



# Modeling Quality Assurance Project Plan for the Snake River Mercury TMDL

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# Table of Contents

Table of Contents.....	4
List of tables.....	6
List of figures.....	6
Abbreviations .....	7
1. Introduction.....	8
2. Problem definition and management objectives.....	12
3. Conceptual model: Key processes and variables.....	13
3.1 Overview of mercury cycling.....	13
4. Technical approach .....	15
4.1 Overview.....	15
4.2 Model selection.....	15
4.3 Software development quality assessment .....	17
5. Model development .....	17
5.1 Model boundaries .....	17
5.2 Spatial and temporal resolution .....	19
5.3 Source characteristics .....	20
5.4 Data availability and quality .....	24
5.5 Time frame of simulation .....	26
5.6 Data gaps .....	27
5.7 Assumptions.....	30
5.8 Model calibration .....	30
5.9 Model parameters.....	31
5.9.1 CE-QUAL-W2.....	31
5.9.2 FweB4.....	36
6. Model evaluation and acceptance .....	37
6.1 Model uncertainty and sensitivity.....	37
6.2 Model acceptance .....	38
7. Documentation in model reports.....	39
8. Peer review.....	39
9. Management scenarios .....	40
9.1 Existing conditions.....	40
9.2 Critical conditions .....	40

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9.3	Identify load targets .....	40
9.4	Reductions in point sources .....	41
9.5	Reductions in loadings from Oregon tributaries .....	41
9.6	Reductions in nonpoint loadings directly to riverine and reservoir assessment units... 41	
9.7	Reductions in background sources .....	41
9.8	Reduction of methylmercury originating from riverine assessment units.....	42
9.9	Reduction of methylmercury originating from reservoir assessment units .....	42
9.10	Management of aquatic food webs.....	42
9.11	Attainment scenarios .....	43
10.	Project organization .....	43
10.1	Project team/roles.....	43
10.2	Expertise and special training requirements.....	48
10.3	Reports to management .....	48
10.4	Project schedule .....	48
10.5	Data management.....	49
10.6	Recordkeeping, archiving, and records retention .....	50
10.7	QAPP review and approval .....	50
10.8	Implementation and adaptive management .....	50
11.	References .....	51
12.	Appendix A .....	54
13.	Appendix B .....	55

## List of tables

Table 1. Listing categories for methylmercury (MeHg) human health criterion and total mercury (THg) aquatic life criteria in Snake River assessment units (AUs) from the 2022 Oregon Integrated Report (“Department of Environmental Quality : EPA Approved Integrated Report : Water Quality : State of Oregon,” n.d.).....	11
Table 2. Major tributaries entering directly into the riverine and reservoir assessment units of the Snake River on the Oregon/Idaho border. GNIS_ID refers to the USGS Geographic Name Information System ID. AU refers to assessment unit ID used in Oregon's Integrated Report...	19
Table 3. Permitted NPDES point sources discharging directly into the Snake River from river mile 409 to 176 on the Oregon-Idaho border. NPDES = National Pollution Discharge Elimination System; MGD = Million Gallons per Day; WWTP = Wastewater Treatment Plant.....	24
Table 4. Data available for use in model development, calibration, and evaluation in the Snake River Mercury TMDL.....	24
Table 5. Methods that may be used to fill data gaps during model development, testing, and calibration of models for the Snake River Mercury TMDL. ....	27
Table 6. Constituents and constituent interactions in the CE-QUAL-W2 model to be used for the Snake River Mercury TMDL.....	31
Table 7. The Roles and responsibilities of team members involved in the Snake River Mercury TMDL. ....	43
Table 8. The Roles and responsibilities technical collaborators involved in the Snake River Mercury TMDL modeling.....	47
Table 9. Project milestones and estimated schedule for the Snake River Mercury TMDL .....	48

## List of figures

Figure 1. Assessment units (AUs) addressed by the Snake River Mercury Total Maximum Daily Load (TMDL). AUs have alternating colors for display purposes.....	10
Figure 2. Modern day global Earth surface mercury cycling budget. From Sonke et al. (2023). 14	
Figure 3. Longitudinal cross-section of the three reservoirs of the Hells Canyon Complex. Inverted red triangles indicate sampling locations from Baldwin et al. (2020). ....	22
Figure 4. Mercury cycling processes represented in the sub model of CE-QUAL-W2 (Wells, Zhang, et al. 2025).....	34

## Abbreviations

AU	Assessment unit
DEQ	Oregon Department of Environmental Quality
EPA	United States Environmental Protection Agency
Hg	Mercury
Hg <sup>0</sup>	Elemental mercury
Hg <sup>2+</sup>	Inorganic mercury
IPC	Idaho Power Company
LA	Load allocation
MeHg	Methylmercury
MOS	Margin of safety
NPDES	National Pollutant Discharge Elimination System
OAR	Oregon Administrative Rule
OHA	Oregon Health Authority
OWRD	Oregon Water Resources Department
QAPP	Quality Assurance Project Plan
THg	Total Mercury
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WLA	Waste load allocation
WQS	Water quality standards
WQMP	Water Quality Management Plan
WWTP	Waste water treatment plant

# 1. Introduction

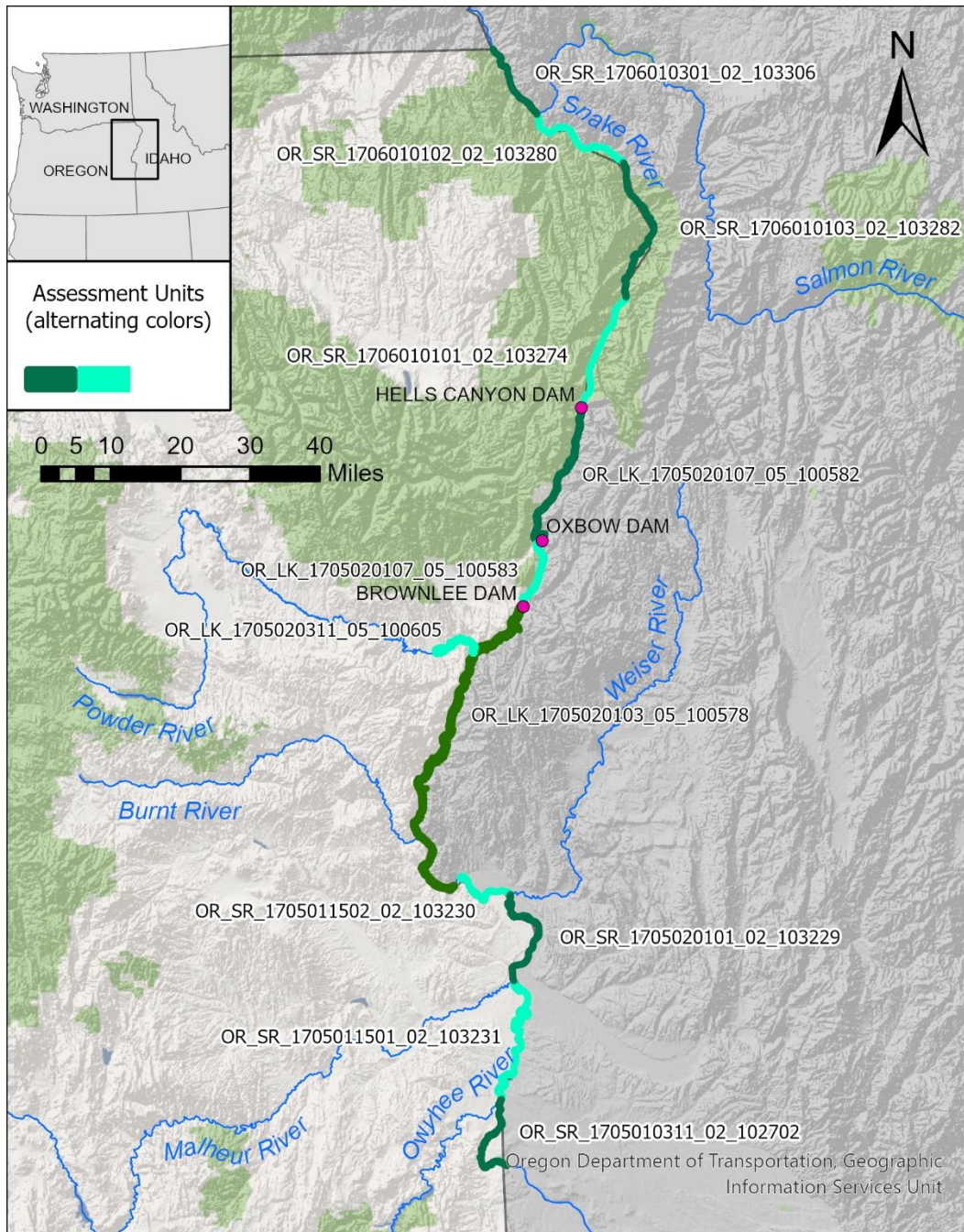
Exposure to elevated levels of the metal mercury, particularly in the form of methylmercury, has toxic effects on the human nervous, cardiovascular, and reproductive systems (US EPA 2015). In aquatic ecosystems, methylmercury accumulates and concentrates, or bioaccumulates and biomagnifies, respectively, in top consumers such as macroinvertebrates and piscivorous fish (US EPA 2015). Consumption of fish and shellfish constitutes the primary exposure pathway of methylmercury to humans. Therefore, waterbodies with high loads of methylmercury require actions to make harvestable species safe for frequent human consumption. These actions may include lowering the loading rates of mercury to waterbodies, controlling one or more other pollutants or environmental conditions that facilitate the transformation of mercury into methylmercury and subsequent bioaccumulation and biomagnification, or a combination of these approaches.

All riverine and reservoir assessment units (AUs) of the Snake River on the shared border between Oregon and Idaho (Figure 1) do not meet the Oregon water quality criterion for minimizing methylmercury exposure to humans via fish and shellfish consumption (Table 1). The Oregon Health Authority (OHA) has issued consumption advisories for all fish from the Snake River from just south of Adrian, Oregon to the Washington border (“Oregon Health Authority : Advisories and Guidelines : Fish and Shellfish Consumption : State of Oregon,” n.d.). In 2016, the Nez Perce Tribe placed a consumption moratorium on white sturgeon (*Acipenser transmontanus*), bull trout (*Salvelinus confluentus*), and smallmouth bass (*Micropterus dolomieu*) downstream of Hells Canyon Dam due to elevated levels of methylmercury (“Nez Perce Tribe Resolves Hells Canyon Litigation | Water & Irrigation | Postregister.Com,” n.d.). This moratorium underscores the nonattainment of Oregon’s water quality criterion for methylmercury in areas of Tribal subsistence and cultural use. The Federal Clean Water Act requires development of Total Maximum Daily Loads (TMDLs) for waterbodies that do not meet water quality criteria. Thus, to reduce methylmercury in fish and shellfish to levels acceptable for frequent human consumption (0.040 mg methylmercury/kg wet weight of tissue; OAR 340-041-8033 Table 40), Oregon DEQ has prioritized the TMDL for mercury in the Snake River in consultation with the Nez Perce Tribe. The TMDL will build on recent data, analyses, and modeling results from the Nez Perce Tribe, US Geologic Survey (USGS), and Idaho Power Company (IPC).

A TMDL provides a reproducible and adaptive approach for managing water quality. TMDLs are designed to attain water quality criteria by identifying, quantifying, and setting limits (allocations) for one or more pollutants loaded to waterbodies, thereby facilitating management of sources. The approach allocates pollutant loads for point source discharges that require a permit (wasteload allocations or WLAs; OAR 340-042-0030(4)(g)) and nonpoint sources from land surface runoff and nonpermitted discharges such as agricultural storm water discharges and return flows from irrigated agriculture (load allocations or LAs; OAR 340-041-0002(42,46), OAR 340-042-0030(4)(h)). TMDLs also identify and quantify, where possible, background sources (OAR 340-042-0030(1)) that account for pollutant loads not originating from human activities

(natural) or from outside of the state's jurisdiction, including loads from bordering states, tribal lands, and other countries. Additionally, TMDLs incorporate a margin of safety (MOS; OAR 340-0042-0040(4)(i)) to account for uncertainty in the analysis and may also include a reserve capacity (RC; OAR 340-0042-0040(4)(k)) to allow for increases in pollutant loads from future growth or expanded sources.

