Mercury Open Water Final Report for Compliance with the Delta Mercury Control Program

Chapter 1. Report Organization and Background

Submitted by the Open Water Workgroup

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Technical Appendices

Contents

Tables

Figures

Acronyms and Abbreviations

BMP	best management practice
CVRWQCB	Central Valley Regional Water Quality Control Board
Delta	Sacramento-San Joaquin Delta
D-MCM	Dynamic Mercury Cycling Model
DSM2	Delta Simulation Model 2
DWR	California Department of Water Resources
Hg	mercury
MeHg	methylmercury
PEST++	parameter estimation and uncertainty analysis
uHg	unfiltered mercury
Workgroup	Open Water Workgroup
Yolo Bypass D-MCM	Yolo Bypass Dynamic Mercury Cycling Model

Background

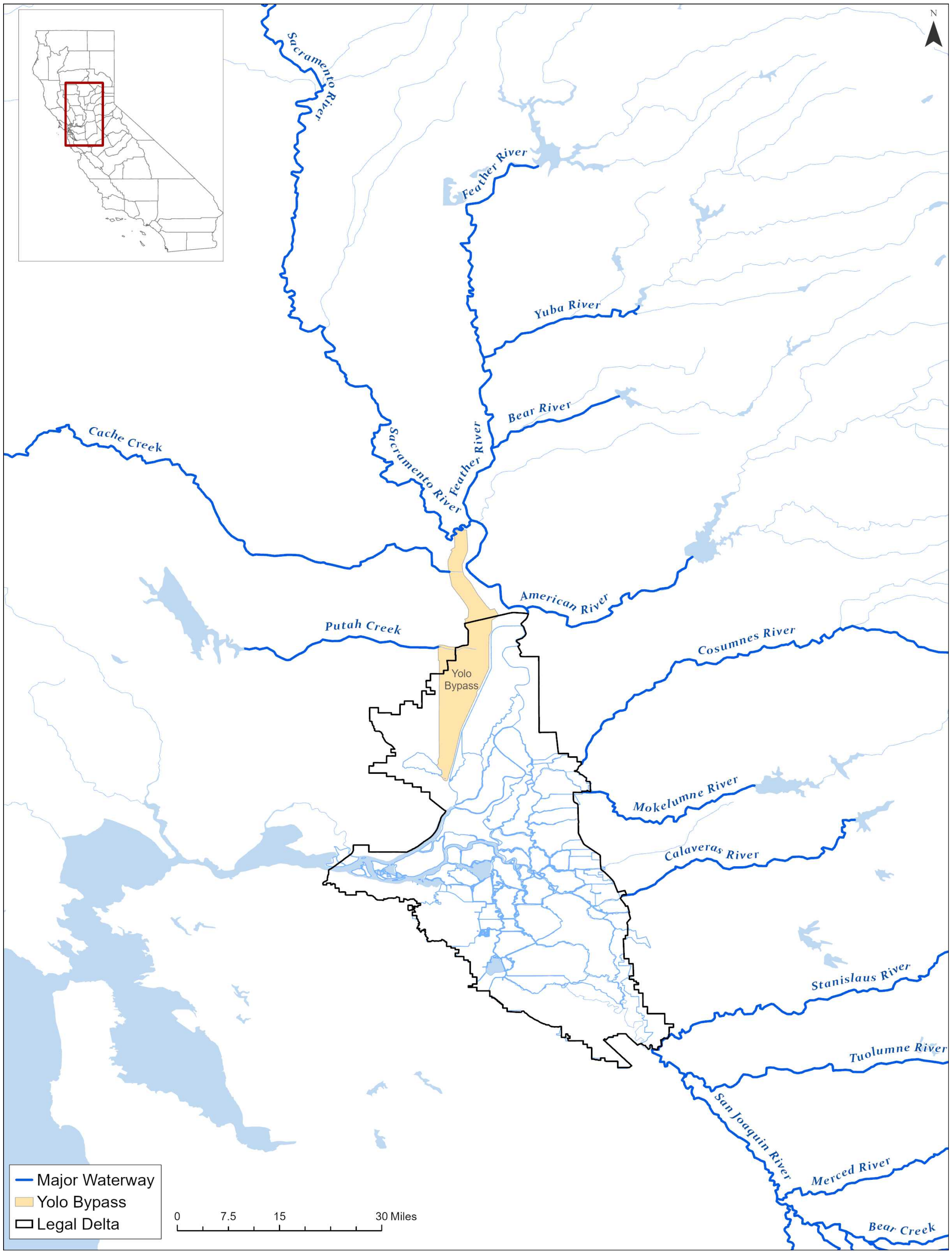
The Sacramento-San Joaquin Delta (Delta) is the largest estuary on the West Coast, consisting of 700 miles of sloughs and waterways. The major rivers that feed the system are the Sacramento, Mokelumne, Cosumnes, Calaveras, and San Joaquin rivers. Of these rivers only the Cosumnes flows into the Delta unobstructed by dams. The Delta receives the runoff from 40 percent (60,000 square miles) of California's land and is the hub of the State's two largest surface water delivery systems, the State Water Project and the federal Central Valley Project. During major flood events the Delta receives runoff from the Yolo Bypass, a 59,000-acre managed floodway that protects the city of Sacramento from floodwaters.

Since 1990, the Delta has been on the State Water Resources Control Board's list of impaired waters for mercury under section 303d of the Clean Water Act because of elevated fish tissue levels of mercury, which pose a risk for human and wildlife consumers. The sources of mercury contamination in the Delta and Yolo Bypass are complex; but, legacy mercury and gold mining within the watershed are considered large contributors to the mercury contamination observed in these areas today. Mercury was mined from naturally occurring deposits in California's Coast Range and was transported to the Sierra Nevada gold fields of the 1800s, where it was used to recover gold (Alpers and others 2005). In the gold fields, it is estimated that 10 million pounds of mercury was lost in placer mines, of which 80 percent to 90 percent were in the Sierra Nevada. In hardrock mines, where gold ore was crushed in stamp mills, approximately 3 million pounds of mercury was lost (Churchill 2000). The Feather River, as well as it's tributary watersheds (the Bear and the Yuba rivers) all drain areas associated with major legacy gold mining operations (Figure 1-1). The Sacramento River is the largest contributor of freshwater to the Delta system. During large storm events, it can also be the largest contributor of freshwater to the Yolo Bypass. Tributaries emptying into the Yolo Bypass also have their own source of legacy mercury contamination. For example, mercury mines are in the watershed of Cache Creek, which drains and empties into the Yolo Bypass via the Cache Creek Settling Basin (Cooke and Morris 2005).

