance of atmospheric inputs the large watershed to lake area ratio. While atmospheric inputs are not important for most of these reservoirs, the allocations should still be done in a scientifically defensible manner that is well articulated in the report.

RESPONSE TO RPM-40

The load allocations for atmospheric deposition is the annual load of total mercury deposited to all surfaces (land and water) by both wet and dry deposition. Chapters 6, 7, and 8 of the staff report provide detailed, scientifically defensible, and well-articulated source assessment and explanation of allocations. See especially section 8.2.2, which explains that the, "allocations apply to the annual load of total mercury deposited in California by atmospheric wet and dry deposition. The allocations include mercury deposited to inland water surfaces … and to land surfaces …." Staff report section 6.1 explains the approach to assessing mercury sources and section 6.4 "describes the local (California) and global sources that emit mercury to the atmosphere, and provides an estimate of how much of the mercury emitted is deposited in California…" Section 6.4 concludes with values used to develop allocations in Chapters 7 and 8.

COMMENT RPM-41

12-4. Given the timescale over which the TMDLs will be implemented there may be the need to redefine the atmospheric loading allocations in the future.

RESPONSE TO RPM-41

Agree, and the program allows for allocations to be modified in the future (see staff report section 9.13).

Conclusion 13.

COMMENT RPM-42

This statement relies on the projections of future global Hg emissions being accurate as there are a number of reservoirs that have atmospheric deposition, predominantly from global sources, as their major input (Statement 8). So, this statement should be refined to indicate this. Also, given that one of the sources is in situ production of MeHg, this may change due to other factors besides inputs of Hg such as climate-related increases in temperature, rainfall etc so there is the potential for other climate changes to impact this "source". In addition, the timescale of the term "future" needs to be stated more clearly.

RESPONSE TO RPM-42

Agree regarding emissions, see response to RPM-41. The potential for climate change to impact *in situ* methylmercury production is considered in staff report section 7.7.5 Lastly, the timescale of the term "future" is one to several decades.

Conclusion 14.

COMMENT RPM-43

This is not well described in the report and is difficult to assess. The choice of the upstream loading concentrations is based on the available information and appears to be conservative in terms of the current data. The atmospheric inputs are constrained by the modeling results but the distribution of inputs between CA and global sources is a model result and not based on any actual data, and therefore is as valid as the errors and uncertainties in the model predictions.

RESPONSE TO RPM-43

The margin of safety is described in staff report section 8.3. Staff plans to revisit the margin of safety in the first program review (see response to CCG-26.) The reviewer's support for load and wasteload allocations for upstream sources is noted. The reviewer repeats comment RPM-34 about uncertainty in atmospheric deposition load estimates.

Conclusion 15.

COMMENT RPM-44

The requirements are consistent with the scientific report and therefore are reasonable if the concerns and caveats outlined above are considered and either shown not to be a concern or are incorporated into the revised versions of the documents.

RESPONSE TO RPM-44

The reviewer's qualified support for conclusion 15 is noted; the reviewer's concerns and caveats were addressed above.

Conclusion 16.

COMMENT RPM-45

The approach appears reasonable, and the oversight is required, given that it is unlikely that there will be a consistent approach and set of actions for the reservoirs. While the report suggests in numerous places that there may be test sites that would allow application to other similar reservoirs, I think this is likely not to be the case as the variables that are proposed for manipulation are not independent and therefore the actual changes will depend on the location and exact characteristics of a particular reservoir and it is unlikely that extrapolation will be possible without actual testing in each case. So, it is likely that each reservoir will be a "special case". If experimental manipulations or other measurements are done it would be worth making the measurements to assess the relative importance of external sources of MeHg to the reservoir.

RESPONSE TO RPM-45

The reviewer's qualified support for conclusion 16 is noted. Appreciate the reviewer's support for Program Review in Section VI of the Reservoir Mercury Provisions. The reviewer repeats comment RPM-33 regarding that each reservoir will be a "special case." Agree with assessing the relative importance of external sources of methylmercury to the reservoir. Staff report section 9.8.4, Work Plans and Reports, describes that, "Additional measures may be included in pilot tests as directed by the Technical Review Committee or at the discretion of reservoir owners and operators to ensure technical adequacy, scientific rigor, or for efficiency. … Additional measures may include… (2) Characterize … methylmercury in reservoir inflows, and compare to in-reservoir mercury conditions; …."

Conclusion 17.

COMMENT RPM-46

I am not a statistician but the 90th percentile appears a reasonable confidence limit and is protective in the majority. The first part of this conclusion is best evaluated by someone trained in statistical methods. However, the second part which relates to the use of consistent fish trophic levels and sizes in making allocations has definite merit, and I agree with this approach. The more detailed and consistent the approach to examining compliance based on fish concentration, the more valid will be the outcome of the determination of compliance.

RESPONSE TO RPM-46

The reviewer's qualified support for conclusion 17 is noted.

Conclusion 18.

COMMENT RPM-47

Many papers, books and chapters on monitoring have endorsed the approach of using resident, young of the year fish for determining change due to a particular implementation even if the overall evaluation of compliance relies on the concentration in a larger, higher food chain species consumed by humans and wildlife.

RESPONSE TO RPM-47

The reviewer's support for conclusion 18 is noted.

S.6 References

This section provides new references cited in response to comments that were not cited by reviewers or cited in April 2017 staff report.

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