An Overview of the Creation of Mercury Models for the Delta and Yolo Bypass: Linking Modeling and Delta Regulatory Decisions

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This poster provides an overview of the effort underway to develop a biogeochemical model of mercury (Hg) and methylmercury (MeHg) cycling for the Delta and Yolo Bypass with input from field and laboratory studies. This effort fulfills the Phase 1 Delta Mercury Control Program requirements for open waters. Regulated entities (collectively known as the open water group, led by the Department of Water Resources) must evaluate whether operational changes or other strategies could be implemented to reduce open water MeHg production. Because the hydrodynamic and environmental settings are so complex, scenario modeling of trends provides a mechanism to understand how operational activities might impact MeHg production throughout the open water channels of the Delta and the Bypass when flooded.

For the Delta, DWR's DSM2 hydrodynamic model is being updated and expanded to include Hg biogeochemistry and sediment transport modules (bed and suspended). DSM2 is a widely used model of Delta flows and water quality. In the Bypass, the Dynamic Mercury Cycling Model (D-MCM) is being used. D-MCM models Hg biogeochemical processes; hydrodynamics are being provided from TUFLOW

Field and laboratory experiments focus on filling data gaps in the Bypass needed by the D-MCM. Erosion microcosm measurements are providing estimates of sediment erodibility associated with common land uses in the Bypass. Flux experiments will provide calibration data of advective and diffusive fluxes of Hg/MeHg between sediment and overlying water. Water samples collected during flood events from the major inlets and outlets of the Bypass will provide loading and mass balance estimates. A vegetation senescence experiment is examining the role of decaying vegetation, overlain by floodwaters, on MeHg production. The loading flux of tidal wetlands is being provided by measurements of Hg/MeHg flux from several tidal wetlands. Preliminary results of modeling and data efforts are shown in posters associated with this cluster.

Keywords: Overview, Mercury, Modeling, Delta, Yolo Bypass

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Modeling Mercury in the Yolo Bypass, a Mercury-Contaminated Floodplain

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The California Bay-Delta region is impacted by ongoing mercury contamination from historical mining. Microbial activity in downstream aquatic environments can convert the inorganic mercury supplied by legacy mining to methylmercury, the most toxic and readily bioaccumulated form of mercury. To protect human and wildlife health, the Delta Mercury Control Program was adopted for methylmercury in 2011. A mechanistic model of mercury cycling (D-MCM) is being applied to the Yolo Bypass, California to identify options to reduce methylmercury supply and meet regulatory requirements. The Yolo Bypass is a 24,000 ha floodplain used for flood control for the Sacramento River, and is a source of water to the Bay-Delta region. The Yolo Bypass is used for a variety of farming and wetland management purposes, and experiences seasonal wetting and drying cycles. These features present unique challenges for modeling rates of methylmercury supply. Model inputs are constructed from a combination of field data, site experiments, and literature. Additional posters in this section describe ongoing studies providing data for the model. Flow depths, velocities and discharges were provided by TUFLOW, a 1D/2D hydrodynamic model. Soil/sediment resuspension rates are estimated by combining hydrodynamic predictions with USGS erosion microcosm measurements of resuspension rates for a range of flow and land use conditions. Mercury loading estimates are being provided by the California Department of Water Resources (DWR). Water column and sediment/soil concentrations of total and methylmercury are being measured by DWR and the Moss Landing Marine Laboratory (MLML). Pore water mercury fluxes and the effects of vegetation senescence on methylmercury production are also being studied experimentally by MLML to provide information for modeling. Model calibration to existing conditions is ongoing. Results will be presented in the poster.