Delta Mercury Control Program

Under the authority of the Clean Water Act and section 13240 of the Porter-Cologne Act, the California State Water Quality Control Board established a Sacramento/San Joaquin River Delta Total Maximum Daily Load (TMDL) and Delta Mercury Control Program as a result of Amendment No. R5-2010-0043 to the Water Quality Control Plan for the Sacramento and San Joaquin River Basins (Basin Plan). In November 2011, under the Delta Mercury Control Program (DMCP), the Central Valley Regional Water Quality Control Board (CVRWQCB) issued the California Department of Water Resources (DWR) a letter identifying DWR and several other State and federal agencies as causing or contributing to elevated levels of mercury (Hg) and/or methylmercury (MeHg) to the Delta or Yolo Bypass based on identified water and land use activities under each agency's jurisdiction. One source identified was open water which was defined in the DMCP as the MeHg load that fluxes to the water column from sediments in open water habitats within channels and floodplains in the Delta and Yolo Bypass (Central Valley Regional Water Quality Control Board 2011).

Figure 1-1 Overview of Major Waterbodies in the Yolo Bypass and Greater Delta



The legal Delta, and the Yolo Bypass when flooded, face significant MeHg contamination. As shown in Figure 1-2, large areas of the regulated area are out of compliance with the DMCP. Mandated reductions in MeHg from open water sediment flux for different regions of the Delta and the Yolo Bypass range from 0 percent to 82 percent (Table 1-1).

The DMCP lays out an implementation strategy for the control of MeHg and total unfiltered mercury (uHg). The regulation is designed to protect people eating one meal per week of trophic levels 3 and 4 Delta fish, plus some non-Delta (commercial market) fish (Central Valley Regional Water Quality Control Board 2011). As part of its implementation strategy, the DMCP requires regulated entities to conduct either control studies to evaluate existing (or new) control approaches to reducing MeHg, or characterization studies to provide information that could lead to new approaches to control MeHg. This report documents Department of Water Resources (DWR) scientific and modeling characterization studies and non-DWR Open Water Workgroup member's efforts to meet regulatory requirements associated with the open water portion of the DMCP.

Figure 1-2 Methylmercury Compliance Areas for the Delta Mercury Control Program

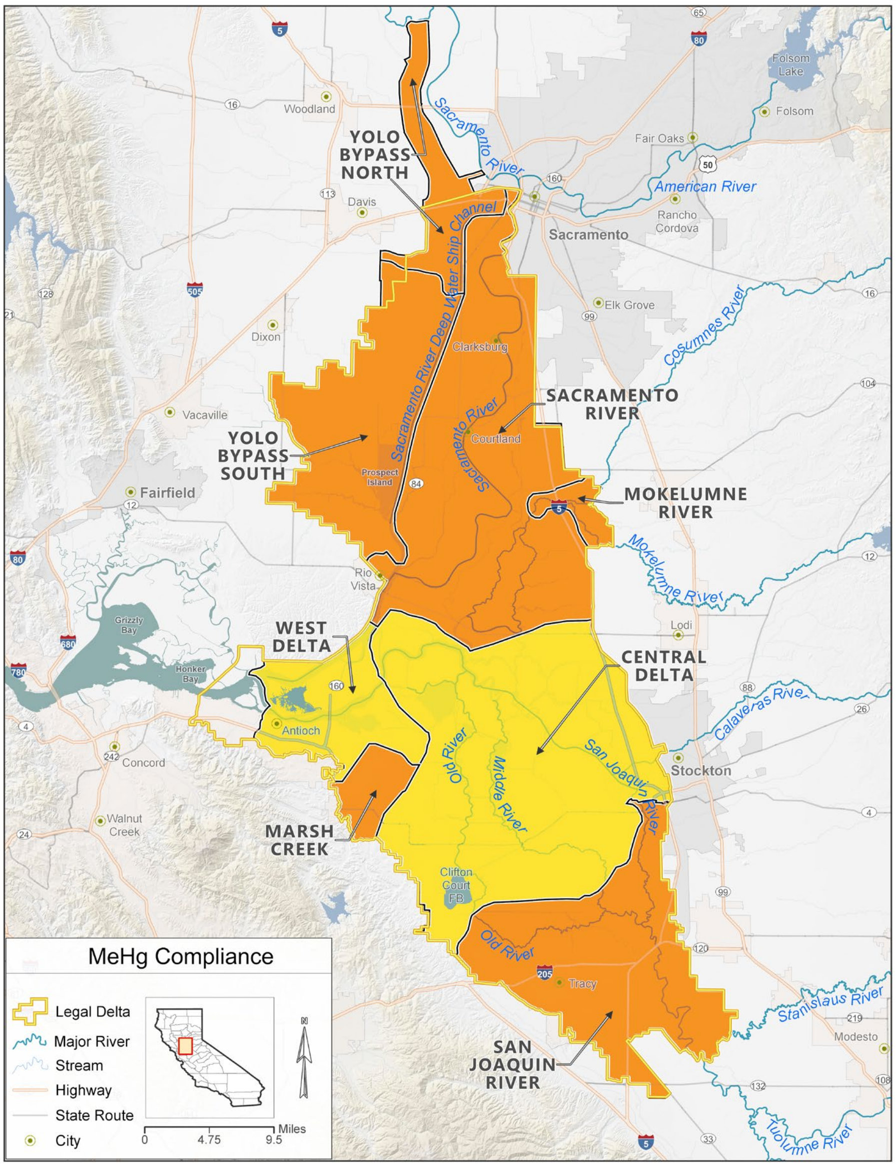


Table 1-1 Net Methylmercury Target Load Allocations (grams/year) and Necessary Percent Reductions to Meet Target Load Allocations for Open Water Areas of the Delta and Yolo Bypass