This document describes the data analyses and modeling planned for development of the Snake River Mercury TMDL by Oregon DEQ. Information presented here adheres to DEQ's and the EPA's Region 10 QAPP guidance for developing, testing, and applying models for TMDL development.



**Figure 1. Assessment units (AUs) addressed by the Snake River Mercury Total Maximum Daily Load (TMDL). AUs have alternating colors for display purposes.**

**Table 1. Listing categories for methylmercury (MeHg) human health criterion and total mercury (THg) aquatic life criteria in Snake River assessment units (AUs) from the 2022 Oregon Integrated Report (“Department of Environmental Quality : EPA Approved Integrated Report : Water Quality : State of Oregon,” n.d.).**

AU Name	AU Description	AU ID	Listing category for MeHg*	Listing category for THg*
Snake River	Salmon River to Stateline	OR_SR_1706010301_02_103306	5	Not assessed
Snake River	Sheep Creek to Getta Creek	OR_SR_1706010102_02_103280	5	2
Snake River	Getta Creek to Salmon River	OR_SR_1706010103_02_103282	5	Not assessed
Snake River	Hells Canyon Reservoir to Sheep Creek	OR_SR_1706010101_02_103274	5	2
Hells Canyon Reservoir	Lake/Reservoir Unit	OR_LK_1705020107_05_100582	5	3
Oxbow Reservoir	Lake/Reservoir Unit	OR_LK_1705020107_05_100583	5	2
Brownlee Reservoir	Lake/Reservoir Unit	OR_LK_1705020311_05_100605	5	Not assessed
Brownlee Reservoir	Lake/Reservoir Unit	OR_LK_1705020103_05_100578	5	2
Snake River	Hog Creek to Mann Creek	OR_SR_1705020101_02_103229	5	3
Snake River	Boise River to Malheur River	OR_SR_1705011501_02_103231	5	Not assessed
Snake River	Malheur River to Mann Creek	OR_SR_1705011502_02_103230	5	Not assessed
Snake River	Idaho to Boise River	OR_SR_1705010311_02_102702	5	Not assessed

\*Listing categories: Not assessed (no data available); 2 (designated beneficial use supported); 3 (insufficient data to determine designated beneficial use support); 4 (designated beneficial use not supported; actions in place to address); 5 (designated use not support and action needed to address) (“Department of Environmental Quality : EPA Approved Integrated Report : Water Quality : State of Oregon,” n.d.).

## 2. Problem definition and management objectives

The decision problem (Conroy and Peterson 2013) for model development in the Snake River Mercury TMDL is:

- Determine loading of methylmercury to the Snake River on the shared Oregon-Idaho border required to meet the human health water quality criterion for minimizing methylmercury exposure from frequent fish and shellfish consumption.

Meeting Oregon's human health water quality criterion for methylmercury by 2045 constitutes the fundamental objective of the Snake River Mercury TMDL. DEQ anticipates that meeting the human health criterion for methylmercury (0.040 mg methylmercury/kg fish tissue; OAR 340-041-8033 Table 40) will ensure attainment of aquatic life water quality criteria for total mercury (acute: 2.4  $\mu\text{g/L}$ ; chronic: 0.012  $\mu\text{g/L}$ ; OAR 340-041-8033 Table 30) and the toxics substances narrative criteria (OAR 340-041-0033(1)). Achieving this objective requires an empirical demonstration that fish and shellfish tissue methylmercury levels remain below the human health criterion throughout riverine and reservoir AUs on the Snake River, including those downstream of Hells Canyon Dam.

DEQ has identified the following interim, or means, objectives (Conroy and Peterson 2013) required to achieve the fundamental objective for the Snake River Mercury TMDL, including:

- Determine fish and shellfish species targeted for human consumption across the Snake River AUs and size ranges that minimize methylmercury exposure from frequent human consumption for each species.
- Determine the relative importance of pollutant loads (including mercury, methylmercury, and others) and environmental conditions that facilitate the bioaccumulation and biomagnification of methylmercury in fish and shellfish tissue across the Snake River AUs.
- Quantify point and nonpoint sources of mercury, methylmercury, and other relevant pollutants and environmental conditions that influence bioaccumulation and biomagnification of methylmercury in Snake River AUs, including those originating on the Idaho side of the border and upstream in Idaho.
- Calculate LAs, WLAs, MOSs, and RCs for methylmercury required to meet the human health criterion.
- Determine pollutant reductions and changes to environmental conditions required to meet the human health criterion in the Snake River AUs under a range of climatic, hydrologic, and thermal conditions representative of the Snake River system.
- Confirm that meeting requirements for the human health water quality criterion will also ensure attainment of the aquatic life water quality criteria.

### **3. Conceptual model: Key processes and variables**

The complexity of environmental mercury cycling makes development of TMDLs targeting bioaccumulation and biomagnification of methylmercury challenging. Numerous environmental factors at a variety of spatial and temporal scales influence the input, movement, retention, and the bioaccumulation and biomagnification of mercury in aquatic ecosystems (Eagles-Smith et al. 2016a; Sonke et al. 2023). Understanding sources of mercury in aquatic environments as well as the factors that facilitate mercury methylation, demethylation, and incorporation of methylmercury into food webs provides the foundation for minimizing the risk of human exposure from frequent consumption of fish and shellfish.

#### **3.1 Overview of mercury cycling**

Mercury naturally enters into ecosystem cycling through volcanic emissions, crustal degassing, and erosion of mercury-rich geologic deposits such as cinnabar (Sonke et al. 2023; Eagles-Smith et al. 2016a). Mercury may cycle through multiple phases and forms (e.g., elemental mercury, inorganic oxidized mercury, and methylmercury) in terrestrial, atmospheric, freshwater, and marine systems before ultimately undergoing diagenesis and re-entering the earth's crust. Prior to the year 1500 (before significant modification of global mercury cycling by human activities), natural releases of mercury to the earth's surface largely balanced with diagenesis of mercury into the crust, although short- and long-term cycles of climate change and volcanic activity periodically disrupted the balance (Sonke et al. 2023).

Human activities over the past 500 years have increased loading of mercury to the earth's surface by seven fold (Sonke et al. 2023). Coal burning, cement production, precious metal and mercury mining, application of mercury-based fungicides, and other activities have all contributed to increased mercury loading from local to global scales. Moreover, alterations to hydrologic cycles, accelerated rates of erosion, agricultural and urban runoff, and point source discharges of industrial, sewage, and medical wastes have greatly increased mercury loading to aquatic systems (Sonke et al. 2023; Eagles-Smith et al. 2016a; Baldwin et al. 2024a). This is due in part to the mobilization of large amounts of legacy mercury accumulated in soils and sediments from natural and anthropogenic sources (Sonke et al. 2023). Current estimates of the modern-day global Earth surface mercury cycling budget appear in Figure 2.

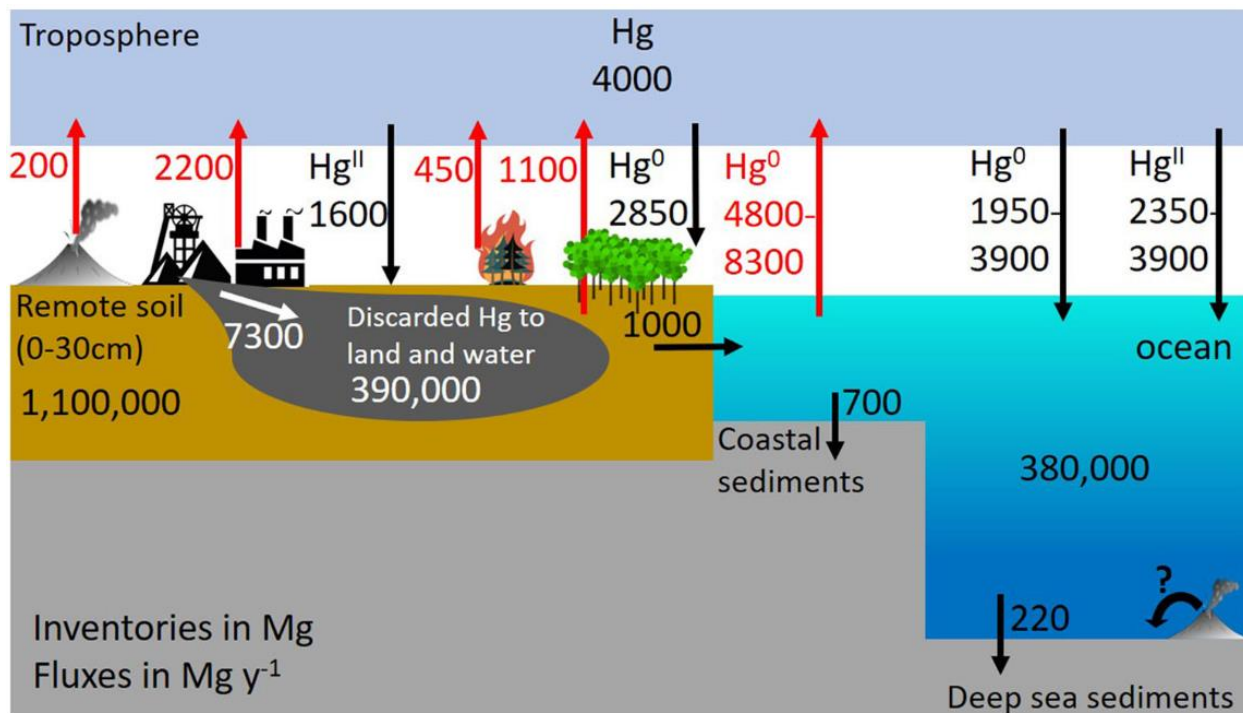


Figure 2. Modern day global Earth surface mercury cycling budget. From Sonke et al. (2023).

Despite large increases in total mercury loading to aquatic ecosystems, only a fraction occurs as methylmercury (Baldwin et al. 2020). However, methylmercury, which may enter waterbodies from the watershed runoff or from internal production, constitutes the most toxic and readily assimilated form of mercury to most forms of life, including humans (Farina et al. 2011). Formation of methylmercury predominantly occurs under anoxic conditions either in the water column or within sediments via microbially-mediated and abiotic processes (Eagles-Smith et al. 2016b; Sonke et al. 2023). Factors that influence methylation rates include temperature, abundance of organic matter, and abundance other substances (e.g., sulfur) that form stable bonds with mercury (Sonke et al. 2023; Barkay and Gu 2022). The process of demethylation, which includes abiotic and biologically-mediated processes, may remove methylmercury from aquatic ecosystems before entering food webs (Barkay and Gu 2022). Factors that influence demethylation rates include abundance of sulfur containing molecules (including organic matter), organic matter, oxygen levels, and degree of ultraviolet light exposure (Barkay and Gu 2022).

Methylmercury readily forms complexes with particulate and dissolved organic matter both in the water column and in sediments (Dong et al. 2010). Organisms at lower trophic levels, including algae, zooplankton, and macroinvertebrates, readily bioaccumulate methylmercury and methylmercury-organic matter complexes either through direct adsorption from the water column or through consumption (Lavoie et al. 2013; Willacker et al. 2025a). Through the process of biomagnification, methylmercury concentration in muscle tissue of top consumers may exceed methylmercury concentration in the water column or sediments by more than one

million times (Lavoie et al. 2013; Willacker et al. 2025a). Moreover, bioaccumulation rates of methylmercury exceed excretion rates by several orders of magnitude; thus years may elapse before fish or shellfish become safe for frequent human consumption following reductions in methylmercury loading (Blanchfield et al. 2022; Willacker et al. 2025a).