Keywords: Modeling, Methylmercury, Yolo Bypass

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Progress on Extending a Delta Model to Include Mercury and Sediment

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A Delta mercury and sediment transport model is being developed to support decision making related to recent Delta methylmercury Total Maximum Daily Load (TMDL) requirements. Methylmercury is the form of mercury that bioaccumulates in the food web. Since mercury is a neurotoxin, eating mercury-laden fish can cause developmental and other health issues. Mercury enters the Sacramento-San Joaquin Delta from both natural sources and legacy sources from historical mining. The Department of Water Resources and consultants from Reed Harris Environmental have teamed up to extend an existing flow and water quality model, the Delta Simulation Model 2 (DSM2), to include suspended sediment, bed sediment and mercury cycling. In order to extend DSM2, the water quality module was replaced with a new General Transport Model (GTM) that is designed to include all of the current water quality parameters simulated in DSM2 and also to allow expansion for additional water quality constituents such as mercury and sediment. Available field data are being evaluated for use in model calibration, validation and application. The goal of the Delta mercury and sediment model is to examine how changes in operation and configuration of the Delta might impact the potential to methylate mercury. This poster will highlight model development and calibration, challenges, and future directions.

Keywords: Mercury, Suspended Sediment, Bed Sediment, Modeling, Delta

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Erodibility of Yolo Bypass Sediments as a Mercury Vector

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The Yolo Bypass serves as a floodway to help protect the city of Sacramento from flooding. When not utilized for this purpose, it serves as a heavily utilized agricultural area, particularly for rice cultivation. Mercury methylation during flooding is a management concern.

Floods can yield velocities sufficient to mobilize sediments. Efforts underway to simulate the fate of mercury within the Yolo Bypass include the key process of sediment transport. Estimates of erodibility are required as input to this model.

The work shown here involved the extraction of sediment cores at 9 locations within the Yolo Bypass, spanning a variety of land uses and crops, and immediately placing the cores within an erosion microcosm. A spinning disk applies shear stress to the water above the core, and this stress is transferred to the sediment column below. With sufficiently high stresses, the sediment is eroded. The turbidity of flow through the microcosm increases and is recorded and later converted to suspended sediment concentration (SSC). The end result is a time series of shear stress and SSC as functions of time. Critical shear stress can be determined, as well as relationships between shear stress and erosion rate, and erosion rate vs. depth into the soil column. Land maintained as disked and undisked wetland was found to have slightly higher erodibility than land used for wild and white rice cultivation. Erosion functions are provided to a numerical model of mercury (Amos et al. 2016 DSC abstract).

Keywords: Sediment transport, Yolo Bypass, Mercury

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Sediment – Water Exchange of Inorganic and Methyl Mercury in the Yolo Bypass

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Production of MeHg is generally accepted to be mediated by sulfate-reducing bacteria, hence, there are a number of environmental variables (organic carbon, sulfate, oxygen) and conditions (temperature, porosity, soil type) that could influence the net production of MeHg and its ultimate release into the water column. This study investigated sediment-water exchange of mercury species from a wide range of habitat types on the Yolo Bypass. Two methods were used to determine sediment-water exchange; first a direct assessment using incubated cores and second, modeling the sediment-water exchange from measurements of interstitial pore water concentration gradients. Results indicate habitat type and land use influence mercury fluxes from sediment in the Yolo Bypass. These results provide calibration data to the Dynamic Mercury Cycling Model (D-MCM) which will be used to improve our understanding of factors controlling production and transport of Hg and MeHg in the Yolo Bypass.

Keywords: mercury, methylmercury, wetlands, modeling, flux, Yolo Bypass, sediment

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Methyl Mercury Production from Senescence Vegetation During Flooding in the Yolo Bypass

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To provide needed data for the Yolo Bypass Dynamic Mercury Cycling Model, a series of inter-related studies are being conducted. The objective of this study is to evaluate the flux of MeHg from plants, when inundated by floodwaters, to assess their importance to the overall mass balance of MeHg in the Yolo Bypass (YB)B.

We estimate that plant biomass associated with non-irrigated pasture in the YB could be several hundred million kgs. If inundated, this is the largest land-use in the YB that could be covered by floodwaters. However, the impacts of senescing vegetation to MeHg production is unknown. Previous field and laboratory studies by Moss Landing Marine Laboratories have documented high concentrations of MeHg (over 10 ng/L in some cases) are released when dried plant material is inundated with water. To test whether MeHg from pasture lands have the potential to contribute to the overall MeHg mass balance in the YB, a pilot study was conducted in the Yolo Bypass to determine the mass of MeHg released. Replicate, 4 inch cores were collected from dryland pasture. In the laboratory, vegetation was dried and the cores were overlain with Sacramento River water. Three of the cores were gently aerated, while 3 were not. All cores were incubated for 2 weeks. Non-aerated cores with sediment and vegetation released the most MeHg. Aerated cores with sediment and vegetation produced less MeHg than the non-aerated cores. The sediment only cores produced the lowest MeHg by far whether aerated or not. A continuous record of oxygen measurements was also taken in pasture lands in the YB during a flood in February. Depressions of oxygen occurred during the flooding events.