Open Water Area	Current Load	Allocation	Reduction
Central Delta	370	370	0%
Marsh Creek	0.18	0.03	82%
Mokelumne River	4.0	1.4	65%
Sacramento River	140	78	44%
San Joaquin River	48	17	65%
West Delta	190	190	0%
Yolo Bypass	100	22	78%

Note: Adapted from Table A, Attachment 1 to Resolution No. R5-2010-0043, (Central Valley Regional Water Quality Control Board 2011)

Overview of Activities

Open Water Workgroup

Affected stakeholders formed the Open Water Workgroup (Workgroup) to jointly address the open water portion of the Delta Mercury Control Program. Stakeholders consist of the State and federal agencies charged with reducing open water loads of MeHg. These agencies are: the State Lands Commission, DWR, the Central Valley Flood Protection Board, the U.S. Army Corps of Engineers and the U.S. Bureau of Reclamation.

In April 2013, the Workgroup submitted a workplan to the CVRWQCB. In response to comments a technical memo was submitted in October 2013. The technical memo revised originally proposed laboratory characterization studies to large-scale experimental ponds located in the Yolo Wildlife Area. In February 2014, the combined workplan and technical memo addendum was approved. The approved workplan and technical memo can be found in Technical Appendix A.

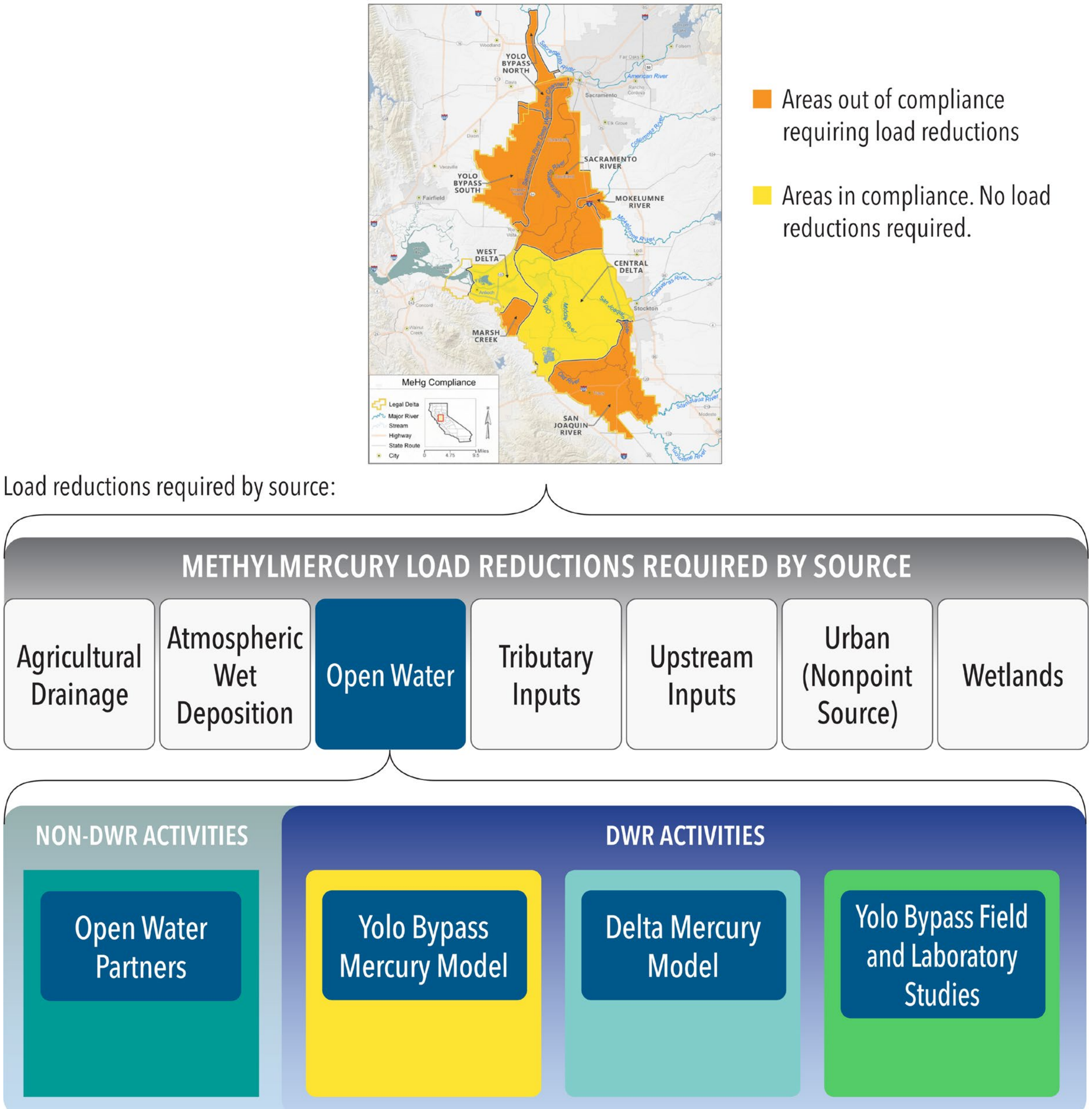
A characterization approach, as opposed to a control study, was approved because of the complexity of the system and the infeasibility of altering operations of the State and Central Valley Water Projects for control study purposes. The characterization studies consisted of field/technical studies and numerical modeling. Creation of an integrative model linking process-based studies, restoration activities, and monitoring was one long-term goal suggested by a panel of experts convened to advise the CALFED Bay-Delta Program on strategies and approaches to use to guide ecosystem restoration and management in the Hg contaminated Delta (Weiner and others 2003). DWR funded and led the technical and modeling studies summarized in the workplan/technical memo. Other Workgroup agencies focused on their areas of jurisdiction. Figure 1-3 provides an overview of how open water stakeholder activities fall within the overall DMCP regulation.