## 4. Technical approach

### 4.1 Overview

Linking bioaccumulation and biomagnification of methylmercury in fish and shellfish with water quality and environmental conditions in the mixed riverine-reservoir system of the Snake River requires considerable effort to assemble data and select appropriate models. Although challenging, significant groundwork has been laid over the past 25 years that facilitates data compilation and model development for use in the Snake River Mercury TMDL. In 2004, Oregon DEQ and Idaho DEQ issued a joint TMDL addressing nutrients, dissolved oxygen, pesticides, sediment, temperature, and dissolved gas. These TMDLs relied, in part, on a water quality model (CE-QUAL-W2) for temperature and eutrophication (excessive aquatic productivity) (“Department of Environmental Quality : Snake River/Hells Canyon Subbasin : Total Maximum Daily Loads : State of Oregon,” n.d.).

The 2004 Snake River-Hells Canyon TMDL did not develop loading capacities and allocations for mercury. However, the project did synthesize source assessments for background, point, and nonpoint sources of mercury and examine mercury data available for the Snake River, including the Hells Canyon reach (“Department of Environmental Quality : Snake River/Hells Canyon Subbasin : Total Maximum Daily Loads : State of Oregon,” n.d.). The TMDL expected that reductions in nutrients, sediments, and other nonpoint source pollutants would also reduce mercury loads to the Snake River, although no quantitative targets for mercury were established at the time. Since 2004, flow normalized concentrations of total phosphorus, chlorophyll *a*, and total suspended sediments flowing into Brownlee Reservoir on the Snake River have declined, some of which may be attributable to management actions put in place after TMDL issuance (Naymik et al. 2023). A mercury TMDL for the system was expected several years after issuance of the 2004 TMDL. Although not yet issued, additional data collected by federal, state, and local entities, including the USGS, over the past 21 years have focused on understanding mercury loading, cycling, and the processes of bioaccumulation and biomagnification in the riverine and reservoir AUs of the Snake River (Baldwin et al. 2020; Willacker et al. 2025b; Krause et al. 2024; Willacker et al. 2023a; Baldwin et al. 2022).

### 4.2 Model selection

The 2004 Snake River TMDL water quality models and the research since its issuance serve as the basis for models and data analysis planned for the Snake River Mercury TMDL. Currently, two CE-QUAL-W2 models based on the same spatial and temporal data have been built: one by

Oregon for use in a temperature TMDL (under development) and one by IPC for developing mercury management scenarios in the three Hells Canyon Reservoirs (Wells, Garstecki, et al. 2025). The CE-QUAL-W2 model developed by IPC includes a novel sub model for mercury cycling that has been preliminarily calibrated but will require further refinement and testing for TMDL applications (Wells, Zhang, et al. 2025) and the ability to feed model outputs into a food web model used for examining bioaccumulation and biomagnification of methylmercury in fish (Appendix A). Because CE-QUAL-W2 models and food web models have been developed for a portion of the TMDL area already, DEQ plans to improve and expand existing calibrated models to develop the Snake River Mercury TMDL.

CE-QUAL-W2 (v.4.5) consists of a two-dimensional, laterally averaged hydrodynamic and water quality model (Wells 2023). It allows calculations of pollutant loading capacities, identification of pollutant sources, and linkages between pollutant sources and water quality thresholds. It also can estimate standing stocks of phytoplankton and zooplankton, two biomass components required for contaminant bioaccumulation and biomagnification modeling. Managers employ CE-QUAL-W2 for water quality decisions around the world (Wells 2023). In Oregon, CE-QUAL-W2 has been used to develop numerous TMDLs, including the 2004 Snake River TMDL for temperature, chlorophyll *a*, and dissolved oxygen, the 2006 and 2025 Willamette River temperature TMDLs, the 2019 Upper Klamath and Lost River temperature, dissolved oxygen, and ammonia TMDLs, and the pending revised Snake River temperature TMDL.

Although CE-QUAL-W2 simulates processes that influence water quality, additional modeling is needed to analyze bioaccumulation and biomagnification of toxics in food webs. IPC also funded the development of a food web model to examine bioaccumulation and biomagnification of mercury in three common fish found in the three Hells Canyon Complex reservoirs (Appendix A). This model, FweB4 v.1.0, simulates bioaccumulation of mercury from metabolism, waste excretion, and growth of specific fish species (Appendix A) and is based on the Fish Bioenergetics 4.0 (FB4) model (Deslauriers et al. 2017). With additional evaluations and improvements, modeled outputs from CE-QUAL-W2, including mercury and methylmercury concentration, zooplankton, temperature, dissolved oxygen, may be used as inputs for the FweB4 model (Appendix A).

A CE-QUAL-W2 v.4.5 model for temperature is under development for use in a revised temperature TMDL (expected in 2027) that covers riverine AUs of the Snake River between river mile 398 to 345 (upstream of Brownlee Reservoir to Oregon/Idaho border) and between river mile 247 to 139 (downstream of Oxbow Reservoir to the confluence with the Clearwater River in Lewiston, ID). DEQ will expand the current CE-QUAL-W2 models developed for temperature (flowing and reservoir AUs) and eutrophication/mercury cycling (reservoir AUs only) for all riverine and reservoir AUs of the Snake River on the shared border between Oregon and Idaho from Adrian, OR, to the triple border of Oregon-Idaho-Washington (Figure 1). This will result in a CE-QUAL-W2 model that simulates temperature, eutrophication, and mercury cycling for all riverine and impounded AUs on the shared border between Oregon and Idaho.

DEQ will also expand the FweB4 model to the same riverine AUs of the Snake River and to other species identified as critical for the TMDL.

DEQ proposes to use the following sequence to establish the TMDL through combined use of the two models:

1. The FweB4 model will relate the fish tissue mercury content to methylmercury in basal food web items.
2. Peer-reviewed literature, including publications produced by the USGS Snake River mercury studies, will be used to determine bioaccumulation factors of methylmercury (dissolved and particulate) into basal food web items.
3. The CE-QUAL-W2 model will be used to relate methylmercury loads to factors influencing methylmercury loading, production, and transport in all AUs comprising the Snake River on the border between Oregon and Idaho.
4. Methylmercury reductions and other surrogate measures, which may include mercury, or other pollutants, and changes to environmental conditions required to attain the human health and aquatic life criteria will be identified by CE-QUAL-W2 and FweB4 models through sensitivity and scenario analyses.

## 4.3 Software development quality assessment

DEQ will work with Dr. Scott Wells of Portland State University, who maintains and updates the CE-QUAL-W2 model ([cee.pdx.edu/w2/](http://cee.pdx.edu/w2/)), and Reed Harris of Reed Harris Environmental Limited to expand, test, and calibrate the model for the Snake River Mercury TMDL. DEQ staff will work to adapt the FweB4 for use in the TMDL and will consult with Reed Harris of Reed Harris Environmental Limited, who developed and tested the FweB4 model for IPC. DEQ staff will work and consult with Dr. Wells and Mr. Harris during the development of the models and will provide reviews of data, code, outputs, and interpretations of model results. DEQ will also request reviews of materials during and after model development from DEQ staff, the EPA, and external reviewers (TBD). All data used for testing, calibration, and scenarios, final models, including source code and executables, model outputs, and reports will be archived with the TMDL materials. Specific methods, including Quality Assurance/Quality Criteria (QAQC) of inputs and outputs, model expansion, calibration, and testing, will be detailed in modeling reports and appendices.

## 5. Model development

### 5.1 Model boundaries

Models developed for Snake River Mercury TMDL will include all AUs listed in Table 1 and depicted in Figure 1. Currently, a CE-QUAL-W2 v.4.5 model for eutrophication, temperature, and mercury cycling and the FweB4 v.1.0 model for bioaccumulation and biomagnification of methylmercury in fish have been developed for the three Hells Canyon Complex reservoirs (Brownlee, Oxbow, and Hells Canyon) between river miles 345 and 247 (Figure 1). A CE-QUAL-W2 v.4.5 model for temperature has also been developed for riverine AUs of the Snake

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River between river mile 398 to 345 (upstream of Brownlee Reservoir to Oregon/Idaho border) and between river mile 247 to 176 (downstream of Oxbow Reservoir to Oregon/Washington/Idaho border; the model also extends into Washington). A CE-QUAL-W2 model for eutrophication, temperature, and mercury cycling and a FweB4 model for methylmercury biomagnification will be developed for the riverine AUs using the existing temperature model as a template.

CE-QUAL-W2 requires boundary conditions for hydraulic simulations, including conditions for the bed, free surface, inlet and outlet, and initial conditions (Wells 2023). Boundary conditions for the bed will be determined from bathymetric and topographic data used in previous CE-QUAL-W2 models. Equations using these data derive the hydraulic friction parameters for the model (Wells 2023). Data describing wind direction and magnitude are required to determine hydraulic boundary conditions at the free surface of water (Wells 2023). The user specifies flow and head conditions at model boundaries (Wells 2023). Data used for describing wind conditions in the modeled reaches will derive from the same sources used for the previous CE-QUAL-W2 models.

Other boundary conditions for the models include flows and pollutant loads from major and minor tributaries draining directly to the Snake River and from irrigation return flows (canals) into the mainstem Snake River. Major tributaries to Snake River AUs appear in Table 2. Contributions of flow, mercury, methylmercury, and other pollutants from major and minor tributaries and irrigation return flows will be estimated from observed data or estimated using methods listed in Table 4. Atmospheric fluxes of mercury to and from water surfaces will serve as additional boundary conditions for the CE-QUAL-W2.

**Table 2. Major tributaries entering directly into the riverine and reservoir assessment units of the Snake River on the Oregon/Idaho border. GNIS\_ID refers to the USGS Geographic Name Information System ID. AU refers to assessment unit ID used in Oregon's Integrated Report.**

Tributary name	GNIS_ID	Receiving AU	Tributary State
Salmon River	00400069	OR SR 1706010301 02 103306	Idaho
Imnaha River	01144009	OR SR 1706010103 02 103282	Oregon
Pine Creek	01147689	OR LK 1705020107 05 100582	Oregon
Wildhorse River	00400174	OR LK 1705020107 05 100583	Idaho
Powder River	01164128	OR LK 1705020311 05 100605	Oregon
Daly Creek	01140606	OR LK 1705020311 05 100605	Oregon
Burnt River	01139008	OR LK 1705020103 05 100578	Oregon
Weiser River	00392986	OR SR 1705020101 02 103229	Idaho
Payette River	00388284	OR SR 1705011502 02 103230	Idaho
Malheur River	01145769	OR SR 1705011502 02 103230	Oregon
Boise River	00378007	OR SR 1705011501 02 103231	Idaho
Owyhee River	01147319	OR SR 1705011501 02 103231	Oregon

## 5.2 Spatial and temporal resolution

The spatial and temporal resolutions of the CE-QUAL-W2 and FweB4 models will align with the requirements for developing the Snake River Mercury TMDL. These requirements include ensuring attainment of the human health criterion in all AUs listed in Table 1, capacity to determine TMDL components (LAs, WLAs, MOS, and RC) for each AU, quantification of seasonal variation, and identification of critical conditions for meeting the TMDL. Aggregation of results may be needed to meet these requirements.

The spatial configuration of CE-QUAL-W2 v.4.5 consists of vertical and horizontal dimensions relative to the axis of downstream flow with the model layers well-mixed laterally (Wells 2023). Existing eutrophication and temperature CE-QUAL-W2 models for the Snake River have a vertical spatial resolution of one meter in each horizontal model segment. Resolution of horizontal model segments range from 60 to 504 m in existing models (Wells, Garstecki, et al. 2025). DEQ expects that spatial resolution of CE-QUAL-W2 models used for the mercury TMDL to mirror that already developed for the system. Horizontal model segments may be

summarized at the spatial scale of assessment units to align with the bioaccumulation and biomagnification model.

Temporal resolution of the CE-QUAL-W2 model may vary according to algorithms that optimize computational efficiency with fit of model outputs to calibration datasets (Wells 2023). In general CE-QUAL-W2 time steps operate at the scales of seconds to minutes (Wells, Garstecki, et al. 2025). DEQ anticipates a similar temporal resolution in models used for the Snake River Mercury TMDL. Model outputs may need to be aggregated to daily values for alignment with the bioaccumulation and biomagnification model.

