Appendix C: Spokane River PCB Mass Balance Assessment Tools

Technical Memorandum

Prepared For: US EPA Region 10 Spokane and Little Spokane Rivers Polychlorinated Biphenyls Total Maximum Daily Loads TMDL Team

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Table of Contents

List of Tables

List of Figures

1 Project Description

The EPA is developing a Total Maximum Daily Load (TMDL) for total polychlorinated biphenyls (PCBs) for the Spokane and Little Spokane Rivers as required by Section 303(d) of the Clean Water Act (CWA) and its implementing regulations at Title 40 of the Code of Federal Regulations (CFR) Section 130.7. The TMDL is required because PCB concentrations exceed the Washington water quality standards based on the state's 303(d) list of impaired waters. Figure C-1 shows the TMDL study area, with starred locations showing the upstream and downstream boundaries of the TMDL project.

Under the Clean Water Act, TMDLs serve as a tool for states and the EPA to assess, and provide information needed to address, water quality impairments on a basin-wide scale. Spanning almost 100 river miles, the TMDL will identify sources of PCB loading to the Spokane River and establish the loading capacity of the river based on the water quality standards. While the TMDL will be developed to address the Washington waters of the mainstem Spokane River, the Spokane Tribe of Indians has adopted more stringent water quality standards for PCBs for the downstream portion of the river within the Spokane Tribe's jurisdiction (Figure C-2). The Washington standards establish a numeric water quality criterion (WQC) of 7.0 pg/L for total PCBs, while the Spokane Tribe's standards establish a WQC of 1.3 pg/L for total PCBs.

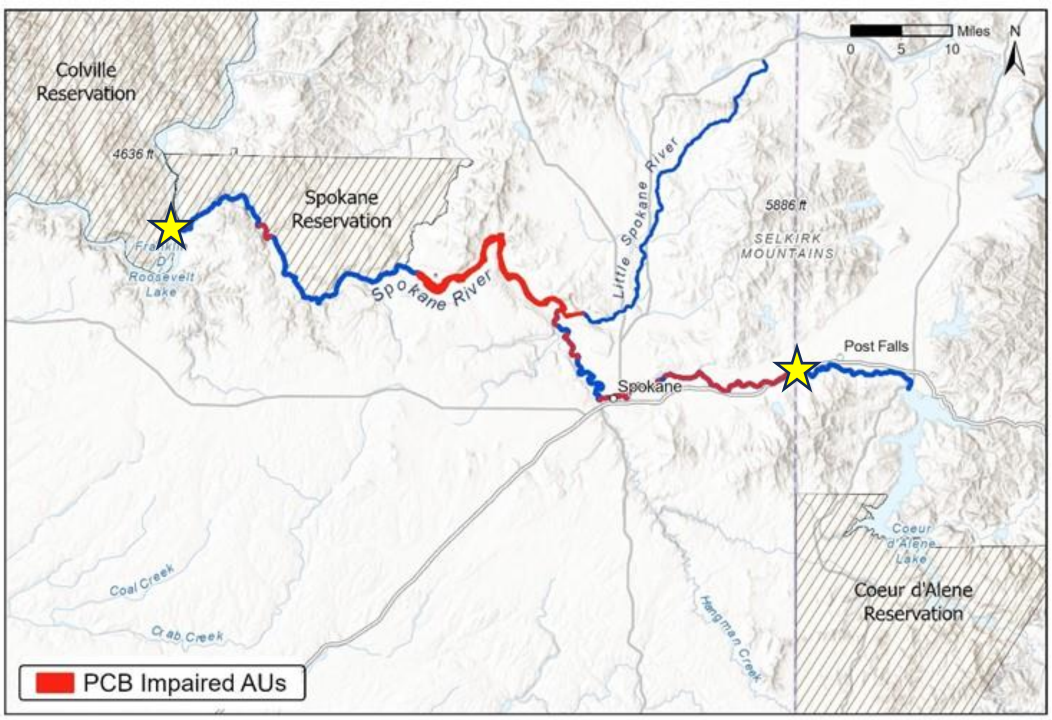

Figure C-1: TMDL study area and impaired segments based on the 2014-2018 Washington 303(d) list. Gold stars are locations of upstream and downstream boundaries of the TMDL project.

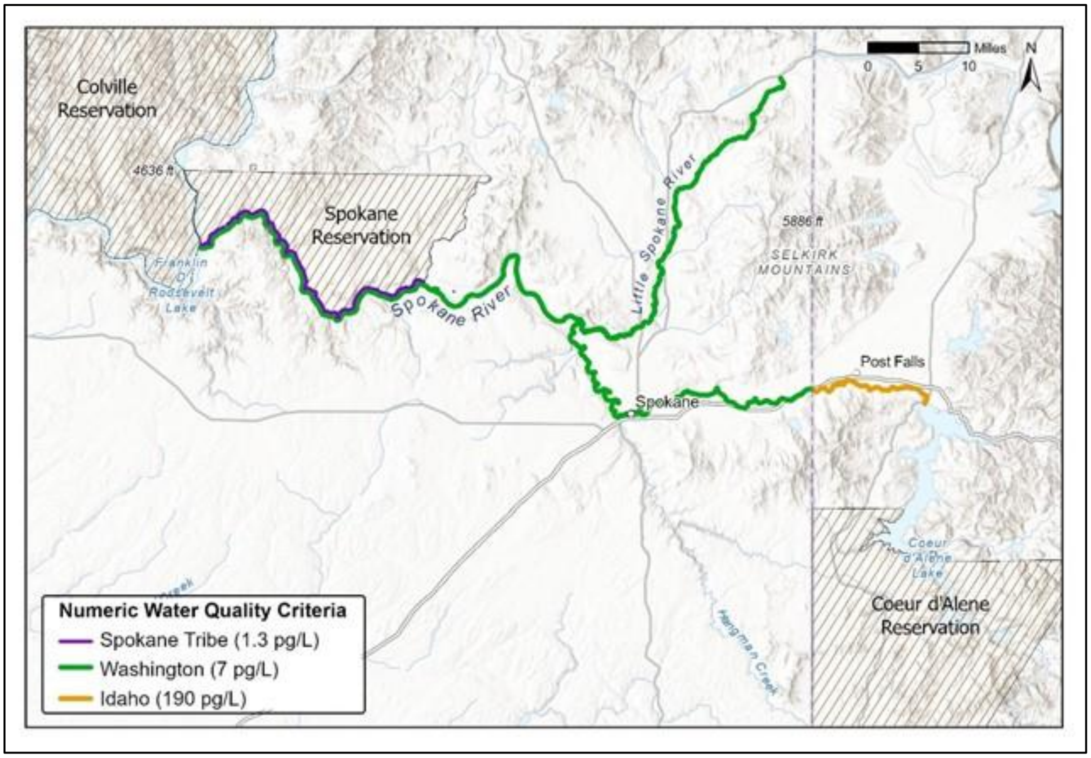

Figure C-2: Applicable total PCB criteria for the Spokane and Little Spokane rivers.

As part of the TMDL development process, EPA is applying a mass balance approach in the calculation of loading capacity and allocation alternatives. This involves two mass balance spreadsheets that assess different aspects of the PCB project.

2 Modeling Approach

The assessment tools used to support this TMDL are simple mass balance models of total PCBs in the mainstem Spokane River. The principal assumptions of the models are that total PCBs released into the river will flow downstream with no loss of instream PCBs due to mechanisms such as settling, volatilization, biological uptake, and chemical breakdown. To the extent these processes may be affecting PCB levels, the model provides conservative estimates of the impact of PCBs releases on mainstem concentrations.