Open Water Characterization Studies

Field Characterization Studies

Models, in general, become more accurate and reliable when a significant abundance of data exists. Relative to the wealth of hydrodynamic and other water-quality data available for the Delta system,

Figure 1-3 Overview of the Open Water Workgroup Activities for Compliance with the Delta Mercury Control Program



relatively little mercury and MeHg data exists; even less data is available for the Yolo Bypass. For example, comparatively little filtered or particulate MeHg data was available for the Yolo Bypass, yet the Yolo Bypass is a net producer of MeHg and can provide as much as 40 percent of the MeHg exported from the Sacramento basin when the Fremont weir is spilling (Foe and others 2008). As a result, field studies were conducted in the Yolo Bypass to meet model data needs and provide information for possible future best management practices (BMPs).

DWR contracted with several different groups and agencies in order to create and adapt new modeling tools for the Yolo Bypass and Delta, and to conduct field and laboratory studies for the Yolo Bypass. The Open Water Mercury Technical Workgroup consisted of researchers from the Moss Landing Marine Laboratory, who provided laboratory analysis and mercury technical support; the Pacific Northwest National Laboratory, who provided mercury, metals, and statistical technical support; and the U.S. Geological Survey, who conducted erosional studies. DWR scientists with the Mercury, Monitoring, and Evaluation Section were responsible for most sample collection, execution of some experimental studies, and statistical support. The Open Water Mercury Modeling Workgroup consisted of Reed Harris Environmental, Ltd. who developed a mercury module for the Delta and adapted a mercury model for use in the Yolo Bypass; the US. Geological Survey, who used the Parameter Estimation (PEST++) software package to refine manual model calibrations and bound model uncertainty; and DWR modelers with the Bay Delta Office, who provided in-house development of the suspended sediment module, animation tools used to visualize modeled results, and support for the consultant's development of the mercury and bed sediment modules in Delta Simulation Model 2 (DSM2).

The research teams focused on several data gaps identified for the Yolo Bypass Hg model. Sediment erosion studies provided the model with erosion values for different land-uses, while sediment-water flux experiments provided the model with diffusive flux from sediments of different land uses. Soil samples were used to provide starting Hg and MeHg soil concentrations for the model. The largest land use in the Yolo Bypass is pasture. To address this major land use, vegetation senescence experiments were conducted, and a vegetation component was added to the model. These studies permitted development of possible approaches for a future BMP for pasture lands. Samples collected from import and export sites of the Yolo Bypass allowed mass balance calculations for the system and provided data on the relative contributions of total, filtered, and particulate analytes. This information was not used directly by the model (sampling occurred outside of the modeled time period), but it provided a valuable check on model patterns.

The relationship between field characterization studies and Yolo Bypass modeling efforts are shown in Figure 1-5, while Table 1-2 shows the relationship between the research teams, the data gap addressed, and the appendices containing the full study write-ups. These technical appendices provide in-depth details on study design, methodology, and in-depth analysis of results. Data including Quality Control will be provided to staff of the Central Valley Regional Water Quality Control Board (CVRWQB). DWR staff are also working on publishing data to the Environmental Data Initiative (EDI) data portal.

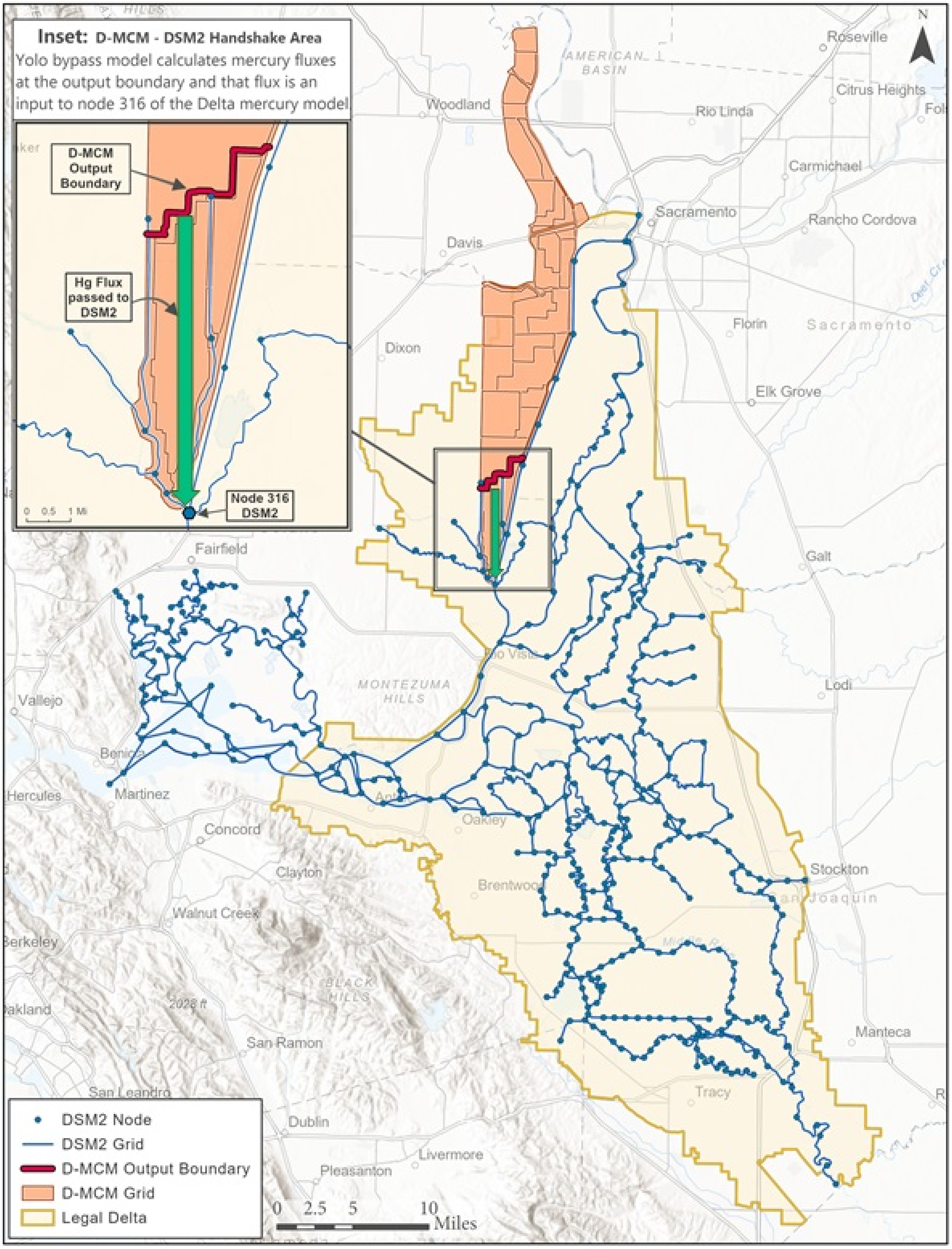
Finally, following workplan/technical memorandum approval, the scope and approach of some studies evolved over time. This included returning to smaller scale mesocosm and laboratory-based approaches for many experimental studies, when the use of experimental ponds proved unfeasible, and reducing the scope of some studies because of time, safety, and resource constraints. But, modifications to study design remained consistent with the approved workplan/technical memorandum. The CVRWQCB staff were kept apprised of all changes. Modifications to the workplan/technical memorandum were approved by the CVRWQCB and are summarized in Technical Appendix A.