The spatial resolution of the bioaccumulation and biomagnification model, FweB4, will align with assessment units for the riverine and reservoir AUs of the Snake River intersecting with Oregon. The temporal resolution of FweB4 is a daily time step (Appendix A). Model results may be aggregated to summaries of longer time periods for TMDL development as needed.

## 5.3 Source characteristics

Fish consumption advisories related to mercury contamination have been issued for the entire length of the Snake River on the shared Oregon-Idaho border since the 1960s (“Department of Environmental Quality : EPA Approved Integrated Report : Water Quality : State of Oregon,” n.d.). Idaho has also issued fish consumption advisories for nearly all upstream portions (“Fish Advisories | Idaho Department of Health and Welfare,” n.d.). These advisories suggest that mercury contamination of the Snake River Basin has been a longstanding issue. Although the same trends and processes responsible for increased loading and cycling of mercury at the global scale occur in the Snake River Basin, several unique aspects of the area, including natural geology, land use history, agricultural practices, and hydromodification, have also contributed to elevated methylmercury in fish tissue (Baldwin et al. 2024a; Willacker et al. 2025a; Baldwin et al. 2022).

Three general sections make up the portion of the Snake bordering Oregon and Idaho:

- Upstream of the Hells Canyon Complex of dams operated by IPC (Brownlee, Oxbow, and Hells Canyon dams)
- The three reservoirs operated by IPC: Brownlee (including the Powder River arm), Oxbow, and Hells Canyon reservoirs
- The tailwaters downstream of Hells Canyon Dam extending to the triple Oregon-Idaho-Washington border

Each of these sections have unique aspects regarding mercury cycling and the bioaccumulation and biomagnification of methylmercury. Additionally, upstream sections influence the timing and spatial patterns of mercury cycling in downstream sections. Different aspects among the sections and degree of downstream influence of one section on another are central for TMDL development in the Snake River.

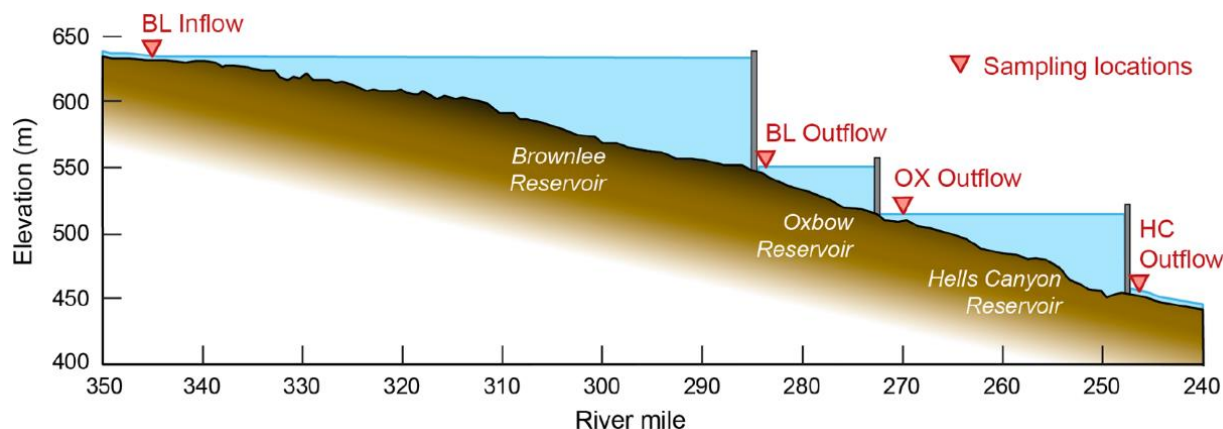
The portion of the Snake River upstream of Brownlee Reservoir to where it first intersects the Oregon-Idaho border (64 miles) receives pollutant loads from drainage areas along the Snake River between Melba, Idaho, and Weiser, Idaho. Extensive agriculture, including center pivot and flood irrigation systems, characterize this section of the river and surrounding landscape. Elevated loads of sediment and nutrients draining directly via overland runoff, irrigation canals, and tributaries have been chronic issues for water quality and led to the development of a TMDL in 2004 addressing excessive productivity and sediment pollution (“Department of Environmental Quality : Snake River/Hells Canyon Subbasin : Total Maximum Daily Loads : State of Oregon,” n.d.).

Mercury entering the Snake River upstream of Brownlee Reservoir comes from multiple sources (Baldwin et al. 2024b). Sources from major tributaries upstream of Weiser include contaminated sediments from historic mining practices, industrial activities, erosion of mercury-rich geologic deposits, erosion of legacy mercury in soils, and atmospheric (dry and wet) deposition (Baldwin et al. 2024b). Erosion and mobilization of sediment and organic matter are also major contributors of mercury entering from irrigation return flows directly into the Snake River (Baldwin et al. 2024b). Ultimate sources of mercury in these loads are less clear and may include naturally-occurring mercury in sediments, contaminated sediments from mining and other activities, and deposition of atmospheric mercury released from natural and anthropogenic processes (Baldwin et al. 2024b).

Inputs from four major tributaries and return flows from irrigation systems increase oxidized inorganic mercury and methylmercury loads entering Brownlee Reservoir two-to-the three times relative to the those in the Snake River upstream near Melba, ID (Baldwin et al. 2024b). Several studies suggest that riparian, wetland, and in-stream processes along this section produce over one third of the methylmercury loaded to Brownlee Reservoir annually (Krause et al. 2024; Baldwin et al. 2024b). Excess loads of fine sediments, carbon, and nutrients (nitrogen and phosphorus) facilitate the environmental conditions (anoxia) required for mercury methylation (Krause et al. 2024). At the same time, demethylation does not equally remove methylmercury from these environments, leading to a net increase in methylmercury loads (Baldwin et al. 2024b). Methylmercury entering from tributaries, irrigation returns, or through internal production may enter into aquatic food webs through adsorption by benthic or planktonic organisms (“Department of Environmental Quality : Snake River/Hells Canyon Subbasin : Total Maximum Daily Loads : State of Oregon,” n.d.). Fish known to have elevated levels of methylmercury in tissue in this riverine section include smallmouth bass and several catfish species (“Department of Environmental Quality : Snake River/Hells Canyon Subbasin : Total Maximum Daily Loads : State of Oregon,” n.d.).

Downstream of Weiser, ID, the Snake River enters the Hells Canyon Complex, which consists of a series of three reservoirs extending for 98 miles along the shared Oregon-Idaho border (Figure 1). In upstream to downstream sequence, these reservoirs include Brownlee (60 miles), Oxbow (16 miles), and Hells Canyon (22 miles). Hydroelectric projects in arid regions of the western North America significantly alter dynamics of mercury cycling and the bioaccumulation and biomagnification of methylmercury (Baldwin et al. 2020; Willacker et al. 2025a; Eagles-

Smith et al. 2016b; Green et al. 2016). Major alterations include retention of mercury through enhanced settling of particulates and other physical processes (Baldwin et al. 2022), facilitation of seasonal temperature stratification and the development of anoxia in bottom waters (thereby creating environments favorable for mercury methylation) (Baldwin et al. 2022), enhancement of the transfer efficiency of methylmercury into and within food webs (Willacker et al. 2025a), and facilitation of downstream transport of methylmercury from reservoirs to riverine segments (Willacker et al. 2023b).



**Figure 3. Longitudinal cross-section of the three reservoirs of the Hells Canyon Complex. Inverted red triangles indicate sampling locations from Baldwin et al. (2020).**

The first reservoir in the series of the Hells Canyon Complex, Brownlee, exerts the largest influence on mercury and methylmercury dynamics in the reservoir complex and downstream riverine sections (Baldwin et al. 2022; Willacker et al. 2023b). Brownlee Reservoir is the largest of the three reservoirs by surface area (23.6 square miles), depth (maximum of 299 feet), and volume (46 billion gallons) (Baldwin et al. 2020). Brownlee also has the longest water residence time (34 days) of the three systems (Baldwin et al. 2020). As the most upstream of the three reservoirs, Brownlee directly receives mercury loads from the upstream riverine section of the Snake River. Additionally, other pollutants that facilitate the transport of mercury and the formation of methylmercury (organic matter and nutrients) enter Brownlee from upstream. Contributions from major Oregon tributaries, particularly the Burnt and Powder Rivers, into Brownlee adds mercury and other pollutants to the reservoir (Baldwin et al. 2024b; “Department of Environmental Quality : Snake River/Hells Canyon Subbasin : Total Maximum Daily Loads : State of Oregon,” n.d.).

Transitioning from a river into a reservoir causes particulate-bound mercury and methylmercury to settle out of the water column into benthic sediments in Brownlee Reservoir (Baldwin et al. 2020). On average, Brownlee retains 50% of total inorganic mercury and 30-40% of total methylmercury loaded from upstream (Baldwin et al. 2020). However, filter-passing methylmercury loads may increase at the outflow of Brownlee relative to inflows in some years due to variations in the timing and magnitude of flows, extent and duration of anoxia in bottom waters, accumulation of methylmercury in bottom waters, and the timing of reservoir

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destratification (Baldwin et al. 2020). Methylmercury accumulates in anoxic zones of the hypolimnion in Brownlee, with a portion transferring into reservoir food webs during destratification in the fall and winter months (Willacker et al. 2025b). The timing, extent, and magnitude of anoxia in the hypolimnion depend on flow, temperature, input of organic matter and nutrients from upstream, and in-reservoir production by phytoplankton (Baldwin et al. 2020; Willacker et al. 2023a). Adult smallmouth bass accumulated high levels of methylmercury over several years of exposure to stratification-destratification sequences in the Brownlee (Willacker et al. 2025b). Additionally, methylmercury accumulated in the seasonal hypolimnion of Brownlee supplies methylmercury to Oxbow Reservoir, Hells Canyon Reservoir (with a smaller portion of methylmercury produced in this reservoir), and the riverine portion of the Snake River that extends to the Oregon-Washington-Idaho border (Baldwin et al. 2020).

Seasonal methylmercury export from Hells Canyon Dam downstream contributes to mercury contamination of fish tissue in the riverine section of the Snake River to the Oregon-Idaho-Washington border (Willacker et al. 2023a). Methylmercury may enter the riverine food web, which includes (but not limited to) white sturgeon and bull trout, through consumption of reservoir fish and other aquatic life “shocked” or killed in or by discharge from the dam, consumption of particulate-bound methylmercury by filter-feeding benthic macroinvertebrates and other organisms, and adsorption of filter-passing methylmercury by benthic organisms at the base of the riverine food web (Willacker et al. 2023a). Information on in-stream and riparian production of methylmercury in the portion of the Snake River downstream of Hells Canyon Dam has not been collected but may contribute to contamination of fish tissue as well. Two major tributaries, the Imnaha River (Oregon) and Salmon River (Idaho) may also contribute to methylmercury loads to this segment of the Snake River. In particular, recent data collected by the USGS suggest that the Salmon River may contribute substantial mercury and methylmercury loads (A. Baldwin, personal communication).

Point sources may also contribute mercury, methylmercury, or pollutants influencing methylation to riverine and reservoir sections of the Snake River. On the Oregon-Idaho border, six individual NPDES permitted facilities discharge to the mainstem Snake River and reservoirs (Table 3). However, this list does not include direct discharges to the Snake River upstream in Idaho or to tributaries draining to the Snake River upstream or in the TMDL area. Stormwater discharge from roads covered by Oregon Department of Transportation’s MS4 (NPDES No. 101822) or discharges covered under NPDES and WPCF General Permits also may contribute to pollutant loads that influence methylmercury loads. However, the 700-PM NPDES Water Quality General Permit (metal mining activities) does not allow discharge of materials that may contain mercury into waters of the state listed as impaired for mercury or methylmercury.