2.1 Two Analytical Tools

Two separate mass balance spreadsheets were developed to address different project needs. The first spreadsheet was developed to allow exploration of different allocation approaches to achieve water quality criteria in a TMDL. The river and tributary flows are set at the design condition for the TMDL, which is the 30-year harmonic mean flow based on long-term USGS gauge data.

A second, assessment spreadsheet, is developed to evaluate the potential range of source loadings. This tool was focused on monitoring of water quality conditions and source loadings during a period (August 2014) when the Spokane River Regional Toxics Task Force (SRRTTF) conducted coordinated sampling throughout the Spokane River reach of interest.

2.2 Geographic Scope and Topology

The mass balance calculations are set up for the Spokane River mainstem from the USGS gauge station near Post Falls, Idaho (river mile 100.7) to the confluence at the Columbia River. The upstream boundary of the TMDL is downstream of the Post Falls USGS gauge at the Washington-Idaho border. The model calculates instream flow and PCB concentration at numerous locations (termed "junctions") including USGS gauge station locations, junctions where discrete inflows occur (e.g., tributary inflows and point source discharges), and key monitoring locations from past river studies.

Figure C-3 and Table C-1 show the topology of the mass balance model. Flow and PCB concentration are calculated at each junction point. All inflows are assumed to mix completely and instantaneously within the mainstem river. Screenshots of the spreadsheets are provided in Attachments 1 and 2

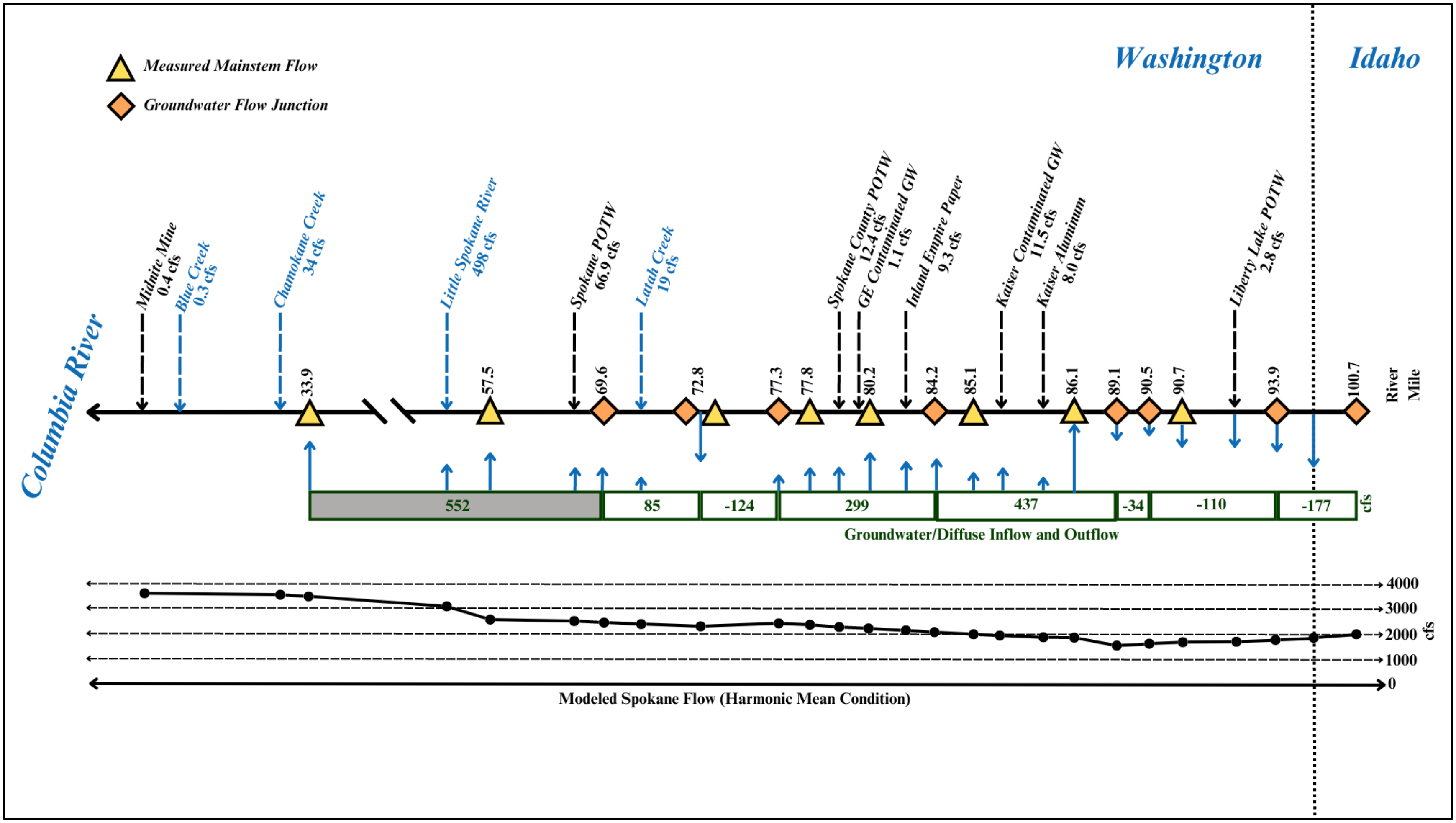

Figure C-3: Spokane River total PCB mass balance model with TMDL flow inputs.

Table C-1: Spokane River total PCB mass balance model topology.

River Mile	Junction	Junction Type
100.7	Post Falls GW Junction 1	Groundwater Study Monitoring Location
96.5	Spokane R at Stateline	Calculation Point
93.9	GW Junction 2	Groundwater Study Monitoring Location
92.3	Liberty Lake POTW	Point Source
90.7	Barker Road	Monitoring Location
90.5	GW Junction 3	Groundwater Study Monitoring Location
89.1	GW Junction 4	Groundwater Study Monitoring Location
86.1	Mirabeau Point	Monitoring Location
86.0	Kaiser Aluminum	Point Source
85.5	Kaiser contaminated GW	Groundwater Source
85.1	Trent Bridge	Monitoring Location
84.2	GW Junction 5	Groundwater Study Monitoring Location
82.8	Inland Empire Paper	Point Source
80.2	Upriver Dam	Monitoring Location
80.1	GE contaminated GW	Groundwater Source
78.9	Spokane County POTW	Point Source
77.8	Spokane R at Greene St	Monitoring Location
77.3	GW Junction 6	Groundwater Study Monitoring Location
72.8	Spokane R at Spokane	Monitoring Location
72.8	GW Junction 7	Groundwater Study Monitoring Location
72.2	Latah (Hangman) Creek	Tributary
69.6	GW Junction 8	Groundwater Study Monitoring Location
67.4	Spokane POTW	Point Source
57.5	Spokane R at Nine Mile	Monitoring Location
56.3	Little Spokane River	Tributary
33.9	Spokane R at Long Lake Dam	Monitoring Location
32.5	Chamokane Creek	Tributary
12.3	Blue Creek	Tributary
12.0	Midnite Mine	Point Source

2.3 Mass Balance Calculations

The mass transport of a water constituent in flowing water is defined as the product of the flow rate and the constituent concentration.