Model Development

At the time of model construction, there was no single hydrodynamic numerical model unifying the Delta and Yolo Bypass. After an evaluation of available modeling tools, two Hg models were developed to characterize Hg dynamics in the Delta and Yolo Bypass. An existing proprietary mercury model, the Dynamic Mercury Cycling Model (D-MCM), was adapted for the Yolo Bypass (Electric Power Research Institute 2019). For the remainder of the Delta, mercury and sediment functions were added to DWR's DSM2, an existing, well-established 1-D model (California Department of Water Resources 2019), creating a final product known as DSM2-Hg. The full modeling domain of the two mercury models is shown in Figure 1-4.

For the Yolo Bypass model, following manual calibration, the PEST++ software package was used to fine-tune manual calibrations, optimize parameter estimates, and provide uncertainty analysis for sensitivity runs.

Figure 1-4 Domains for the Yolo Bypass D-MCM and Delta DSM2-Hg Models



Notes: D-MCM = Dynamic Mercury Cycling Model, DSM2 = Delta Simulation Model 2
Model used for the Delta was the DSM2-Hg model and for the Yolo Bypass, the D-MCM model was adapted to the Yolo Bypass (Yolo Bypass D-MCM).

Table 1-2 Relationship of Technical Studies to Yolo Bypass D-MCM Modelling Development

Study	Model Data Gap	Research Team	Technical Appendix
Mass balance loading study (Yolo Bypass	Used as a check on model results and expanded upon CALFED mass load work by including collection of filter Hg and MeHg as well as samples collected below Liberty Island.	DWR	B
Sediment-water flux	Addressed Hg and MeHg flux from sediments of different land uses.	MLML	C
Gust chamber	Addressed soil erosion of different land uses under different flow velocities.	USGS	D
Vegetation Senescence	Addressed possible vegetation impacts associated with the largest actively managed land use and investigated possible BMPs.	DWR MLML	E & E1
Spatial soil sampling for mercury	Supplemented previous work (Heim and others 2010) to extend the spatial coverage of Hg and MeHg in soils of different land uses.	MLML DWR	F

Notes: BMPs = best management practices, CALFED = CALFED Bay-Delta Program, D-MCM = Dynamic Mercury Cycling Model, DWR = California Department of Water Resources, Hg = mercury, MeHg = methylmercury, MLML = Moss Landing Marine Laboratories, USGS = U.S. Geological Survey

Yolo Bypass Mercury Model Development

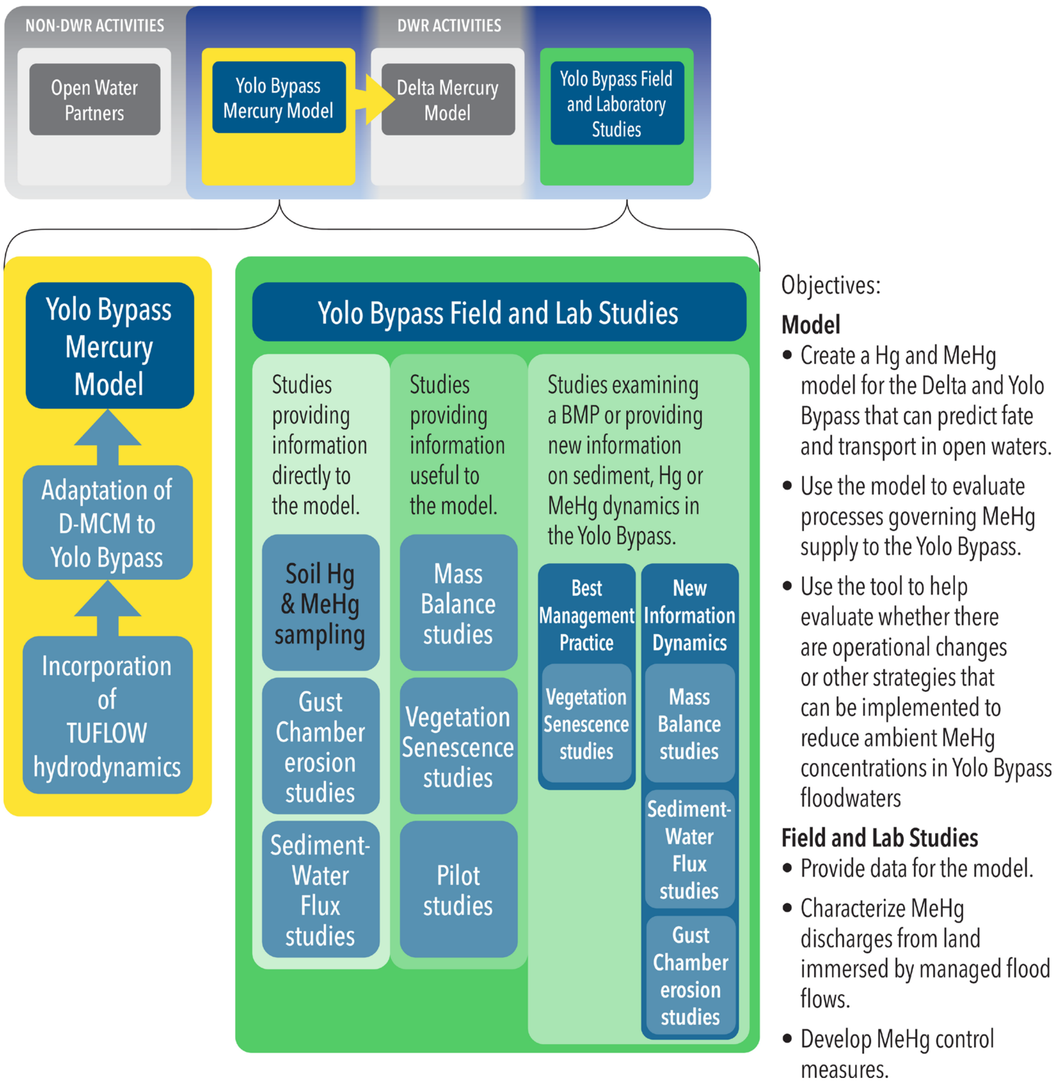
The objectives of the Yolo Bypass Dynamic Mercury Cycling Model (Yolo Bypass D-MCM) were to:

- Create a Hg and MeHg model for the Yolo Bypass that can predict fate and transport in the Yolo Bypass.
- Use the model to evaluate processes governing MeHg supply to the Yolo Bypass.
- Use the model to help evaluate whether there are operational changes or other strategies that can be implemented to reduce ambient MeHg concentrations in Yolo Bypass floodwaters.

The D-MCM v.4.0 is a proprietary Windows-based simulation model for personal computers and has been used to model Hg and MeHg biogeochemical cycling and bioaccumulation in a number of ecosystems including the Gulf of Mexico (Harris and others 2012). The model is a time dependent, mechanistic mass balance model for Hg cycling and bioaccumulation and is an extension of the D-MCM published by Hudson and others (1994). It simulates the cycling and fate of three major forms of mercury (methylmercury, inorganic Hg (II), and elemental mercury in aquatic systems. It is capable of simulating mercury for a wide range of 1-D to 3-D situations. Model compartments include one or more layers in the water column and sediments, macrophytes (where relevant), and a food web defined by the user. The regulation required evaluation of open water sediment-water flux, as a result, only the sediment and water compartments of the model were used.

The D-MCM was adapted to the Yolo Bypass by creating a coarse resolution grid consisting of 47 cells defining the top eight land uses in the Yolo Bypass. Based on Hg and MeHg data availability, the period modeled was from October 1996 to May 2012. Hydrodynamics were provided by coupling the Yolo Bypass D-MCM to a TUFLOW hydrodynamic model developed to simulate flows for a separate DWR /USBR project in the Yolo Bypass (DOI/DWR, 2019). Outputs from the Yolo Bypass model at the downstream end of the domain provided boundary inputs for the Delta model (Figure 1-4). Figure 1-5 summarizes the different modeling components required to build the Yolo Bypass D-MCM. Technical Appendix G provides in-depth details on model assumptions and manual calibration results. Technical Appendix H provides details on the use of PEST++ for model calibration and sensitivity results. While D-MCM is a proprietary model the approach to mercury cycling in D-MCM has been published (Harris and others, 2012, Hudson and others, 1994). In addition to information in Technical Appendix G, any model input and output information, which is not proprietary are available on request.

Figure 1-5 Components Associated with the Adaptation of the D-MCM Model to the Yolo Bypass Including the Relationship Between the Model and Field/Lab Studies



Notes: BMP = best management practice, D-MCM = Dynamic Mercury Cycling Model, DWR = California Department of Water Resources, Hg = mercury, MeHg = methylmercury

Delta Mercury Model Development

The Delta was modelled by integrating mercury and methylmercury production biogeochemistry into DWR's Delta Simulation Model 2-Mercury Model (DSM2-Hg). DSM2 also provided the hydrodynamics for the Delta. The DSM2-Hg model was created by adding equations for bed sediment, suspended sediment, and mercury as modules to DSM2. Yolo Bypass boundary fluxes from the Yolo Bypass D-MCM served as the Yolo Bypass input to DSM2-Hg (Figure 1-6).