**Table 3. Permitted NPDES point sources discharging directly into the Snake River from river mile 409 to 176 on the Oregon-Idaho border. NPDES = National Pollution Discharge Elimination System; MGD = Million Gallons per Day; WWTP = Wastewater Treatment Plant.**

Permittee	Water Quality File Number	EPA Number	Location (river mile)	Treatment Type	Design flow (MGD)
Hells Canyon Dam Power Plant (Idaho Power Company)	41297	OR0027278	247	Turbine cooling water and sump discharge	10.5
Oxbow Dam Power Plant (Idaho Power Company)	41299	OR0027286	273	Sump discharge and turbine cooling water	11
Brownlee Dam Power Plant (Idaho Power Company)		ID0020907	285	Sump discharge and turbine cooling water	15
City of Weiser WWTP		ID0020290	352	Activated sludge	2.4
City of Ontario WWTP	63631	OR0020621	369	Facultative lagoon	3.1
Simplot	63810	OR0002402	370	Activated sludge	3.4

## 5.4 Data availability and quality

A preliminary list of data sources available for use in development, testing, calibration, and scenario evaluation of the CE-QUAL-W2 and FweB4 models appears in Table 4. Other data may be accessed depending on model requirements and availability. All data used for modeling will undergo a quality review, and the level of confidence or limitations will depend on the source (e.g., NPT, USGS, IPC).

**Table 4. Data available for use in model development, calibration, and evaluation in the Snake River Mercury TMDL.**

Model	Input type	Parameter(s)	Source(s)	Use
CE-QUAL-W2	Weather	Air temperature Wind direction Wind speed	Weather and Research Forecast Model - North American Mesoscale (WRF-NAM)	Calibration

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Model	Input type	Parameter(s)	Source(s)	Use
		Relative humidity Shortwave solar radiation Dew point Cloud cover	Idaho Power Company USGS NOAA Oregon State University PRISM model	
CE-QUAL-W2	Flow	15-minute discharge Daily average discharge Spill flow Turbine flow Water level Water availability	Idaho Power Company (13275000: Burnt River at Huntington; 13286700: Powder River near Richland; 13288300: Eagle Creek at Richland; 13289030: Daly Creek below Diversion near Richland; 13289960: Wildhorse River at Brownlee; 13290190: Pine Creek near Oxbow; 13289720: Snake River below Brownlee Dam; 13290030: Snake River below Oxbow Dam; 13290450: Snake River below Hells Canyon Dam) USGS (13269000: Snake River at Weiser Idaho) Oregon Water Resources Division flow data  Oregon Water Resources Division Water Availability Reporting	Boundary conditions
CE-QUAL-W2	River geometry	Bathymetry Volume tables Elevation tables	Idaho Power Company Tetra Tech USGS	Boundary conditions
CE-QUAL-W2	Water quality	Water temperature Dissolved oxygen pH Dissolved organic carbon Total organic carbon	USGS National Water Quality Information System Oregon DEQ water quality data Idaho DEQ water quality data	Boundary conditions Calibration Validation

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Model	Input type	Parameter(s)	Source(s)	Use
		Total suspended solids Orthophosphate Total phosphorus Nitrate-nitrite Ammonium Total Kjehldal nitrogen Total nitrogen Sulfate Inorganic sulfide Iron Manganese Elemental mercury (filtered, unfiltered, and sediment) Inorganic mercury (filtered, unfiltered, and sediment) Methylmercury (filtered, unfiltered, and sediment) Chlorophyll a	Idaho Power Company (water temperature) Water Quality Portal Oregon DEQ Wastewater Permit Documents Database Oregon DEQ 401 Hydropower Certification database	
FweB4	Biological	Total mercury in fish tissue (various species) Total mercury in zooplankton	Nez Perce Tribe USGS Idaho Power Company	Calibration Validation
All	Landscape/remotely sensed	Land use/land cover Riparian vegetation conditions Watershed characteristics	National Land Cover Database Oregon DEQ EPA watershed characteristic databases	Boundary conditions

## 5.5 Time frame of simulation

The time frame of the simulations for the CE-QUAL-W2 models will be determined from the identification of critical conditions for production, transport, and the bioaccumulation and

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biomagnification of methylmercury in the Snake River system. Data used for calibration will span the interval of the joint USGS-IPC water quality study (2014-2018).

The FweB4 model will initially be simulated across five-year periods to examine critical conditions and management scenarios detailed in Section 9. The time frame may be adjusted as needed following initial model runs. Data collected from 2014 to 2021 and gathered from peer-reviewed literature will be used for calibration of the modified FweB4 model.

## 5.6 Data gaps

Data gaps expected include mercury and methylmercury production, transport and cycling below Hells Canyon Dam, the bioaccumulation and biomagnification of methylmercury in white sturgeon, and weather information for use in CE-QUAL-W2 modeling. To address these gaps and others encountered during development, testing, and calibration of the models, peer-reviewed literature will be consulted to identify or derive methods to fill in the gaps. Gaps in other data, such as water quality time series data, flow/water management, or physiological parameters for important fish species, will be evaluated on a case-by-case basis. Methods used to fill data gaps may include those used for calibration of the CE-QUAL-W2 model for productivity related parameters in the Hells Canyon Complex reservoirs (Wells, Garstecki, et al. 2025), statistical techniques to interpolate or extrapolate estimated values for missing or censored data, and estimates derived from best professional judgment or consultation with subject matter experts (Table 5). Best professional judgement will include a written rationale for the derivation of the estimates and may include multiple estimates to assess sensitivity of model outputs. Influences of data gaps or missing data on model outputs may be evaluated with sensitivity analyses or other identified methods.

**Table 5. Methods that may be used to fill data gaps during model development, testing, and calibration of models for the Snake River Mercury TMDL.**

Method	Possible parameters	Description
Direct surrogates	Tributary inputs, meteorological inputs, groundwater/subsurface inputs and conditions	Neighboring or nearby tributary watersheds may share climatological and landscape features. Model parameters that have an incomplete record or no data may be parameterized using data from a neighboring or nearby location.
Calibration adjustments	All inputs	Estimates of important inputs may be missing for appropriate representation in the model. For example, data on groundwater inputs of heat and pollutants may not be available. Data describing such inputs can be estimated by adjusting

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		the necessary values within acceptable ranges (from peer-reviewed literature or previously developed models) during the calibration process.
Literature based values or values from previous models	All inputs	Values derived from peer-reviewed literature or previous models (from the same or different system) may be used for model parameters or unquantified model inputs when limited or no data are available.
Mass balance	Tributary and groundwater inflows	On riverine and reservoir segments, missing tributary and groundwater flows and inputs may be estimated using a mass balance approach using data for the river/reservoir segments and other tributary/groundwater measurements.
Statistical estimates	All inputs and model parameters	Averages, medians, specific quantiles, or distributions based on other available data from the system or from peer-reviewed literature may be used to estimate missing inputs and parameters. These estimates may be based on unweighted or weighted (e.g., drainage area, drainage area ratio, watershed size, reach length) estimates
Interpolation	All inputs and model parameters	Methods such as linear and nonlinear regression, logistic regression, and general additive models may be used to interpolate input and parameter estimates using available data for system or from peer-reviewed literature. Interpolation is generally more acceptable than extrapolation because estimates fall within the range of available data for use in the model system.
Extrapolation	All inputs and model parameters	Methods such as linear and nonlinear regression, logistic regression, and general additive models may be used to extrapolate input and parameter estimates using available data for system or from peer-reviewed literature. Extrapolation is

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		generally less acceptable than extrapolation because it assumes that patterns in data are similar beyond the range of available data for us in the model system.
Flow-probability-probability-flow (QPPQ)	Tributary flows	The flow-probability-probability-flow (QPPQ) method makes use of relating flow duration curves between a gauged tributary and an ungauged tributary. The flow duration curve at ungauged sites is estimated using regression and the online USGS tool StreamStats.
Adiabatic adjustment	Air temperature	Air temperature can vary throughout a watershed due to elevation, network, azimuth, and other factors. Air temperature inputs to watershed and water quality models may be adjusted using an equation that scales measurements from a meteorological station to another elevation using the dry adiabatic lapse rate of $-9.8\text{ }^{\circ}\text{C}/\text{km}$ elevation increase.
GIS Data	Channel geometry, watershed topography and orientation, elevation, land cover, point sources, nonpoint sources	Several landscape scale GIS data sets can be used to derive model inputs and parameters. Digital orthophotos or satellite imagery may be used to classify landcover and estimate vegetation type, height, density, and overhang. These images may also be used to determine stream position, stream aspect, and channel width. A digital elevation model consists of digital information that provides a uniform matrix of terrain elevation values. GIS information on pollutant sources, including point and nonpoint sources, may be used to estimate pollutant loads the model domain.

Identification of data gaps will serve as a basis for the study designs for monitoring and reporting during implementation of the TMDL. Data collected during implementation may be

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used to refine model predictions and update the TMDL in the future as part of the adaptive management cycle.

## 5.7 Assumptions

Assumptions for modeling mercury cycling and food web incorporation in the Snake River include those related to modeling eutrophication processes in the riverine and reservoir AUs, those for controlling kinetics of mercury cycling, and those influencing bioaccumulation and biomagnification of methylmercury in the food web model.

Assumptions in the CE-QUAL-W2 model include the designation of inorganic suspended solids (ISS) groups, the way in which organic matter is represented, stoichiometric relationships that drive nutrient limitation, and factors influencing rate parameters, particularly in the mercury sub model (Wells, Garstecki, et al. 2025; Wells, Zhang, et al. 2025). In the FweB4 model, assumptions that may influence model outputs include the proportion of diet items for each consumer over time and by life stage and environmental constraints (e.g., temperature kinetics and oxygen consumption) on growth (Appendix A).

Sensitivity analysis and scenario testing will provide quantitative information on influences of specific assumptions, including model structure and the relationships among parameters. Feedback from internal DEQ staff and external subject experts will also be used to evaluate assumptions. All assumptions in model development, testing, and calibration will be documented in technical reports describing development, calibration, and scenario testing.

## 5.8 Model calibration

Calibration of the CE-QUAL-W2 model, including the mercury sub model, will rely on comparisons of model outputs to observed data and published literature. The calibration process may seek to minimize the difference between model predictions and observed data for all outputs together, not individually, to avoid optimizing outputs for one parameter that may result in inaccurate representation of the modeled system.

Calibration of the mercury sub model may also use a weight of evidence approach by comparing fit between model outputs and observed data and agreement with published literature on the modeled process. External feedback from subject matter experts may also be considered. Criteria used to determine sufficient model calibration for the CE-QUAL-W2 model and mercury sub model will be documented in technical reports.

As with the mercury sub model, calibration of the modified FweB4 model will consider a weight of evidence approach with feedback from external subject matter experts. Visual comparisons of modeled and measured data and goodness-of-fit statistics will provide initial assessments of model calibration. Feedback from subject matter experts will be used in combination with the

initial calibration assessment to determine sufficiency of model calibration. The calibration assessment will be detailed in technical reports.

## 5.9 Model parameters

### 5.9.1 CE-QUAL-W2

Constituents modeled by CE-QUAL-W2 and the companion sub model for mercury are listed in Table 6. A full listing of rates and equations used to simulate these constituents may be found in user guides and technical reports for the models (Wells 2023; Wells, Zhang, et al. 2025).