$$Load = mass\ per\ unit\ time = Q \cdot c$$

where,

Q = Flow

c = Concentration

The mass balance spreadsheets track the mass load at each junction as well as calculating the river concentration. The instream PCB concentration at a given junction in the Spokane River is calculated as follows:

$$C_d = \frac{(Q_u C_u + Q_t C_t + Q_e C_e + Q_s C_s + Q_c C_c \pm Q_{gw} C_{gw})}{Q_d}$$

where,

C_d= River flow and PCB concentration calculated at a given location

Q_u , C_u= Upstream mainstem river flow and mainstem PCB concentration
Q_t , C_t= Tributary flow and PCB concentration
Q_e , C_e=Point source effluent flow and PCB concentration
Q_s , C_s= Stormwater and CSO flow and PCB concentration
Q_c , C_c= Contaminated groundwater inflow and PCB concentration
Q_{gw} , C_{gw} = Groundwater and diffuse gain/loss and PCB concentration

Q_d= Mainstem river flow at calculation point
= $Q_u + Q_t + Q_e + Q_s + Q_s + Q_c \pm Q_{gw}$

The following are assumptions in this approach:

1. Concentrations calculated at a given location assume that inflows are completely mixed with the mainstem Spokane River flow.
2. The flow balance assumes that diffuse and groundwater inflows and outflows are similar to conditions measured in the USGS groundwater study in September 2004.
3. The flow balance assumes that diffuse and groundwater inflows are the only unmeasured flows. Estimated groundwater inflows/outflows are distributed uniformly between gauge locations.

2.4 Time Frames

The assessment spreadsheet provides estimates for the timeframe of the SRRTTF synoptic sampling study in August 12-20, 2014. The TMDL spreadsheet is representative of long-term average conditions (specifically 30-year harmonic mean flow) rather than a specific year or time frame.

3 Supporting Information for the Models

3.1 Available Monitoring Data

The sources of data used in the development of the mass balance model are listed in Table C-2.

Table C-2: Information sources for the Spokane River total PCB mass balance models.

Data Type	Specific Data Description	Period of Record Used	Source
River Flow	Daily average mainstem river flow at Post Falls, at Spokane, and at Long Lake Dam	1991-2021	USGS NWIS website
Tributary Flow	Daily average flow for: Latah (Hangman) Creek Little Spokane River Chamokane Creek Blue Creek	1991-2021	USGS NWIS website
Groundwater Inflow/Outflow	Synoptic flow measurement to determine gain/loss	Special study: September 2004	USGS 2005
River and Tributary PCB Concentration	Grab samples at multiple locations	August 2014	Spokane River Toxics Task Force
Point Source PCB Concentration and Discharge Flow	Flow and PCB monitoring under NPDES permit	August 2014 flow and conc. Annual average flow	NPDES Permittee submittals Spokane River Regional Toxics Task Force summaries
Contaminated groundwater characterization	PCB concentrations in monitoring wells	2011-2022	Kaiser Aluminum and GE technical reports Monitoring data from WA Dept of Ecology Spokane River Regional Toxics Task Force (2023)

The two spreadsheets require separate input values for flow (August 2014 for the source assessment spreadsheet and 30-year harmonic mean flow for the TMDL spreadsheet). Specific flow values for the Spokane River and tributaries within the TMDL study area are shown in Table C-3 and Table C-4, respectively.

Table C-3: Spokane River flow information.

Station Name Full naming convention: "Spokane River…[suffix below])"	USGS Station Number	River Mile	Period of Record Complete years through 2021	August 2014 Mean Flow[1] (cfs)	30-year Harmonic Mean Flow (1991-2021) (cfs)
Near Post Falls, ID	12419000	100.7	1913-2021	742	1988
At Barker Road, WA	NA	90.7	NA	399	NA
At Greenacres, WA	12420500	90.5	1948-2011	NA	NA
Below Trent Bridge near Spokane, WA	12421500	85.1	1949-1954	974	NA
Below N Greene St at Spokane, WA	12422000	77.8	1950-1952; 2018-2021	1374	NA
At Spokane, WA	12422500	72.8	1891-2021	1119	2639
At 7 mile Bridge near Spokane, WA	12424500	69.6	1948-1952	NA	NA
Below Nine Mile Dam at Spokane, WA	12426000	57.5	1949-1950; 2017-2021	NA	NA
At Long Lake, WA	12433000	33.9	1939-2021	1815	3535
Below Little Falls near Long Lake, WA	12433500	29.3	1913-1940	NA	NA
[1]Source: City of Spokane (2018)					

Tributary data values for PCBs and flow are shown in Table C-4. There are no data for PCBs for Chamokane Creek and Blue Creek, which are small tributaries downstream of the SRRTTF study area. Continuous flow gauge records for Little Spokane River (1998-2021) and Blue Creek (1991-1998) are not of sufficient length to estimate a 30-year harmonic mean flow, so the harmonic mean flow for the available period of record is used for these tributaries.

Table C-4: Tributary PCB concentrations and flows near confluences with Spokane River.

Station Name	Station Number	Period of Record (complete years)	August 2014 PCB Conc. (pg/L)	August 2014 Mean Flow (cfs)	30-year Harmonic Mean Flow (1991-2021) (cfs)
Latah (Hangman) Creek at Spokane, WA[1]	12424000	1949-2021	59.8[4]	14	19
Little Spokane River near Dartford	12431500	1949-1951; 1998-2021	116.9[5]	376	498[2]
Chamokane Creek below falls near Long Lake, WA	12433200	1972-1978; 1988-2021	NA	34	34
Blue Creek near mouth near Wellpinit, WA	12433561	1984-1998	NA	NA	0.3[3]

[1] Latah Creek was formerly named Hangman Creek
[2] 23-year harmonic mean flow (1998-2021)
[3] 7-year harmonic mean flow (1991-1998)
[4] Source: City of Spokane (2016)
[5] Source: Estimated from midpoint of loading range in LimnoTech (2016) and August 2014 mean flow

Point source flows were obtained from SRRTTF information for August 2014. The NPDES permit fact sheets provided the effluent flows used in the TMDL spreadsheet. Values are shown in Table C-5.

Table C-5: Process wastewater flows for NPDES permitted point sources.

Facility	River Mile	August 2014 Discharge[1] (mgd)	Fact Sheet: Discharge[2] (mgd)	Averaging Metric Provided in NPDES Fact Sheet
Liberty Lake	92.3	0.72	1.80	Monthly average annual design flow
Kaiser Aluminum	86.0	8.91	5.65	Average annual flow for human health carcinogen
Inland Empire Paper	82.8	7.17	7.47	Average annual flow for human health carcinogen
Spokane County	78.9	7.56	8.00	Monthly average dry weather design flow
City of Spokane	67.4	28.49	43.2	Monthly average critical season design flow
Midnite Mine	12.0	NA	0.78	Max discharge (average not listed in NPDES Fact Sheet)

[1]Source: City of Spokane (2016)
[2]Source: NPDES Fact Sheets

The estimated total PCB concentrations in point source discharges from the August 2014 SRRTTF study, summarized in a 2016 workshop, are shown in Table C-6. Note that the Midnite Mine discharge is located downstream of the SRRTTF study area.