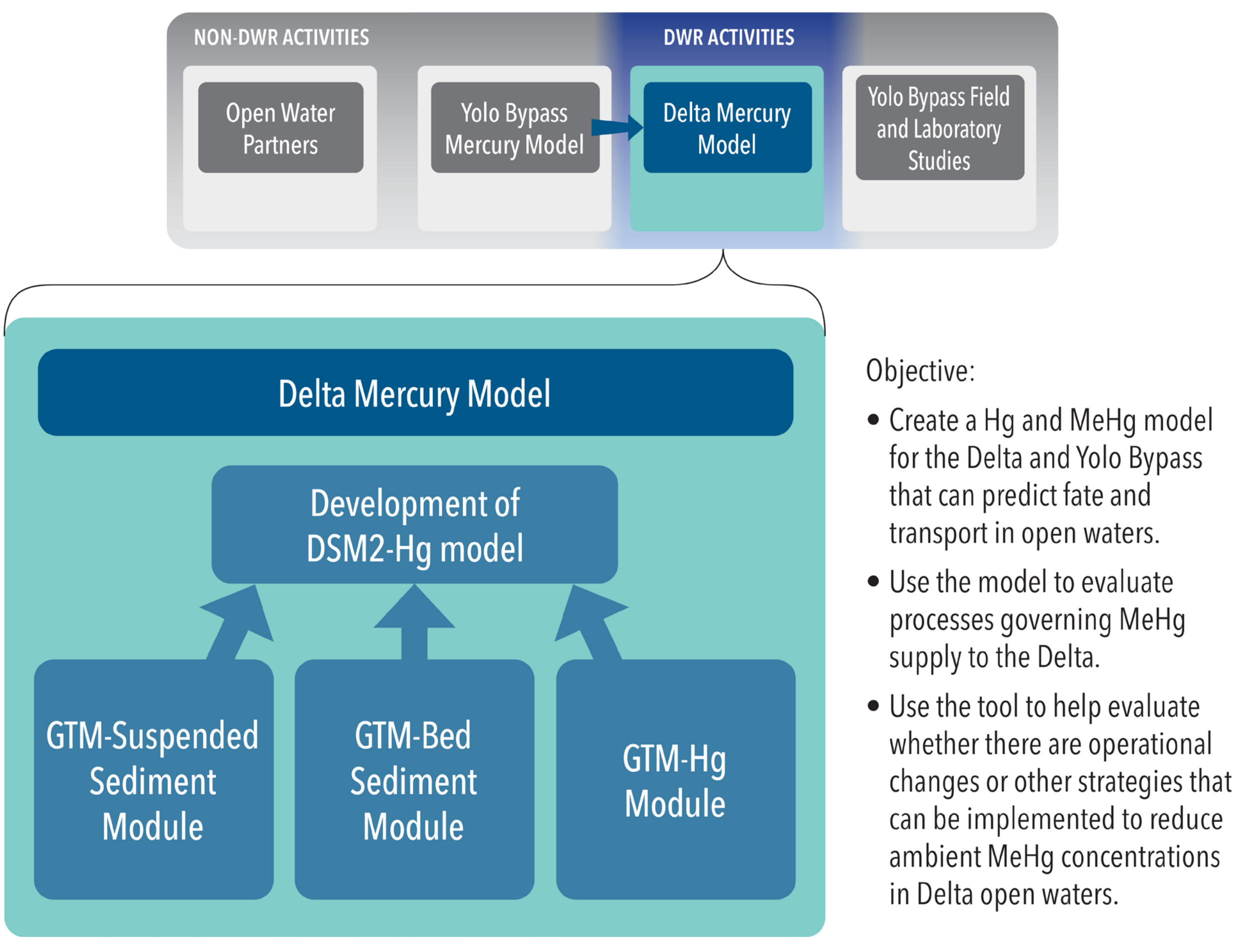
The objectives of the DSM2-Hg model were to:

- Create a Hg and MeHg model for the larger Delta that can simulate fate and transport in the larger Delta system.

- Use the model to evaluate processes governing MeHg supply to the larger Delta.
- Use the model to help evaluate whether there are operational changes or other strategies that can be implemented to reduce ambient MeHg concentrations in the open waters of the larger Delta.

Figure 1-6 summarizes the different modules that were added to the DSM2 model. Similar to the Yolo Bypass D-MCM, the DSM2-Hg model simulates the cycling and fate of three major forms of mercury (methylmercury, inorganic mercury [II], and elemental mercury) in the water column. Tributary inputs and atmospheric deposition were inputted into the model which, in turn calculated open water sediment flux, photodegradation and water column concentrations. This effort provided the basic framework for mercury modeling. Based on the regulatory definition of the source of open water flux, the model focused on flux from the sediments and concentrations and loads of MeHg in the water. Technical Appendices I and J provide in-depth details on data sources, model assumptions, and calibration results for the mercury model and bed and suspended sediment models. When packaged for public release, DWR will publish model source code, executable files, and other information on the DSM2 website (DWR, 2020).

Figure 1-6 Components Associated with the Development of the DSM2-Hg Model.



Notes: DSM2 = Delta Simulation Model 2, DWR = California Department of Water Resources, GTM = general transport model, Hg = mercury, MeHg = methylmercury

Workplan/Technical Memo Objectives and Hypotheses

Objectives

The four approved objectives as outlined in the workplan and the approach used to address each objective is summarized below.

1. Provide working models for Hg and MeHg supply, transport, and fate in the open waters of the Delta and Yolo Bypass.
   A. Objective 1 was addressed by creating Hg and MeHg models for the Delta and Yolo Bypass which provided a foundational platform for future mercury modeling improvements and questions. The models were calibrated manually and with PEST++ (Yolo Bypass D-MCM only) and can be used for sensitivity analyses and exploring hypotheses and scenarios. Creating the mercury model for the Delta included creating models for suspended sediment and bed sediment, which are also valuable tools for understanding sediment transport in the Delta.
2. Apply the models to identify processes governing MeHg supply to the Delta and Yolo Bypass.
   A. Objective 2 was addressed by conducting sensitivity runs with the Yolo Bypass D-MCM which helped identify key processes affecting MeHg supply. Sensitivity runs consist of holding all parameters constant, except the parameter of interest, and adjusting its contribution to determine its effects on MeHg production and transport. Discussion between DWR and CVRWQCB staff resulted in a suite of agreed upon sensitivity runs for the Yolo Bypass D-MCM. This approach allowed DWR to ask hypothesis-driven questions to examine which processes or inputs had the biggest impacts on modeled MeHg production. These hypothesis driven questions are listed in Table 1-3. As discussed, and approved by the CVRWQCB, sensitivity runs were not conducted for the DSM2-Hg model (Technical Appendix A).
3. Apply the models to examine the potential impacts of proposed operational changes in water management and flood conveyance in the Delta and Yolo Bypass on MeHg supply and compare to the total maximum daily load allocations.
   A. Objective 3 was met by conducting sensitivity runs. Sensitivity runs provided insights into how operational changes might affect MeHg production. For example, sensitivity runs adjusting MeHg outputs from the Cache Creek Settling Basin provides information on how MeHg outputs might change if operational modifications were made to the basin. Adjusting the amount of MeHg leaving the Yolo Bypass provides clues on the overall MeHg response to the Delta. Because of resource, time, and technical constraints, forecast scenarios proposed in the workplan were not conducted for the Yolo Bypass or the Delta. All changes were approved by the CVRWQCB (Technical Appendix A).
4. Use existing data to the extent possible, supplemented as needed, to meet Objectives 2 and 3. This includes collecting sample data in the Yolo Bypass and the laboratory to elucidate fundamental MeHg processes under flooding events.
   A. Objective 4 was addressed through field and laboratory studies. At the time of workplan approval, little MeHg data existed for the Yolo Bypass, relative to the Delta. As shown in

Figure 1-5, and discussed previously, field studies were conducted in the Yolo Bypass to provide data for the model so that modeling requirements could be met for Objective 2.