These results suggest that senescent vegetation may be an overlooked contributor to MeHg loads associated with flooding of the YB.

Keywords: Methyl Mercury, Vegetation, Flooding, Yolo Bypass

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Mercury and Methylmercury Mass Balance Estimates of the Yolo Bypass during Flooding Events

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In response to regulatory requirements, consultants for the Department of Water Resources (DWR) are developing the Dynamic Mercury Cycling Model (D-MCM) to simulate methylmercury (MeHg) cycling and transport within the Yolo Bypass floodplain. Reliable total mercury (THg) and MeHg loads at the inputs and outputs of the Yolo Bypass are necessary to calibrate the D-MCM model. Foe and others (2008) quantified input and output loads for the Bypass, but they only collected whole-water samples for THg and MeHg. Understanding the amount of mercury in the particulate phase versus the amount in the dissolved phase provides greater insights into the sources of MeHg production. To fill this data gap for the D-MCM model, DWR is collecting data to quantify particulate and dissolved THg and MeHg loads at the inputs and outputs of the Yolo Bypass during times when the Bypass floods.

During the study period of 2013-2016, California has been in a historic drought, and the Yolo Bypass has flooded twice: a small flood in December 2014 and a large-scale flood in March 2016. DWR conducted one water sampling event during each of these two floods. Water samples were analyzed for filtered and total THg and MeHg, as well as for various ancillary parameters. During the December 2014 sampling event, the Bypass was a net source of THg (44.6 g/day) and MeHg (2.7 g/day). The greatest increase in total MeHg loads occurred between I-80 and Lisbon. The Bypass was a net source of THg entirely due to its particulate fraction, while it was a source of MeHg due to relatively equal contributions from the particulate and filtered phases. This suggests that the observed MeHg production was likely the result of a combination of processes, including sediment resuspension and diffusion from sediments, with some being more important than others.

Keywords: Mercury, Methylmercury, Loads, Yolo Bypass, Modeling, Water Quality, Flooding, Delta

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Methylmercury Imports and Exports of a Freshwater Tidal Wetland in the Yolo Bypass

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Mercury and methylmercury (MeHg) are contaminants of concern in the Sacramento-San Joaquin Delta (Delta). The Department of Water Resources (DWR) is currently doing a study of four freshwater and brackish water tidal wetlands to determine total mercury (THg) and MeHg loads, in addition to loads of other relevant constituents such as total suspended solids and organic carbon. These loads will be used for two main purposes for compliance with the Delta Mercury Control Program, promulgated by the Central Valley Regional Water Quality Board; first, the loads will be used as a boundary condition for the DWR Mercury Model for the Delta and Yolo Bypass; and second the loads will be used to characterize imports and exports of THg and MeHg of tidal wetlands in the Delta and Yolo Bypass.

DWR began the study in May 2014, and completed a one-year load study of a freshwater tidal wetland in the Yolo Bypass. Staff collected samples for flood and ebb tides of 10 tidal cycles, monthly during the warm months and bimonthly during the cold months. DWR is continuing to study additional wetlands and will through 2018.

The preliminary data at the tidal wetland in the Yolo Bypass indicate that the tidal wetland was always a sink for water, and generally a sink for THg and MeHg. THg and MeHg flood and ebb concentrations were not significantly different ($p > 0.05$ for both). Filtered MeHg and dissolved organic carbon were not correlated, although total suspended solids were correlated with both particulate THg and MeHg. The dissolved THg was usually a small portion of the total THg, whereas the dissolved MeHg was a more variable fraction of the total MeHg concentration.

Keywords: Mercury, Methylmercury, Yolo Bypass, Tidal Wetlands, Sacramento San-Joaquin Delta, Loads

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