**Table 6. Constituents and constituent interactions in the CE-QUAL-W2 model to be used for the Snake River Mercury TMDL.**

Constituent	Constituent Interaction
Total dissolved solids Generic constituents Inorganic suspended solids Mine fine tailings	No interactions with phytoplankton, nutrients, or dissolved oxygen dynamics
Dissolved inorganic phosphorus Ammonium Nitrate-nitrite Dissolved silica Particulate biogenic silica Total metals (Iron) Labile dissolved organic matter Labile dissolved organic nitrogen Labile dissolved organic phosphorus Refractory dissolved organic matter Refractory dissolved organic nitrogen Refractory dissolved organic phosphorus Labile particulate organic matter Labile particulate organic nitrogen Labile particulate organic phosphorus Refractory particulate organic matter Refractory particulate organic nitrogen	Affecting phytoplankton, nutrients, or dissolved oxygen dynamics

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Constituent	Constituent Interaction
Refractory particulate organic phosphorus Carbonaceous Biochemical Oxygen Demand Carbonaceous Biochemical Oxygen Demand – nitrogen Carbonaceous Biochemical Oxygen Demand – phosphorus Dissolved oxygen Zooplankton Phytoplankton Manganese ion (Mn <sup>2+</sup> ) Iron (Fe <sup>2+</sup> ) Manganese oxide (MnO <sub>2</sub> (s)) Iron oxide (FeOOH(s)) Methane (CH <sub>4</sub> ) Hydrogen sulfide (H <sub>2</sub> S)	
Epiphyton Periphyton Organic sediments Sediment carbon Sediment nitrogen Sediment phosphorus Sediment iron Sediment manganese Sediment methane Sediment hydrogen sulfide Macrophytes	Interact with phytoplankton, nutrients, or dissolved oxygen dynamics but are not transported
Total inorganic carbon (water column) Total inorganic carbon (sediments) Alkalinity (water column) Alkalinity (sediments)	May be transported and necessary for computing pH and carbonate species

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Constituent	Constituent Interaction
Elemental mercury (Hg <sup>0</sup> ) Freely dissolved inorganic mercury (Hg <sup>2+</sup> ) Dissolved organic carbon-inorganic mercury Total dissolved inorganic mercury Total phytoplankton-inorganic mercury Labile organic carbon-inorganic mercury Refractory organic carbon-inorganic mercury Total suspended solids-inorganic mercury Dissolved methylmercury Dissolved organic carbon-methylmercury	Mercury in the water column
Freely dissolved inorganic mercury (Hg <sup>2+</sup> ) in porewater Dissolved organic carbon-inorganic mercury in porewater Organic solids-inorganic mercury in sediment Total inorganic solids-inorganic mercury in sediment Dissolved methylmercury in porewater Dissolved organic carbon-methylmercury in porewater Organic solids-methylmercury in sediment Total inorganic solids-methylmercury in sediment	Mercury in sediment layer

The mercury sub model (Appendix B) simulates transfer of mercury among elemental, oxidized inorganic, and methylmercury forms in the water column and sediment layer within the aquatic system (Figure 4). Rates vary according to organic carbon levels, photosynthetically active radiation, pH, water temperature, dissolved oxygen (methylation not based on carbon turnover only), water depth, and water velocity (Wells, Zhang, et al. 2025).

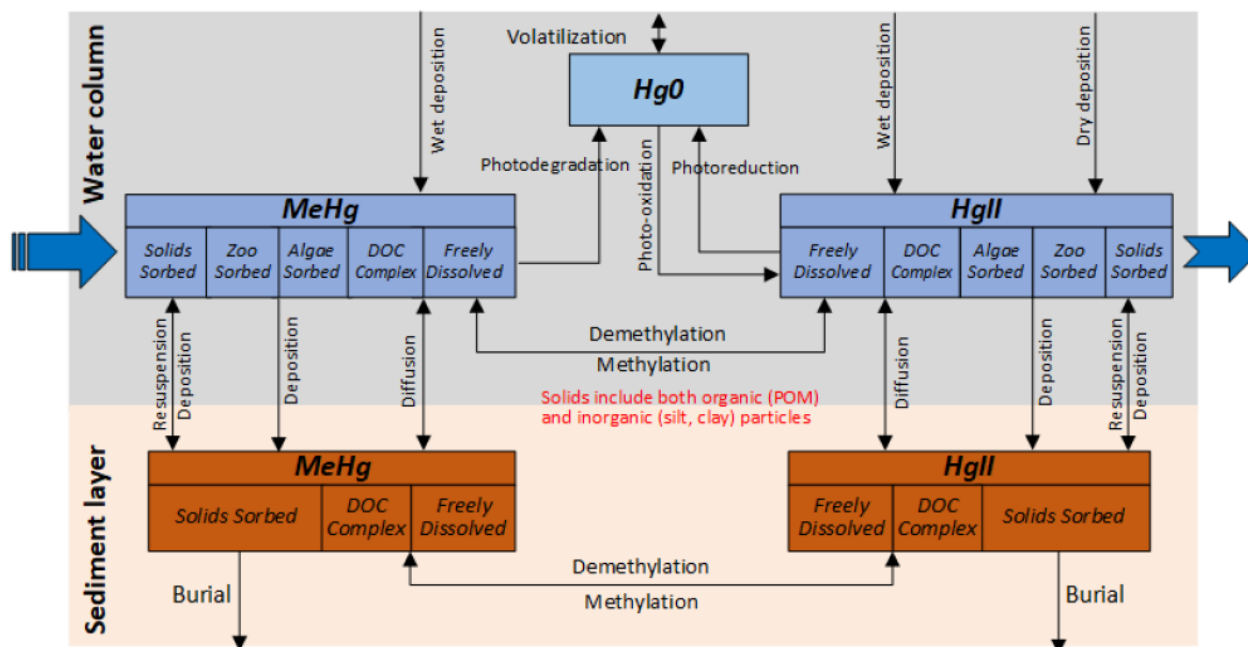


Figure 4. Mercury cycling processes represented in the sub model of CE-QUAL-W2 (Wells, Zhang, et al. 2025).

### 5.9.1.1 Water column

The mercury sub model simulates concentrations of three forms of mercury in the water column: dissolved elemental mercury, oxidized inorganic mercury, and methylmercury. The governing equation for all water column constituents is the laterally averaged 2-D advective-diffusion equation:

$$\text{Equation 1: } \frac{\partial B\Phi}{\partial t} + \frac{\partial UB\Phi}{\partial x} + \frac{\partial WB\Phi}{\partial z} - \frac{\partial}{\partial x} \left[ BD_x \frac{\partial \Phi}{\partial x} \right] - \frac{\partial}{\partial z} \left[ BD_z \frac{\partial \Phi}{\partial z} \right] = q_\Phi B + S_\Phi B$$

where:

- $\Phi$  = laterally averaged Hg constituent concentration,  $\mu\text{g m}^{-3}$
- $D_x$  = longitudinal temperature and constituent dispersion coefficient,  $\text{m}^2 \text{sec}^{-1}$
- $D_z$  = vertical temperature and constituent dispersion coefficient,  $\text{m}^2 \text{sec}^{-1}$
- $q_\Phi$  = lateral inflow or outflow mass flow rate of constituent per unit volume,  $\mu\text{g m}^{-3} \text{sec}^{-1}$
- $S_\Phi$  = laterally averaged source/sink term,  $\mu\text{g m}^{-3} \text{sec}^{-1}$ .

The CE-QUAL-W2 User Manual (Wells 2023) describes how the velocity field and dispersion coefficients are computed and solved numerically.

Dissolved inorganic mercury and methylmercury are each grouped into two components, those bound to DOC and solids and those freely dissolved. Inorganic mercury and methylmercury are found in multiple types of solids: refractory particulate organic matter (RPOM), labile particulate matter (LPOM), inorganic suspended solids groups, algae groups, and zooplankton groups. The model will also be updated to include inorganic and methylmercury complexed with iron and manganese. The model computes distributed concentrations of total (unfiltered) inorganic mercury and methylmercury in the water column as derived variables in the CE-QUAL-W2. In the current application, two inorganic suspended solids groups have been assumed: fine and coarse (but the current model framework is not limited to only two components). See Appendix B for a full list of inorganic mercury and methylmercury components, transformation processes, and equilibrium partitioning/distribution in the sub model.

Methylation and demethylation of mercury may be represented in the sub model as a function of carbon turnover or as dependent on anoxia and temperature. Equations detailing the representations may be found in Appendix B.

#### **5.9.1.2 Sediment-water interface**

Dissolved mercury species in the bed sediment can transfer across the sediment-water interface, or vice versa. The mass transfer velocity ( $v_m$ ) of inorganic mercury and methylmercury across the sediment-water interface can be either a user specified parameter (constant over time and space) or determined from the sediment diagenesis model which computes the diffusion velocity from the water to the aerobic layer and from the aerobic to the anaerobic layer. To compute an average velocity from the bed to the water column, an overall velocity based on resistance model in series to compute the average velocity. The model user can scale that velocity for use in the mercury model. From the sediment diagenesis model, the sediment transfer velocity from the aerobic layer to the water, the porewater diffusion velocity (from anaerobic layer to aerobic layer) and the particle mixing velocity (accounting for bioturbation) are used to compute an average sediment-water transfer velocity. Appendix B provides details on the processes and equations governing the sediment-water interface in the sub model.

#### **5.9.1.3 Methylmercury**

The following six processes are simulated for water column methylmercury:

- Methylation
- Photodegradation
- Volatilization
- Biological demethylation
- Settling of sorbed fractions
- Diffusion across the sediment-water interface

The internal source and sink rate equation for the total concentration of methylmercury in the water column is:

**Equation 2:**  $\frac{d[MeHg]}{dt} =$   
 $-MeHg \rightarrow Hg^0$     $-MeHg \rightarrow Hg^{2+} + Hg^{2+} \rightarrow MeHg$     $-MeHg \rightarrow Bed$     $-MeHg \leftrightarrow Bed$     $+ S_{atm\_dep\_MeHg}$   
 photodegradation   demethylation   methylation   settling   diffusion

where  $S_{atm\_dep\_MeHg}$  is the atmospheric deposition source term for the surface layer only. Advective and dispersive fluxes in x and z within the water column are part of the CE-QUAL-W2 hydrodynamic modeling framework (Wells 2023). Specific processes are described in detail in Appendix B.

## 5.9.2 FweB4

FweB4 models bioaccumulation of contaminants using mass balance in terms of bioenergetics for specific fish species (Appendix A). Consumption (C) represents balance of metabolism (R), energy spent on activity (A), specific dynamic action (SDA), egestion (F), excretion (U), and growth (G):

**Equation 3:**      $C = R + A + SDA + F + U + G$

FweB4 expands on the FB4 model (Deslauriers et al. 2017) by simulating multiple cohorts and fish species simultaneously and linking methylmercury in the water column to fish tissue concentrations for specific length (Appendix A).

There are three basic types of input parameters in FweB4:

- Site conditions, including temperature, dissolved oxygen, methylmercury concentrations in the water column, and mercury content of prey.
- Bioenergetics constants related to species specific fish energy budgets, fish growth rates, and fish diets. Default values for a wide range of fish species are included in the FB4 model (Deslauriers et al. 2017).
- Rates related to methylmercury dynamics in fish species.

Methylmercury uptake by individual fish ( $U_D$ ) is represented as:

**Equation 4:**      $U_D = (C * W) * Prey_{Hg} * AE$

Where  $C$  is the weight-specific consumption rate (g/g ww/d),  $W$  is the fish weight (g ww),  $Prey_{Hg}$  is the diet-weighted mean concentration of mercury in prey (ug/g ww), and  $AE$  is the diet-weighted gross assimilation efficiency of Hg in prey (unitless) (Appendix A).

Uptake from water across the fish's gills ( $U_{Aq}$ ) is calculated as:

**Equation 5:**      $U_{Aq} = W * K * UF * MeHg_{D.Aq}$

Where  $W$  is the weight of the fish (g ww),  $K$  is the water flow across the gills (L/g/day),  $UF$  is the contaminant uptake efficiency across the gills (unitless), and  $MeHg_{D.Aq}$  is the dissolved concentration of methylmercury in water (ug/L) (Appendix A). Methylmercury uptake through

gills generally represents a small fraction of total methylmercury uptake as compared to dietary uptake (Deslauriers et al. 2017).

Water flow across the gills ( $K$ ) is calculated by the model based on the fish's bioenergetic oxygen demand (Deslauriers et al. 2017).

**Equation 6:** 
$$K = \frac{Req.O_2}{Conc.O_2}$$

Where  $Req.O_2$  is the oxygen required by the fish (mg  $O_2$ /g/day) and  $Conc.O_2$  is the oxygen concentration in water (mg  $O_2$ /L).