As discussed in the workplan/technical memo, field and laboratory studies were primarily conducted to provide needed information for the model. The mass balance, sediment-water flux, and Gust Chamber studies were not hypothesis driven. They either provided necessary data for identified model data gaps or were used by modelers as a check on observed modeling patterns. In the case of vegetation senescence experiments, study results filled an identified data gap in the model and were also hypothesis driven. Objectives for these studies are provided below.

B. **Mass-balance study**: (1) Quantify input, output, and net loads of unfiltered MeHg, uHg, and suspended particles during mini-flood events and periods of time when the bypass is flooded, (2) investigate the possible sources that contribute to within-bypass production of MeHg during floods, including evaluating filtered vs. particulate loads and correlations with ancillary parameters, and (3) evaluate load contributions from the east and west sides of the Yolo Bypass. In addition, the data from this study was used to validate results from the Yolo Bypass D-MCM developed by consultants for DWR. As discussed, and approved by the CVRWQCB, not all monitoring could be conducted due to lack of flooding and safety concerns (Technical Appendix A).

- **Sediment-water flux study**: (1) Provide flux rates, for filtered MeHg and Hg, for land use types found within the Yolo Bypass, and, (2) provide data useful to setting up and calibrating the D-MCM.
- **Gust Chamber study**: Quantify the erodibility of surface soils associated with different land uses modeled in the Yolo Bypass D-MCM model.
- **Vegetation senescence study**: (1) Address the role of vegetation in the internal production and cycling of MeHg in the Yolo Bypass, (2) conduct pilot experiments to test and validate methodologies for the larger scale studies, to help fill data gaps for the Yolo Bypass modelling effort, and, (3) develop information that could be used to help develop BMPs to reduce the production of MeHg and export loads from the upper reach of the Yolo Bypass.

Hypotheses

Sections 2.2.1 and 2.2.2 of the workplan lists suggested hypotheses to be addressed by the MeHg models. Based on feedback from the technical advisory committee, the technical memo refined these hypotheses. Within this framework, the CVRWQCB listed a number of questions in the technical memo. Based on the original hypotheses and questions listed in the workplan and technical memo, DWR and the CVRWQCB staff prioritized questions to create a final set of Yolo Bypass and Delta sensitivity analyses to examine drivers of interest but stay within the timeline and modeling constraints. Table 1-3 lists the sensitivity investigations associated with the Yolo Bypass D-MCM model. While not framed as hypotheses, the questions lead to logical hypotheses and modeled results associated with each question. As discussed with the CVRWQCB, time constraints prevented sensitivity runs for the Delta.

In the case of vegetation senescence experiments, there were both pilot-study and full-study hypotheses to help understand possible BMPs. Study results filled an identified data gap in the model and were also hypothesis driven.

The hypotheses tested in vegetation senescence pilot studies included:

- Plants are a more significant contributor to methylmercury production (release to overlying water) than sediments alone (without plants).
- Irrigated and non-irrigated pastures release different amounts of MeHg to overlying water.
- The duration of the senescence period is important to understanding the timing of the release or production of MeHg from the plant material. A lag period is likely to occur after a flood event before significant release or production is observed.
- Aeration of overlying water affects the release of MeHg to overlying water.

The hypotheses tested in vegetation senescence studies conducted in 2017, 2018, and 2019 were:

- Grazing land will lower MeHg releases to overlying flood water.
- Disking land will lower MeHg releases to overlying flood water.
- More vegetation results in more MeHg releases to overlying flood water.

Table 1-3 Sensitivity Questions Addressed by the D-MCM Yolo Bypass Model

Category	Parameter
Particle Related	Investigate sensitivity of simulated MeHg to changes in suspended sediment inputs to the Yolo Bypass. Begin by varying suspended sediment concentrations from the Cache Creek Settling Basin (CCSB).
External Inorganic Hg Loads	Investigate sensitivity of simulated MeHg to changes in inorganic Hg inputs from tributaries to the Yolo Bypass. Begin by varying CCSB inorganic Hg concentrations to the Yolo Bypass. Investigate sensitivity of simulated MeHg to changes in atmospheric inputs.
External MeHg Loads	Investigate sensitivity of simulated MeHg to changes in MeHg inputs from tributaries to the Yolo Bypass. Begin by varying CCSB MeHg concentrations to the Yolo Bypass.
Internal MeHg Loads	Investigate sensitivity of simulated MeHg to the rate of MeHg supply generated within the Yolo Bypass.
Influence of Vegetation	Investigate sensitivity of simulated MeHg to vegetation effects in the Yolo Bypass. Begin by reducing pasture or seasonal wet-land vegetated areas in the model.

Notes: D-MCM = Dynamic Mercury Cycling Model, Hg = mercury, MeHg = methylmercury

Report Organization

The open water final report consists of two stand-alone pieces. The first part of the report consists of an executive summary and 7 chapters. The second part consists of 12 technical appendices. The technical appendices provide additional in-depth, supporting material. The field and laboratory appendices include methods, sampling locations, statistical analyses, and quality assurance/quality control. The modeling appendices include model documentation, calibration, validation, and sensitivity runs.

Chapter 1 provides a high-level summary of the requirements and processes leading to the final products and orients the reader to the organization of the report.

Chapter 2 summarizes the actions undertaken by non-DWR Open Water Workgroup members, who, to the extent allowable by their regulatory authority, were required to direct project applicants, grantees, and loan recipients to apply to or consult with the CVRWQCB to ensure full compliance with the DMCP.

Chapters 3 summarizes technical results from scientific studies conducted in the Yolo Bypass. Technical appendices that support this chapter are: Technical Appendices A, B, C, D, D, E, E1 and F.

Chapter 4 summarizes modeling results for the Yolo Bypass. Technical appendices supporting this chapter are Technical Appendices G and H.

Chapter 5 summarizes findings associated with the development of a manually calibrated Delta Mercury Model. Technical appendices supporting this chapter are: Technical Appendices I and J

Chapter 6 provides information on the possible impacts associated with climate change and methylation factors in the Yolo Bypass and the Delta.

In Chapter 7, the report concludes with the possible management implications associated with the experimental and modeling results.

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