Table C-6: NPDES permitted total PCB Concentrations for August 2014

Facility	River Mile	August 2014 Total PCBs[1] (pg/L)	Notes
Liberty Lake	92.3	218	--
Kaiser Aluminum	86.0	3949	--
Inland Empire Paper	82.8	2978	--
Spokane County	78.9	361	--
City of Spokane	67.4	972	--
Midnite Mine	12.0	NA	Facility not included in SRRTTF studies
[1]Source: City of Spokane (2016)			

The August 2014 study occurred during a dry weather period, so stormwater discharges are not included in the source assessment spreadsheet. Since the TMDL applies to annual loadings, annual average stormwater is included in the TMDL spreadsheet. The only municipality with stormwater discharges that reach the Spokane River (i.e., not captured in control structures such as dry wells) is the City of Spokane. Estimated annual average stormwater and CSO discharges are shown in Table C-7.

Table C-7: NPDES point source stormwater and combined sewer overflow volumes.

Facility	Discharge Type	Annual Average Discharge[1] (mgd)
City of Spokane	Stormwater	1.03
City of Spokane	CSOs	0.16

3.2 Synoptic PCB Sampling

SRRTTF has conducted synoptic PCB sampling of the river, where samples are taken at the same time at multiple locations. As noted above, EPA selected the August 2014 sampling period for the setup of the source assessment spreadsheet and used the values reported in the SRRTTF Comprehensive Plan document for that period (Limnotech 2016; see Table C-8 below). Due to concerns about field sample contamination at low concentrations, the SRRTTF did not use any individual congener in a field sample that was less than three times the concentration of that congener in the method blank associated with the field sample. This is commonly referred to as “3x blank correction.”

Table C-8: Total PCB results from the SRRTTF Comprehensive Plan (LimnoTech 2016).

Lake Coeur d'Alene (SR-15)		
Sample Month	Samples	Concentration
May 2014	6	23 pg/L
August 2014	7	13 pg/L
August 2015		
March 2016	2	14 pg/L
April 2016	1	15 pg/L
May 2016	1	72 pg/L
June 2016	1	3 pg/L
Arithmetic Mean – 17 pg/L **Geometric Mean - 14 pg/L**		

Trent Bridge/Plante's Ferry (SR-7)		
Sample Month	Samples	Concentration
May 2014		
August 2014	8	172 pg/L
August 2015	6	148 pg/L
March 2016	1	51 pg/L
April 2016	2	16 pg/L
May 2016	1	112 pg/L
June 2016	1	65 pg/L
Arithmetic Mean – 133 pg/L **Geometric Mean – 107 pg/L**		

Post Falls (SR-12)		
Sample Month	Samples	Concentration
May 2014		
August 2014	8	21 pg/L
August 2015		
March 2016		
April 2016		
May 2016		
June 2016		
Arithmetic Mean – 21 pg/L **Geometric Mean - 18 pg/L**		

Greene Street Bridge (SR-4)		
Sample Month	Samples	Concentration
May 2014		
August 2014	8	128 pg/L
August 2015	5	153 pg/L
March 2016	1	67 pg/L
April 2016	1	76 pg/L
May 2016	2	57 pg/L
June 2016	1	78 pg/L
Arithmetic Mean – 118 pg/L **Geometric Mean – 105 pg/L**		

Greenacres/Barker Rd. (SR-9)		
Sample Month	Samples	Concentration
May 2014		
August 2014	8	19 pg/L
August 2015	6	32 pg/L
March 2016		
April 2016		
May 2016		
June 2016		
Arithmetic Mean – 24 pg/L **Geometric Mean – 14 pg/L**		

Spokane Gage (SR-3)		
Sample Month	Samples	Concentration
May 2014		
August 2014	8	202 pg/L
August 2015	5	175 pg/L
March 2016	1	65 pg/L
April 2016	1	57 pg/L
May 2016	1	50 pg/L
June 2016	2	57 pg/L
Arithmetic Mean – 154 pg/L **Geometric Mean – 131 pg/L**		

Mirabeau Point (SR-8a)		
Sample Month	Samples	Concentration
May 2014	10	33 pg/L
August 2014		
August 2015	6	44 pg/L
March 2016		
April 2016		
May 2016		
June 2016		
Arithmetic Mean – 37 pg/L **Geometric Mean - 18 pg/L**		

Nine Mile Dam (SR-1)		
Sample Month	Samples	Concentration
May 2014		
August 2014	8	163 pg/L
August 2015		
March 2016	1	100 pg/L
April 2016	1	68 pg/L
May 2016	1	187 pg/L
June 2016	1	62 pg/L
Arithmetic Mean – 144 pg/L **Geometric Mean – 132 pg/L**		

3.3 Data Quality and Data Gaps

The model tools were developed using measurements of flow and total PCBs in the mainstem river, tributaries, point source discharges and estimates of groundwater inflow and outflow from USGS studies. Overall, a significant database of measurements has been collected by the USGS and SRRTTF, and the quality of the data is underpinned by quality control and assurance measures. As noted above, blank contamination is an important source of uncertainty in the data values, particularly in samples with low PCB concentrations.

Data gaps present a significant uncertainty in model development because the model represents single "snapshots" of river conditions. Ideally, for the given period chosen for the analysis, flow and PCB samples would be available in that period at all tributaries, point sources, and mainstem locations. Some of the sampling programs to date have employed "synoptic" (simultaneous) data collection as a goal, but others include only a fraction of the locations/times of interest. This requires the model developer to fill a number of gaps in the available information. The gaps are more substantial in the PCB data than the flow data because flow is systematically monitored for water management purposes. The goal in any effort to fill data gaps is to use values that are reasonably representative of the expected conditions in the system.

4 Model Development

The spreadsheet model requires upfront decisions about the key conditions to be evaluated (described above). The model provides a "snapshot" of steady-state PCB concentrations and loadings at a single period of time or design condition (e.g., long-term average). Once decisions were made about the time of year and flow condition of interest, the available data were reviewed to determine when sampling data are adequate to provide reasonable model input values and to allow for a comparison of measured and predicted instream flow and PCB concentrations.

For the August 2014 time frame, the model inputs are collected in the spreadsheet and the accuracy of the model predictions can be assessed. There are two core steps to model development for this type of model. First, the flow balance is constructed, and predicted flows are compared to measured flows at USGS gauge stations. Second, once the flow balance is established, the available data for PCB concentrations are assigned to the flow inputs (e.g., municipal and industrial point sources, groundwater, contaminated groundwater plumes, tributaries) and the predicted instream PCB concentrations are compared to measured concentrations.

The mass balance models do not contain process rates and parameters that can be calibrated to achieve a good fit to measured conditions. Rather, boundary inputs and gaps in the data that characterize the boundary inputs are evaluated as the model predictions are compared to measured conditions. As noted above, for the August 2014 assessment tool, the estimation of regional groundwater and contaminated plume loadings are important elements in model development and evaluation.

4.1 Flow Balance

The first step in model development is building the flow structure. This involves the incremental addition of each inflow to the mainstem river downstream of the USGS gauge at Post Falls Dam, including tributaries and point sources. In the Spokane River, groundwater inflows and outflows are substantial, so accounting for groundwater is an important element of flow prediction.