Methylmercury clearance ( $Clear$ ) is calculated following the empirical relationship implemented in FB4 (Deslauriers et al. 2017):

**Equation 7:** 
$$Clear = MeHg_{Fish} * e^{(0.066 T - 0.20(\ln(W)) - 6.56)} * M$$

Where  $MeHg_{Fish}$  is the burden of methylmercury in the fish (ug),  $T$  is temperature (Celsius),  $W$  is the weight of the fish (g ww), and  $M$  is a contaminant clearance multiplier (unitless). By default,  $M$  should be set to one, but is included to allow users to manually increase or decrease clearance rates if necessary to better fit field data or other empirical expectations.

An alternative formulation of methylmercury clearance equation is included in FweB4, which models clearance as a function of excretion.

**Equation 8:** 
$$Clear = \frac{Ex}{E} * MeHg_{Fish} * M$$

Where  $Ex$  is nitrogenous waste excretion (J /g bw / day),  $E$  is the energy density of the fish (J / g),  $MeHg_{Fish}$  is the burden of methylmercury in the fish (ug), and  $M$  is a contaminant clearance multiplier (unitless).

## 6. Model evaluation and acceptance

The CE-QUAL-W2 and FweB4 models developed for the Snake River Mercury TMDL will be evaluated and accepted for use in implementation through the following steps. Model evaluation will include testing model performance with new data, evaluating plausibility of scenarios, and feedback from subject matter experts and the public. Model acceptance will be determined using weight of evidence based on objective model testing and input from external reviews.

### 6.1 Model uncertainty and sensitivity

Model uncertainty describes the combined influence of sampling errors, model structural uncertainty, and predictive uncertainty in model outputs. Sampling errors include those associated with the sampling process in the field and with laboratory analyses (e.g., limits of detection). Structural model uncertainty results from imperfect representation of system dynamics in the model or from the choice of mathematical equations in the model. Predictive

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uncertainty results from imperfect replication of calibration and validation data, which may be characterized by goodness-of-fit statistics comparing model outputs with observed data. For the CE-QUAL-W2 and FweB4 models used in the Snake River Mercury TMDL, these sources of uncertainty will be documented and quantified in technical reports.

Model sensitivity refers to the influence of systematic changes to one or a related set of parameters on model outputs. Changes to “sensitive” parameters result in large changes in model outputs whereas changes to “insensitive” parameters result in minimal changes on model outputs. Identification of “sensitive” parameters allows for the selection and evaluation of alternative management scenarios and provides a basis for the development of monitoring plans for use in adaptive management.

Sensitivity of selected parameters for the CE-QUAL-W2 model will be made in consultation with Dr. Scott Wells of Portland State University (current model steward). From previous CE-QUAL-W2 models, DEQ anticipates testing the sensitivity of meteorological parameters, hydrodynamic parameters, parameters associated with phosphorus and other nonpoint source pollutants, and mercury methylation parameters on model outputs. Other parameters may also undergo sensitivity analyses as needed. Overall influences of parameter uncertainty and sensitivity may be evaluated using PEST (<https://pesthompage.org/>), a software package that automates analysis of highly parameterized models, or other Bayesian statistical techniques.

Sensitivity analyses of the FweB4 model will encompass all parameters used for model simulations. Sensitivity analyses will be performed by systematically varying one parameter or sets of related parameters for individual model runs. Overall effects of parameter uncertainty and sensitivity may be evaluated using PEST (<https://pesthompage.org/>) or other Bayesian techniques.

## 6.2 Model acceptance

The “acceptance” of the CE-QUAL-W2 and FweB4 models for use in the Snake River Mercury TMDL will be determined based on the following criteria. Please note that “acceptance” does not mean “final” as these models may be further modified and refined in the adaptive management cycle of TMDL implementation.

1. Incorporation of data determined useful for the time frame of model development, calibration, and scenario testing. This will include a comprehensive review of data, regional studies, and peer-reviewed literature.
2. Reasonable estimation methods and assumptions to fill gaps in the observations. This will include use of peer reviewed methods for consideration of missing/censored data.
3. Calibration of model parameters and unmeasured boundary conditions within reasonable bounds to improve agreement between simulated and observed water quality. This may include comparing model predictions to data not used in model

development, use of methods such as PEST (<https://pesthompage.org/>), or consultation with subject matter expert.

4. Identification of key parameters and processes through model calibration and sensitivity analysis. This may be done through consultation with subject matter experts, use of methods such as PEST (<https://pesthompage.org/>), or other peer reviewed methods.
5. Communication of key assumptions during model development. This will be accomplished through internal meetings with the project team and agency leadership and external meetings with the regulated community, local advisory groups, and the public.
6. Clear written documentation of all important elements in the model, including model setup, boundary conditions, assumptions, and known areas of uncertainty. This will include the material provided in this QAPP, Technical Support Documents, and final TMDL documents.
7. Peer review described in Section 8.

## 7. Documentation of model reports

The documentation of the CE-QUAL-W2 and FweB4 models will occur in stages throughout the project. The QAPP will serve as the first document for the project. Additional documents will include technical memos describing data analysis, statistical model, and a technical report describing model setups, model calibration results, model scenario setup, and model scenario results. Documentation will also include presentations made to external groups, including subject matter experts, advisory committees, and the public.

The technical report will include:

- Details on the calibrated model domain and layout
- Spatial and temporal resolution
- Timeframe of simulation
- Summary of data used for model inputs
- Summary of methods used to fill data gaps
- Summary of data used for calibration
- Time series plots comparing observed and model predictions
- Goodness-of-fit statistics
- Description of management scenarios
- Methods and data sources used to set up scenarios
- Summaries of scenario results

## 8. Peer review

All phases and documents of modeling for the Snake River Mercury TMDL will undergo at least one level of peer review. These reviews may consist of internal DEQ review, review by EPA Region 10, external review by subject matter experts from universities or independent

organizations, the TMDL advisory committee, or some combination of these entities. The scope of the requested reviews will vary by the stage of the project and material sent for review. DEQ will consider feedback on model scenarios and results provided by the TMDL technical advisory committee and may make changes as appropriate.

## **9. Management scenarios**

Management scenarios evaluated by the models will be guided by the methylmercury loads required to meet the human health and aquatic life criteria in all AUs covered by the TMDL. Management scenarios will also be set according to critical conditions to ensure that actions taken are designed to achieve the criteria across a wide range of plausible conditions. DEQ will identify, evaluate, and choose which management scenarios to use for setting allocations and TMDL implementation. Contractors may be used to conduct scenario analyses. However, all decisions related to the TMDL will rest with DEQ.

### **9.1 Existing conditions**

This scenario will use the calibrated models to characterize the range of conditions leading to contemporary methylmercury loads for individual AUs in the project area. These loads will be used in conjunction with other scenarios to determine reductions and managements actions required to attain water quality standards. This scenario will rely on the time series of flow and water quality conditions measured from 2014-2018 and inputs generated from methods in Table 5.

### **9.2 Critical conditions**

This scenario will use the calibrated models to characterize critical conditions that influence methylmercury loads for individual AUs in the project area. Critical conditions evaluated include those that may result from individual or combined effects of extreme low flows (7Q10), extreme high flow based on historical data, high rates of pollutant loads observed or expected based on literature reviews, expected or observed extremes of river and reservoir temperature regimes, and extreme scenarios of food web structure and composition based on observed or expected changes in biological communities. The critical conditions scenario will be used as the baseline scenario for identifying water column and sediment methylmercury targets (Section 9.3) and evaluating reductions from specific sources (Sections 9.4-10).

### **9.3 Identify load targets**

This scenario will determine the methylmercury loads required for individual AUs to attain human health and aquatic life criteria. Loads will be determined by using species specific bioaccumulation factors in the FweB4 model. Species specific bioaccumulation factors will incorporate expected stream temperature regimes achieved through implementation of the

Snake River Temperature TMDL and critical conditions (Section 9.2). Target loads will be used to evaluate other management scenarios with the CE-QUAL-W2 model.

## **9.4 Reductions in point sources**

This scenario will examine individual and cumulative effects of reducing point source inputs of mercury and other pollutants from Oregon in comparison to the methylmercury loads required to meet the human health criterion for fish tissue (Scenario 9.39.3) while holding other loadings and environmental conditions constant to the critical conditions scenario (Section 9.2).

Reduction scenarios may also include setting allocations to zero for one or more point source inputs.

## **9.5 Reductions in loadings from Oregon tributaries**

This scenario will examine individual and cumulative effects of reducing inputs of mercury, methylmercury, and other pollutants from Oregon tributaries in comparison to the methylmercury loads required to meet the human health criterion for fish tissue (Scenario 9.39.3) while holding other loadings and environmental conditions constant to the critical conditions scenario (Section 9.2). Reduction scenarios may include setting loadings from one or more anthropogenic sources to zero in individual tributaries.

## **9.6 Reductions in nonpoint loadings directly to riverine and reservoir assessment units**

This scenario will evaluate individual and cumulative effects of reducing inputs of mercury, methylmercury, and other pollutants from minor tributaries, agricultural return flows, and nonpoint source runoff from Oregon in comparison to the methylmercury loads required to meet the human health criterion for fish tissue (Scenario 9.39.3) while holding other loadings and environmental conditions constant to the critical conditions scenario (Section 9.2).

## **9.7 Reductions in background sources**

This scenario will evaluate individual and cumulative effects of reducing inputs of mercury, methylmercury, and other pollutant loads from background sources, which includes non-anthropogenic inputs from Oregon and inputs (both natural and anthropogenic in origin) coming from outside Oregon's jurisdictional boundaries (OAR 340-042-0030(1)), in comparison to the methylmercury loads required to meet the human health and aquatic life criteria (Scenario 9.39.3) while holding other loadings and environmental conditions constant to the critical conditions scenario (Section 9.2). For the Snake River Mercury TMDL, sources beyond Oregon's jurisdiction include those originating from atmospheric emissions beyond the state's

border and those originating from land-based sources of mercury, methylmercury, and other pollutants along the Snake River in Idaho, Idaho tributaries to the Snake River, and point source inputs to the Snake River permitted by Idaho.

## **9.8 Reduction of methylmercury originating from riverine assessment units**

This scenario will evaluate reductions in methylmercury production, transport, and retention in riverine AUs of the Snake River, which may contribute significantly to the system (Krause et al. 2024), in comparison to methylmercury loads required to meet the human health criterion for fish tissue (Scenario 9.39.3) while holding other loadings and environmental conditions constant to the critical conditions scenario (Section 9.2). The scenario will include reductions in loadings of total mercury loading and other pollutants that facilitate the production of methylmercury as well as the modification of riparian and aquatic habitats that act as locations of methylmercury production and facilitate the transfer of methylmercury into aquatic food webs. Reduction scenarios may include elimination of loadings from anthropogenic sources and restoration of riparian and aquatic habitats.

## **9.9 Reduction of methylmercury originating from reservoir assessment units**

This scenario will evaluate reductions in methylmercury production, transport, and retention in the three major reservoir sections of the Snake River: Brownlee, Oxbow, and Hells Canyon reservoirs in comparison to methylmercury loads required to meet the human health and aquatic life criteria (Scenario 9.39.3) while holding other loadings and environmental conditions constant to the critical conditions scenario (Section 9.2). The three reservoirs, particularly Brownlee, exert considerable influence on methylmercury dynamics in riverine AUs downstream (Baldwin et al. 2020; Willacker et al. 2023a). The scenario will include reductions in loadings of total mercury loading and other pollutants that facilitate the production of methylmercury (e.g., anoxia) in the reservoirs. The goal of this scenario is to isolate the influences of reservoir dynamics on bioaccumulation and biomagnification of methylmercury in reservoir and downstream riverine food webs from the influence of reducing nonpoint and point sources of mercury and other pollutants.

## **9.10 Management of aquatic food webs**

This scenario will evaluate influences of changes to aquatic food webs on methylmercury bioaccumulation in target species in riverine and reservoir AUs of the Snake River in comparison to methylmercury loads required to meet the human health and aquatic life criteria (Scenario 9.39.3) while holding other loadings and environmental conditions constant to the critical conditions scenario (Section 9.2). Changes may include reduction or elimination of

invasive species, alteration of the food base in riverine AUs downstream of Hells Canyon Reservoir (e.g., restoring anadromous salmon returns to higher levels than current levels), or other bottom-up or top-down food web alterations.