USGS led a series of hydrologic studies of the Spokane River between 2003 and 2007 that included estimates of the groundwater inflows and outflows (Caldwell and Bowers 2003, Hortness and Covert 2005, Kahle et al., 2005, Hsieh et al., 2007, Kahle and Bartolino 2007). Several studies focused on groundwater inflows and outflows and involved synoptic sampling at numerous locations, focused particularly on the reach between Post Falls Dam (RM100.7) and downstream of the Latah (Hangman) Creek confluence (RM 69.6). The USGS studies focused on summer and fall conditions. Kahle et al. (2005) reported results from a study conducted in September 13-16, 2004, and this study provides particularly useful information for the PCB mass balance model development, because the mainstem Spokane River flow during this period at Post Falls (645 cfs) was similar to the flow (742 cfs) during the period the Spokane River Task Force sampled the river in August 2014. Given the similarity in flows, the estimated groundwater inflows/outflows from the 2004 USGS study were used as the groundwater conditions in the model setup for August 2014 PCB conditions. This direct use of the groundwater flows from the 2004 USGS study led to reasonable agreement with 2014 flow measurements at the long-term USGS gauge at Spokane (river mile 72.8). From this location to the USGS gauge at Long Lake (river mile 33.9), the spreadsheet incorporates distributed inflows from groundwater and/or diffuse surface inflows to match the recorded flow at the Long Lake gauge. The model-estimated and measured monthly average flow for August 2014 is shown in Figure C-4.

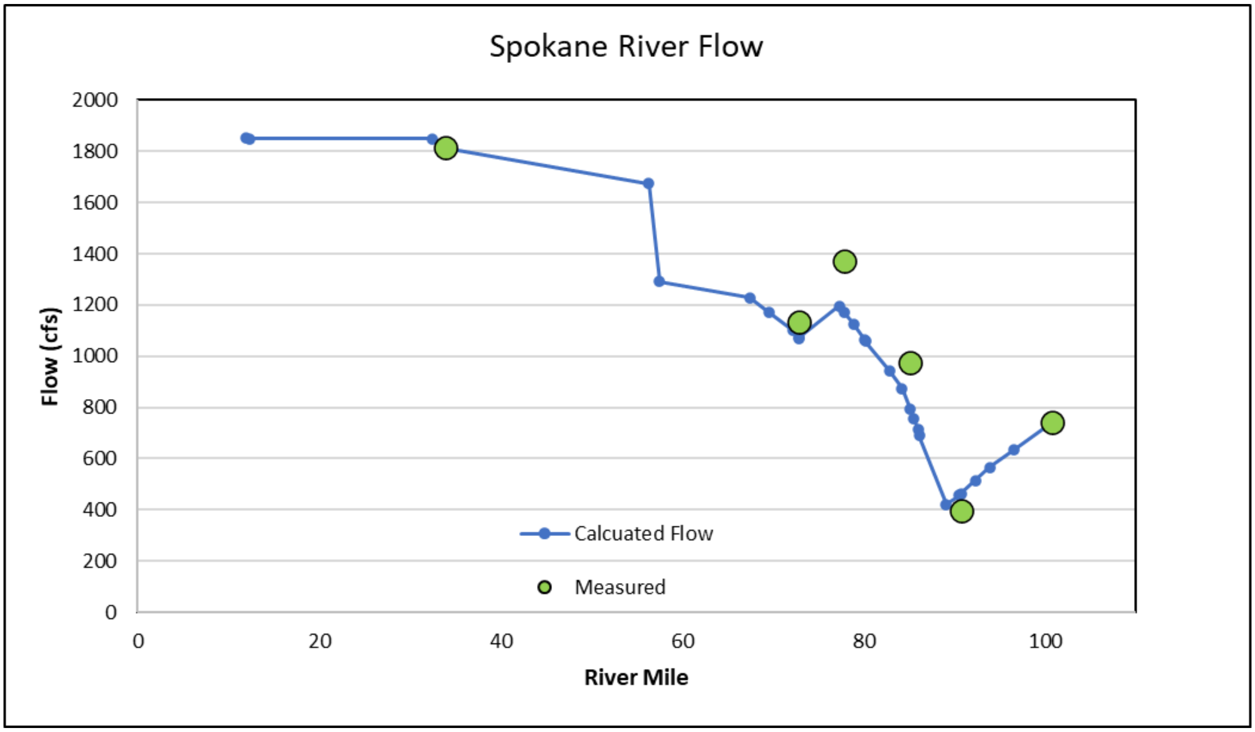

Figure C-4: Comparison of measured and model-predicted Spokane River mean flow in August 2014.

A different flow condition is used for the TMDL spreadsheet. The design flow statistic for the TMDL is the 30-year harmonic mean flow (calculated at the Spokane and Long Lake flow gauges and tributary flow gauges). The same groundwater inflows/outflows from the 2004 USGS study are used in the TMDL spreadsheet, since these provide a reasonably good fit with the harmonic mean mainstem flows. The same approach is also used to complete the flow balance at the USGS Long Lake gauge by adding distributed groundwater/surface water inflows between the Spokane and Long Lake gauges.

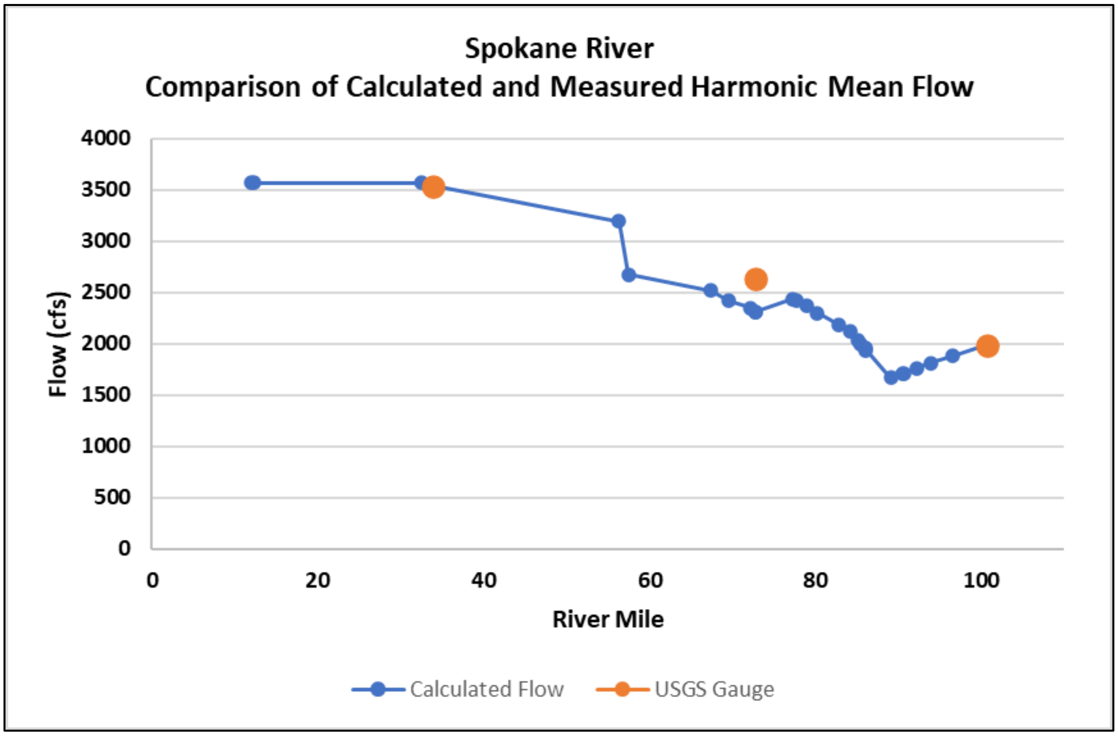

Figure C-5: Comparison of measured and model-predicted Spokane River harmonic mean flow.

4.2 Total PCB Prediction for August 2014

Once the flow balance is complete, a PCB mass balance can be applied by assigning PCB concentrations to each boundary input (upstream boundary, tributaries, point sources, contaminated site groundwater, regional groundwater, and stormwater) and tracking the mass load in the river (and associated concentration). The model does not include any loss of total PCBs from the water column due to degradation, biological uptake or settling.

The assessment spreadsheet predicts flow and PCB concentration in August 2014 for purposes of assessing current conditions and PCB sources. For August 2014 predictions, SRRTTF sampling information included total PCB concentrations at the upstream boundary (Post Falls), tributaries, and several Spokane River mainstem locations. Point source effluent flows were obtained from NPDES permit fact sheets for each facility. For point source PCB concentrations, the SRRTTF's comprehensive plan document (SRRTTF 2016) only includes summary information for 25th and 75th percentile loadings. More specific information for August 2014 is provided in a workshop map posted on the SRRTTF website (City of Spokane, 2016). These 2014 estimates are used for assessment purposes and do not factor into TMDL allocation decisions or calculations.

Some PCB source loadings and/or concentrations have not been measured and were estimated through best professional judgment or trial-and-error based on instream PCB levels. This category of unmeasured sources includes regional groundwater inflow loadings and loadings from contaminated groundwater.

For regional groundwater, the PCB concentration was assumed to be 21 pg/L based on August 2014 river concentrations measured at Post Falls, which is based on the assumption that this value represents a reasonable background level for the basin under current conditions. This value produced reasonable agreement between calculated and measured mainstem PCB concentrations.

For the Kaiser site, EPA obtained PCB data for monitoring wells at the site from the Washington Department of Ecology (Schmidt, personal communication, June 2023). Two wells within the plume are located near the river (MW-27 and MW-28) and have been sampled twice per year since 2011. The average total PCB concentration (5,680 pg/L) in all samples at both wells was used in the spreadsheet for the PCB concentration in the plume. While this value is derived from 53 samples, there is substantial uncertainty in the overall plume characteristics, with total PCB concentrations ranging from 193 to 37,700 pg/L and a median value of 2,420 pg/L.

To estimate the mass loading of this source using the mass balance model, the PCB concentration in the plume was fixed at 5,680 pg/L, and the flow of the groundwater plume was varied incrementally until the model-estimated PCB concentration in the river matched the measured PCB concentration below the Kaiser site at Trent Bridge. The mass load estimated for the contaminated plume for August 2014 is 160 mg/day based on a plume flow into the river of 11.5 cfs and PCB concentration of 5,680 pg/L. This mass loading estimate is in reasonable agreement with the SRRTTF's estimate (132 mg/day) of the PCB loadings into the reach of the contamination site between Mirabeau Point and Trent Bridge (LimnoTech 2019) and TetraTech's estimate of increased PCB loads between Mirabeau and Plante's Ferry for August 2018 of 193 mg/day (TetraTech, 2021). As a check on the reasonableness of the flow estimate, the groundwater inflow to the river in this reach is estimated at 89 cfs/mile. If this inflow is uniformly distributed, an assumed plume width of 650 feet would produce a flow of 11.5 cfs into the river. Monitoring wells at the cleanup site indicated a plume width of approximately 400 feet at some distance from the river (Hart Crowser 2022). The individual values for flow and PCB concentration within the contaminated plume are plausible but uncertain. Nevertheless, the mass load estimate is grounded in the observed increase in river concentration and mass load at this location.

The GE site is farther from the Spokane River than the Kaiser site, but groundwater at this location flows toward the river and well samples indicate high PCB concentrations in the groundwater. A recent assessment conducted by the SRRTTF (LimnoTech 2023) linked observed PCB concentrations on biofilms in the river to the PCB composition ("fingerprint") of contaminated groundwater at the GE site. SRRTTF estimated a 22% increase in biofilm PCB concentration at the location where the PCB composition matches the GE groundwater. The draft SRRTTF report also provides well-sampling information for the GE site. One sample was taken at each of the 8 wells sampled, and the total PCB concentrations ranged from 300 to 123,000 pg/L, with a mean concentration of 36,400 pg/L and a median of 18,000 pg/L. The flow, and mass loading, of the contaminated groundwater to the Spokane River has not been estimated. Given that sampling in 2014 and more recently was conducted in the month of August, an initial screening estimate is developed in the August 2014 spreadsheet by assuming that the GE groundwater is entering the Spokane River at the mean measured value of 36,400 pg/L at the site wells, and then adjusting the assumed groundwater flow by trial-and-error to reach a 22% increase in the PCB concentration in the river at the location of the elevated biofilm samples. A groundwater inflow of 1.1 cfs, coupled with the mean PCB concentration of 36,400 pg/L, results in a 22% increase in river concentrations under August 2014 conditions. Based on this approach, the screening estimate for mass loading of contaminated groundwater from this site is 98 mg/day.

A comparison of model-estimated and measured total PCB concentration in the Spokane River is shown in Figure C-6. The model uses the measured concentration at Post Falls as the upstream boundary condition, so the measured and model-estimated concentrations are identical at this location. They are also identical at the Trent Bridge location (river mile 85.5), because the measured concentration at Trent Bridge was used to back-estimate the Kaiser groundwater loading just upstream of this location. From this point downstream, changes in the model-estimated concentration are resulting from estimated source flows and PCB concentrations.

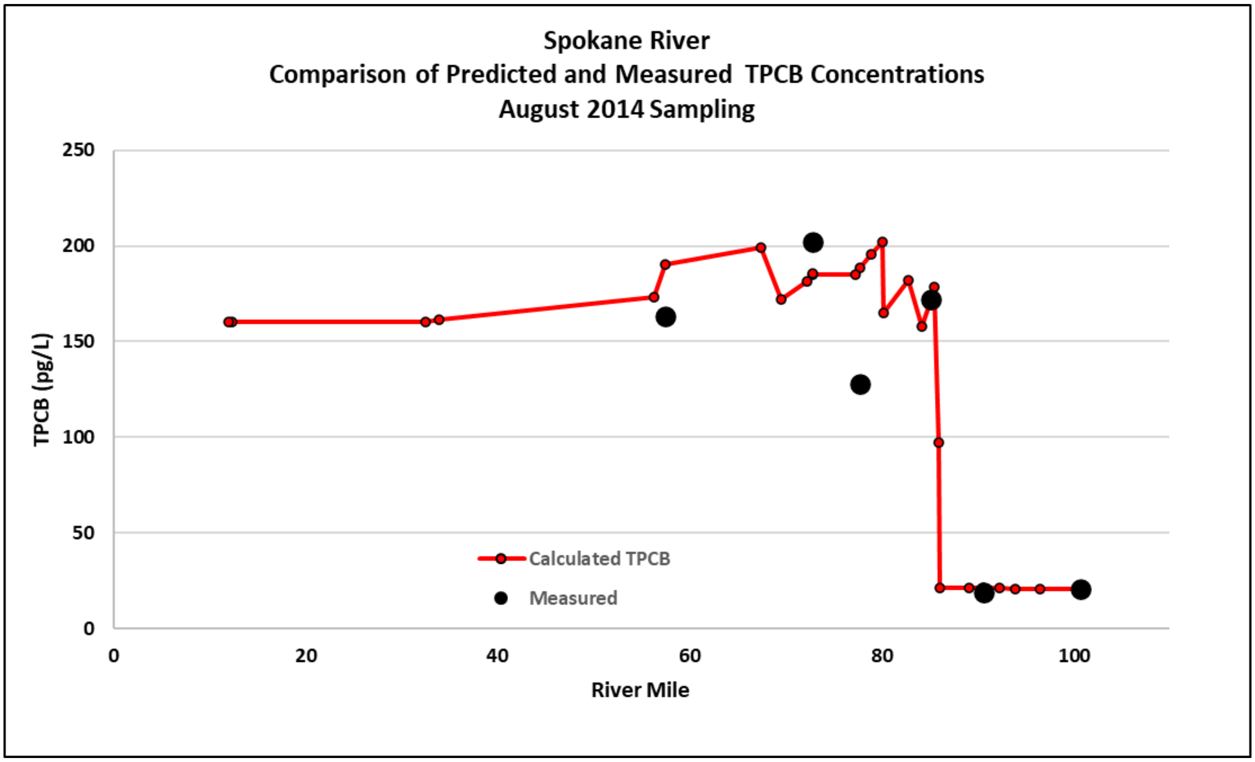

Figure C-6: Comparison of measured and model-predicted total PCB conditions for August 2014.