## 9.11 Attainment scenarios

These scenarios will adjust the calibrated model to determine loads of mercury, methylmercury, and other pollutants as well as reservoir and other environmental conditions required to meet the human health and aquatic life criteria (Scenario 9.3). The attainment scenario will consider critical conditions that may result from individual or combined effects of extreme low flows (7Q10), extreme high flows, high rates of pollutant loads, river and reservoir temperature regimes, and food web characteristics. Model conditions that may also be varied to determine attainment include boundary conditions for flow, meteorological conditions, water temperature, mercury loading, nutrient loading, and other pollutant loadings from point and nonpoint sources (Sections 9.4-10). Combinations of scenarios may be selected by the project team and in consultation with subject matter experts.

## 10. Project organization

### 10.1 Project team/roles

Table 7. The Roles and responsibilities of team members involved in the Snake River Mercury TMDL.

Name(s)	Position	Role and Responsibilities
Steve Mrazik	Manager, Watershed Management, Oregon DEQ	Sponsor <ul style="list-style-type: none"> <li>• Provide support to team and project manager.</li> <li>• Review and approve project products.</li> <li>• Maintain support of decision makers at their level.</li> <li>• Remove roadblocks to achieving project objectives.</li> <li>• Approve changes to project scope, budget, or timelines.</li> <li>• Communicate progress to other managers, administrators, and Director.</li> <li>• Provide periodic review of project status.</li> <li>• Ensure communications with project members affected by administrative changes.</li> </ul>

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Name(s)	Position	Role and Responsibilities
Michele Martin/Amanda Ondrick	Project Manager, Oregon DEQ	<p>Project Manager</p> <ul style="list-style-type: none"> <li>• Establish regular meetings to keep management (regional and headquarters) and sponsor informed about project.</li> <li>• Develop project charter with team input.</li> <li>• Establish file sharing structure for meetings, document sharing, and project planning documents:               <ul style="list-style-type: none"> <li>○ Develop project plan, including major tasks, milestones, project schedule, and communication plan.</li> <li>○ Develop team meeting agendas in consultation with members.</li> <li>○ Document meeting decisions and notes, keep track of team ideas, refer to decision rights.</li> </ul> </li> <li>• Assign project tasks and deadlines for team members.</li> <li>• Track outcomes and deliverables.</li> <li>• Sustain engagement of team members and team performance</li> <li>• Lead team closeout of project and document lessons learned</li> </ul>
Tyler Dearman  Amanda Ondrick  Vanessa Rose	Basin Coordinator, Oregon DEQ  Basin Coordinator, Oregon DEQ  401 WQC and Hydropower Specialist, Oregon DEQ	<p>Regional Coordinators</p> <ul style="list-style-type: none"> <li>• Facilitate meetings, effective meeting management</li> <li>• Provide feedback and leadership in the development of meeting</li> </ul>

Name(s)	Position	Role and Responsibilities
		agendas, activities during meetings, and tasks <ul style="list-style-type: none"> <li>• Provide feedback on project planning and design</li> <li>• Develop team meeting agendas</li> <li>• Develop communications plan for external engagement</li> <li>• Control project scope (with Technical Lead)</li> <li>• Coordinate team communication: Emails, SharePoint, shared drives</li> <li>• Coordinate engagement with WA and ID colleagues, as needed</li> <li>• Review QAPP and TMDL</li> <li>• Write WQMP and implementation documents</li> <li>• TMDL Advisory Committee coordinator</li> <li>• Participate and present at TMDL public meetings</li> <li>• Respond to public comments</li> </ul>
Daniel Sobota	Senior Water Quality Analyst, Watershed Management, Oregon DEQ	Project Technical Lead <ul style="list-style-type: none"> <li>• Lead, oversee, and direct development of the project QAPP</li> <li>• Coordination with EPA and contractors</li> <li>• Lead, oversee, and direct DEQ technical staff and technical contractors</li> <li>• Oversee model calibration and evaluation</li> <li>• Run model scenarios</li> <li>• Analyze and interpret model results</li> <li>• Lead, oversee, and direct document writing</li> <li>• Participate and present at TMDL public meetings</li> <li>• Respond to public comments</li> </ul>
Yuan Grund	Water Quality Analyst, Watershed	Technical support

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Name(s)	Position	Role and Responsibilities
	Management, Oregon DEQ	<ul style="list-style-type: none"> <li>• Perform data evaluation and compilation</li> <li>• Develop GIS maps and web applications</li> <li>• Run model scenarios</li> <li>• Analyze and interpret model results</li> <li>• Support TMDL document development</li> <li>• Participate in TMDL public meetings</li> <li>• Respond to public comments</li> </ul>
Kevin Brannan	Senior Water Quality Analyst, Watershed Management, Oregon DEQ	Technical support <ul style="list-style-type: none"> <li>• Perform data evaluation</li> <li>• Conduct literature reviews</li> <li>• Research and interpret rules, regulations, laws, agency guidance and agency procedures</li> <li>• Consult on model scenarios</li> <li>• Analyze and interpret model results</li> <li>• Review project documents</li> <li>• Participate and present at TMDL public meetings</li> <li>• Respond to public comments</li> <li>• Assist with project needs</li> </ul>
Erica Figliulo	DEQ Agency QA Officer, Oregon DEQ	Review QAPP
Anika Marriott	Oregon Department of Justice	Legal Counsel
Justin Sterger	Water Quality Specialist, Oregon DEQ	<ul style="list-style-type: none"> <li>• Project team point of contact to NPDES permit program and permittees</li> <li>• Review wasteload allocations</li> </ul>
Rebecca Veiga-Nascimento	EPA Region 10	TMDL coordinator <ul style="list-style-type: none"> <li>• Review QAPP and other TMDL documents</li> <li>• Provide feedback for TMDL approval</li> </ul>
Lisa Kusnierz	EPA Region 10	TMDL reviewer

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Name(s)	Position	Role and Responsibilities
		<ul style="list-style-type: none"> <li>Review QAPP</li> <li>Review work products, as needed</li> </ul>
Chris Eckley	EPA Region 10	Subject Matter Expert <ul style="list-style-type: none"> <li>Review QAPP</li> <li>Review technical results</li> <li>Provide consultation on mercury and methylmercury science</li> </ul>

**Table 8. The Roles and responsibilities technical collaborators involved in the Snake River Mercury TMDL modeling.**

Name	Position	Role and Responsibilities
Colin Eagles-Smith Austin Baldwin	USGS	<ul style="list-style-type: none"> <li>Lead, oversee, and direct field studies</li> <li>Provide feedback on model development and data interpretation</li> <li>Participate and present to advisory committees as needed</li> </ul>
Scott Wells	Portland State University (Contractor)	<ul style="list-style-type: none"> <li>Develop and configure water quality model (CE-QUAL-W2)</li> <li>Perform model calibration/evaluation</li> <li>Run model scenarios</li> </ul>
Reed Harris	Reed Harris Environmental Ltd. (Contractor)	<ul style="list-style-type: none"> <li>Consult on food web model</li> <li>Provide subject matter expertise on methylmercury biomagnification in food webs</li> </ul>
Jay Hesse	Nez Perce Tribe	<ul style="list-style-type: none"> <li>Consult on project scope and schedule</li> <li>Provide technical and policy feedback on proposed TMDL models, scenarios, and results</li> </ul>
TMDL advisory committee	This TMDL will have an advisory committee	<ul style="list-style-type: none"> <li>Participate in TMDL advisory committee meetings</li> <li>Provide input to DEQ on TMDL and WQMP elements</li> </ul>

## 10.2 Expertise and special training requirements

Expertise required for this project includes proficiency in:

- Water quality data analysis
- Water quality modeling
- Watershed modeling
- GIS analysis
- Statistical analysis
- Aquatic food web modeling
- Mercury cycling
- Oregon Administrative Rules on TMDL development and implementation

DEQ staff and contracted entities involved in developing and configuring models, performing model calibration, running model scenarios, and analyzing model results have previous professional experience with many subject areas of the project. Additional training through universities, the EPA, or other venues may be necessary. The Project Manager has experience managing large complex projects and will ensure strict adherence to the project protocols.

## 10.3 Reports to management

The DEQ Project Manager (or designee) will provide progress reports to DEQ management and EPA as needed based on new project information. As appropriate, these reports will provide information on the following:

- Adherence to project schedule and budget.
- Deviations from approved QAPP as determined from project assessment and oversight activities
- The influence of any deviations on model application quality and uncertainty
- The need for and results of response actions to correct any deviations
- Potential uncertainties in decisions based on model predictions and data
- Data quality assessment findings regarding model input data and model outputs

## 10.4 Project schedule

Table 9. Project milestones and estimated schedule for the Snake River Mercury TMDL

Milestone	Estimated Completion
Project team assembled	March 2025
Draft QAPP completed for internal staff review	July 2025

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Milestone	Estimated Completion
Revise QAPP and have EPA Region review	September 2025
Receive feedback from Nez Perce Tribe and TMDL Technical Advisory Committee on QAPP	November-December 2025
Work with Portland State University to set up modeling contract	Fall 2025
Compile water quality, biological, and other data needed for model setup and calibration	Fall 2025
CE-QUAL-W2 model development, calibration, and testing, including calibration reports	2026
FweB4 model development, calibration, and testing, including calibration reports	2026
Scenario analyses of calibrated models	Fall 2026
Technical reviews of scenario analyses	Winter 2026-2027
Completion of model technical reports for use in TMDL development	Spring 2027

## 10.5 Data management

Data used for this modeling project will include publicly available water quality, fish tissue, flow and water levels, and spatial information on landscape and weather conditions originating from the USGS, Nez Perce Tribe, and DEQ (see Section 5.4). Data will be managed through DEQ’s Ambient Water Quality Management System (<https://www.oregon.gov/deq/wq/pages/wqdata.aspx>) and in a project folder maintained on DEQ’s Microsoft SharePoint site designated for the Snake River Mercury TMDL. DEQ will assume that data originating outside of the agency will be maintained by the entity responsible for the source of the data.

Model-generated data resulting from testing, calibration, and scenarios will be stored by DEQ in the Snake River Mercury TMDL SharePoint site. Metadata describing the content, date, and personnel involved in modeling will be documented alongside raw and summarized data. Upon completion of the Snake River Mercury TMDL, project files may be archived on DEQ’s internal servers.

## **10.6 Recordkeeping, archiving, and records retention**

All official data and documents generated during the TMDL project will be archived according to the current Oregon State Archives Records Retention Schedules. TMDL documents must be retained by the agency for 15 years after issuance.

## **10.7 QAPP review and approval**

The following sequence will be used for review and approval of this QAPP:

- Internal DEQ staff review of draft QAPP
- Incorporation internal DEQ reviews into draft QAPP
- External review of draft QAPP by EPA Region 10
- Incorporation of EPA review into draft QAPP
- Presentation and discussion of QAPP with the Nez Perce Tribe and TMDL Technical Advisory Committee
- Review of draft QAPP by DEQ leadership
- Incorporation of DEQ leadership review into draft QAPP
- Approval of QAPP by DEQ leadership

The QAPP will be presented to the technical advisory committee for the Snake River Mercury TMDL and will consider feedback but not necessarily alter content.

Official copies of the final, approved QAPP will be retained in DEQ's document control system. If any change(s) to the QAPP are required during the project, they must be described in a memorandum and approved by the signatories to this QAPP and attached to the QAPP.

## **10.8 Implementation and adaptive management**

Updates and modification to the modeling QAPP will be done as needed through communication and reviews among DEQ staff, DEQ leadership, the Nez Perce Tribe, and the EPA.

## 11. References

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## **12. Appendix A**

Attachment 1: FweB4 v1.0 - Technical Guide

R-based Model of MeHg Bioaccumulation in Aquatic Food Webs built off the Fish Bioenergetics  
4 (FB4) Model

## **13. Appendix B**

Attachment 2: Hg Model Development in CE-QUAL-W2 for the Hells Canyon Complex