5 Model Application for TMDL

As noted above, the TMDL spreadsheet allows the user to enter PCB concentrations for source categories and computes the resulting instream mass and concentration at each calculation junction. The process of setting allocations in TMDLs involves numerous policy considerations, and these allocation decisions are constrained by the water quality goal and the fate and transport characteristics of the pollutant and receiving water. The fate and transport of the pollutant is calculated in the mass balance computations.

5.1 Assimilative Capacity Scenarios

The TMDL allocation process involves policy considerations to arrive at a reasonable set of allocations that achieve water quality standards. The following model scenarios are provided to inform TMDL development. The allocations will be established in the TMDL process with public involvement.

Four simple scenarios were run through the TMDL mass balance spreadsheet to demonstrate the information it can provide. The first scenario is a baseline scenario where all inflows are set to the

Spokane Tribe's WQC for total PCBs of 1.3 pg/L. As would be expected if the calculations are set up properly, the resulting concentration is 1.3 pg/L at each calculation junction in the spreadsheet. The second scenario adjusts the instream concentration at the Washington-Idaho border to the Washington criterion of 7 pg/L and reduces all other inflows to zero. The third scenario is similar to Scenario 1 but reduces the regional groundwater inflow by half and increases the border concentration by trial-and-error to a concentration (1.8 pg/L) that achieves the 1.3 pg/L criterion at the mouth. The fourth scenario reduces the border concentration and groundwater/diffuse inflows to half the 1.3 pg/L criterion, sets tributaries to half the 7.0 pg/L criterion, and sets point sources and contaminated groundwater to 7.0 pg/L; this combination meets the 1.3 pg/L criterion at the mouth.

The scenario specifications are shown in Table C-9 and graphical results are shown in Figure C-7. For point sources, the average flow listed in Table C-5 is used in these TMDL scenarios. As noted above, the estimated flow of the contaminated groundwater plume has a higher uncertainty than other flow estimates for sources, and the current flow estimate can be revised based on new information.

Table C-9: TMDL test scenario inputs.

Source Category	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	TPCB (pg/L)	TPCB (pg/L)	TPCB (pg/L)	TPCB (pg/L)
Washington-Idaho Border	1.3	7.0	1.8	0.65
Point Sources	1.3	0	1.3	7.0
Tributaries	1.3	0	1.3	3.5
Stormwater	1.3	0	1.3	7.0
Groundwater/Diffuse Inflow	1.3	0	0.65	0.65
Contaminated Groundwater	1.3	0	1.3	7.0

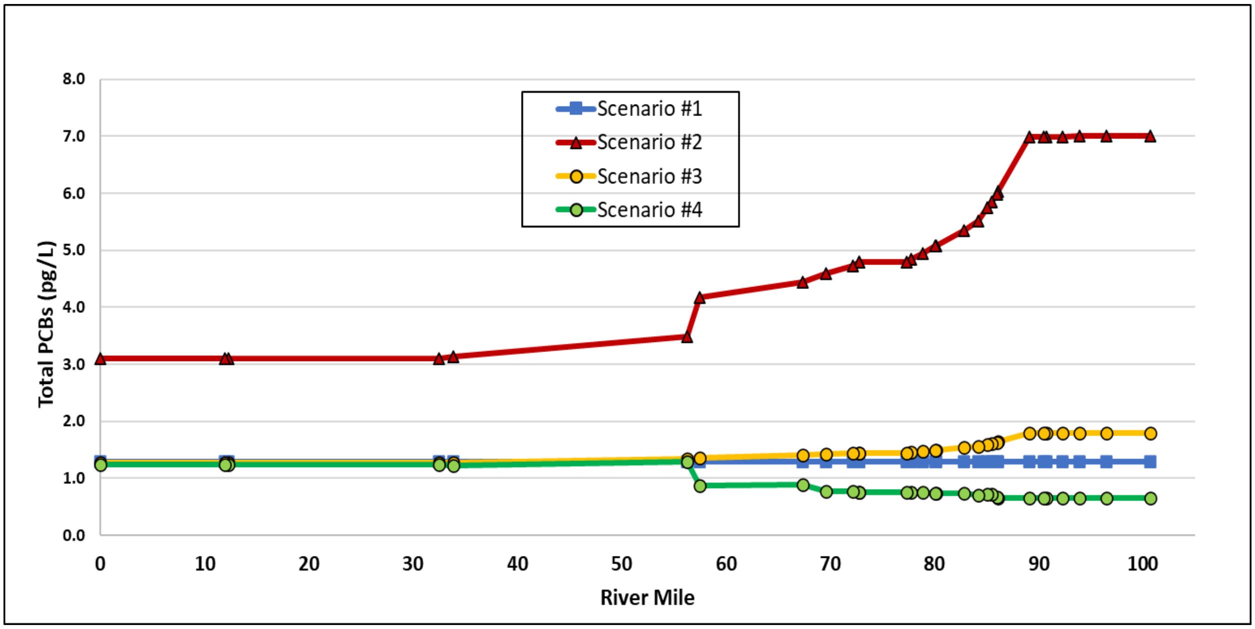

Figure C-7: TMDL test scenario results.

These scenario results indicate that achieving the applicable Spokane Tribe PCB WQC (1.3 pg/L) in the lower reaches of the action area will likely require setting a boundary condition concentration at the Washington-Idaho state line at a level below the Washington PCB WQC (7 pg/L). Additionally, these results illustrate the trade-off between higher point source loadings and lower state line and regional groundwater loadings.

5.2 Uncertainty and Limitations of the Model Predictions

All environmental models should be developed and applied with a recognition of the uncertainties and limitations in model predictions. The mass balance model used for this analysis is a simplified representation of the system and factors affecting PCB fate and transport. The model provides a steady state “snapshot” of conditions, so predictions are limited to the time frames and/or flow conditions selected for analysis.

A more complex model of PCB fate and transport would be difficult to develop due to significant limitations and gaps in the available data, particularly at the low concentrations of the applicable WQC. In addition, TMDLs must be developed to meet water quality standards with a margin of safety. In this context, the assumptions underlying the model that PCBs are not lost through settling or degradation provide a conservative approach for TMDL development.

A specific area of uncertainty for the Spokane River mass balance is estimation of PCB loadings from regional groundwater and the contaminated groundwater plumes. The estimates for the mass loading from contaminated groundwater are based on limited information and back-calculations based on observed river loadings upstream and downstream of the groundwater inflow zones. PCB concentrations in wells at both cleanup sites are very high, so these sites are expected to be significant sources of PCB mass to the river.

The same limitations and uncertainties in the available monitoring information that limit the ability to quantify in-stream transport and fate lead to uncertainties in the mass balance estimates for August

2014. Nevertheless, the general agreement of model-predicted PCB concentrations with the measured concentrations suggests that the model construct provides reasonable predictions.

6 References

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6.2 Spokane River Regional Toxics Task Force Studies

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6.3 Other References

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Attachment 1: TMDL support spreadsheet (TMDL test scenario 4 example).

	****User Entry ****
	TPCB (pg/L)
WA/ID Border	0.65
Point Sources	7
Tributaries	3.5
Stormwater	7
Groundwater/Diffuse	0.65
Contaminated GW	7.0

Point Source, Tributary, or Mainstem	Site Name	River Mile	Flow (cfs)	Inflow TPCB Conc (pg/L)	Storm-water and CSO (cfs)	SW and CSO TPCB (pg/L)	Diffuse Inflow/Outflow (cfs)	Gain TPCB (pg/L)	Calculated Mainstem Flow	Calculated Mainstem TPCB (pg/L)
Mainstem	GW Junction - Post Falls	100.7	1988	0.65					1988	0.7
Mainstem	Spokane R@ at Stateline	96.5					-109	0.7	1878	0.7
Mainstem	GW Junction - abv Liberty Bridge	93.9					-68	0.7	1811	0.7
Point Source	Liberty Lake POTW	92.3	2.8	7.0	0.000	7.0	-52	0.7	1762	0.7
Mainstem	Barker Road	90.7					-52	0.7	1710	0.7
Mainstem	GW Junction - Greenacres	90.5					-6	0.7	1703	0.7
Mainstem	GW Junction - Flora Rd	89.1					-34	0.7	1669	0.7
Mainstem	Mirabeau Point	86.1					268	0.7	1937	0.7
Point Source	Kaiser Aluminum	86.0	8.0	7.0			9	0.7	1954	0.7
GW	Kaiser contaminated GW	85.5	11.5	7.0			33	0.7	1999	0.7
Mainstem	Trent Bridge	85.1					36	0.7	2034	0.7
Mainstem	GW Junction - Centennial ped bridge	84.2					80	0.7	2115	0.7
Point Source	Inland Empire Paper	82.8	9.3	7.0			61	0.7	2184	0.7
Mainstem	Upriver Dam	80.2					113	0.7	2297	0.7
GW	GE contaminated GW	80.1	1.1	7.0			3	0.7	2301	0.7
Point Source	Spokane County POTW	78.9	12.4	7.0	0.000	7.0	52	0.7	2366	0.8
Mainstem	Spokane R@Greene St	77.8					48	0.7	2414	0.8
Mainstem	GW Junction - blw Greene St	77.3					22	0.7	2435	0.8
Mainstem	Spokane R@Spokane	72.8					-124	0.8	2311	0.8
Mainstem	GW Junction - at Spokane gauge	72.8					0	0.7	2311	0.8
Tributary	Latah Creek	72.2	19	3.5			16	0.7	2346	0.8
Mainstem	GW Junction - blw TJ Meenach bridge	69.6					69	0.7	2415	0.8
Point Source	Spokane POTW	67.4	66.9	7.0	1.839	7.0	34	0.7	2518	1.0
Mainstem	Spokane R@Nine Mile	57.5					153	0.7	2671	0.9
Tributary	Little Spokane River	56.3	498	3.5			19	0.7	3188	1.3
Mainstem	Spokane R@Long Lake Dam	33.9					347	0.7	3535	1.3
Tributary	Chamokane Creek	32.5	34	3.5			0	0.7	3569	1.3
Tributary	Blue Creek	12.3	0.3	7.0			0	0.7	3570	1.3
Point Source	Midnite Mine	12.0	0.4	7.0			0	0.7	3570	1.3
Mainstem	Confluence	0.0					0	0.7	3570	1.3

Attachment 2: August 2014 source assessment spreadsheet.

Point Source, Tributary, or Mainstem	Site Name	River Mile	Flow (cfs)	Inflow TPCB Conc (pg/L)	Inflow TPCB Load (mg/day)	Storm-water (cfs)	SW TPCB (pg/L)	Diffuse Inflow/Outflow (cfs)	Diffuse TPCB (pg/L)	Calculated Mainstem Flow	Calculated Mainstem TPCB (pg/L)	Aug 2014 Measured TPCB (pg/L)
	GW Junction	100.7								742	21.0	21.0
Mainstem	Spokane R@ at Stateline (calculated)	96.5						-109	21.0	633	21.0	
	GW Junction	93.9						-68	21.0	565	21.0	
Point Source	Liberty Lake POTW	92.3	1.1	218.0	0.6	0	0.0	-52	21.0	514	21.4	
Mainstem	Barker Road	90.7						-52	21.4	463	21.4	19.0
	GW Junction - Greenacres	90.5						-6	21.4	456	21.4	
	GW Junction	89.1						-34	21.4	422	21.4	
Mainstem	Mirabeau Point	86.1						268	21.0	690	21.3	
Point Source	Kaiser Aluminum	86.0	13.8	3949.0	133.3			9	21.0	712	97.3	
GW	Kaiser contaminated GW	85.5	11.5	5680.0	159.8			33	21.0	757	178.8	
Mainstem	Trent Bridge	85.1						36	21.0	793	171.7	172.0
	GW Junction	84.2						80	21.0	873	157.9	
Point Source	Inland Empire Paper	82.8	11.1	2978.0	80.9			61	21.0	945	182.2	
Mainstem	Upriver Dam	80.2						113	21.0	1057	165.0	
GW	GE contaminated GW	80.1	1.1	36400.0	98.0			3	21.0	1062	202.1	
Point Source	Spokane County POTW	78.9	11.7	361.0	10.3	0	0.0	52	21.0	1125	195.4	
Mainstem	Spokane R@Greene St	77.8						48	21.0	1173	188.3	128.0
	GW Junction	77.3						22	21.0	1195	185.3	
Mainstem	Spokane R@Spokane	72.8						-124	185.3	1071	185.3	202.0
	GW Junction	72.8						0	21.0	1071	185.3	
Tributary	Latah Creek	72.2	14	59.8	2.1			16	21.0	1101	181.3	
	GW Junction	69.6						69	21.0	1170	171.9	
Point Source	Spokane POTW	67.4	44.1	972.0	104.9	0	0.0	14	21.0	1228	198.9	
Mainstem	Spokane R@Nine Mile	57.5						62	21.0	1291	190.3	163.0
Tributary	Little Spokane River	56.3	376	116.9	107.5			8	21.0	1674	173.1	
Mainstem	Spokane R@Long Lake Dam	33.9						141	21.0	1815	161.2	
Tributary	Chamokane Creek	32.5	34	116.9	9.7			0	21.0	1849	160.4	
Tributary	Blue Creek	12.3	0.3	116.9	0.1			0	21.0	1849	160.4	
Point Source	Midnite Mine	12.0	1.2	116.9	0.3			0	21.0	1851	160.4	
Mouth	Confluence	0.0						0	21.0	1851	160.4	

Color	Represents
(green)	Measured mainstem flow
(light blue-grey)	Calculated flow
(yellow)	Point Source
(blue)	Tributary
(brown)	GW Flow Junction
(light orange)	Estimated - user entry