PCB Total Maximum Daily Load Development for Mountain Run, Culpeper County, Virginia

Submitted by:

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Draft Report
September 2023

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Background

Section 303(d) of the Clean Water Act (CWA) and the United States Environmental Protection Agency's Water Quality Planning and Management Regulations require states to develop total maximum daily loads (TMDLs) for waterbodies that exceed applicable water quality standards (WQSs). TMDLs represent the total pollutant loading a waterbody can receive without exceeding applicable WQSs.

The Mountain Run watershed is impaired for the fish consumption use due to polychlorinated biphenyl (PCB) contamination. Other designated uses were not assessed for PCBs. The goal of this project was to identify the sources of PCBs in the watershed, model the fate and transport of PCBs through the watershed, and propose PCB source reduction scenarios that would allow the watershed to return to an unimpaired state. These reduction scenarios establish the TMDL loads, i.e., the maximum quantity of PCBs that can enter the impaired waterbody without exceeding the TMDL PCB endpoint.

The PCB impaired segment of Mountain Run begins at the outlet of Lake Pelham and extends downstream 24.53 miles through the Town of Culpeper to the confluence of Mountain Run and the Rappahannock River. Additionally, two unnamed tributaries to Mountain Run are impaired for PCBs, these small tributaries total 1.72 stream miles. The tributaries of Flat Run and Jonas Run have observed fish tissue and water column PCBs considered "fully supporting but having an observed effect" in the 305(b)/303(d) Water Quality Assessment Integrated Report. A Virginia Department of Health (VDH) fish consumption advisory is in effect for the section of Mountain Run extending from Route 15/29 bridge in Culpeper downstream to the confluence with Rappahannock River. The contributing watershed defines the study area for this project and is approximately 58,401 acres. Table ES-1 lists the major impaired segments of the Mountain Run study area, Table ES-2 lists the VDH fish consumption advisory, and Figure ES-1 maps the locations of the impaired water segments.

Table ES-1. PCB impaired segments from the 2020 303(d) list addressed in this TMDL report (DEQ, 2020).

Impaired Segment	305b/303(d) Segment ID	Segment Length (miles)	Initial Listing Year (PCBs in Fish Tissue/Water Column	Description
Mountain Run	VAN-E09R_MTN01A00	7.58	2006 / 2020	Begins at the confluence with Flat Run, continuing downstream to the confluence with Rappahannock River.
	VAN-E09R_MTN02A04	5.67	2006 / 2020	Begins at the confluence with Jonas Run, continuing downstream to the confluence with Flat Run.
	VAN-E09R_MTN03A00	6.65	2006 / 2018	Begins at the Route 15/29 bridge continuing downstream to the confluence with Jonas Run.
	VAN-E09R_MTN04A04	4.63	2016 / 2018	Begins at Lake Pelham outlet, downstream to Route 15/29 bridge.
Unnamed Tributaries to Mountain Run	VAN-E09R_XBE01A18	0.6	– / 2020	Segment begins at the perennial headwaters near E.Chandler St., continuing downstream to the confluence with Mountain Run.
	VAN-E09R_XIH01A18	1.12	– / 2020	Segment begins at the perennial headwaters near Sunset Lane, continuing downstream to the confluence with Mountain Run.

Table ES-2. Mountain Run water bodies with PCB Fish Consumption Advisories from the VDH.

Water Body and Affected Boundaries	Segment Length (miles)	Affected Localities	Initial Advisory Year	Species	Advisories/ Restriction
Mountain Run extending from Route 15/29 bridge in Culpeper downstream to the confluence with Rappahannock River.	19	Culpeper County	2004	American Eel	No more than two meals/month

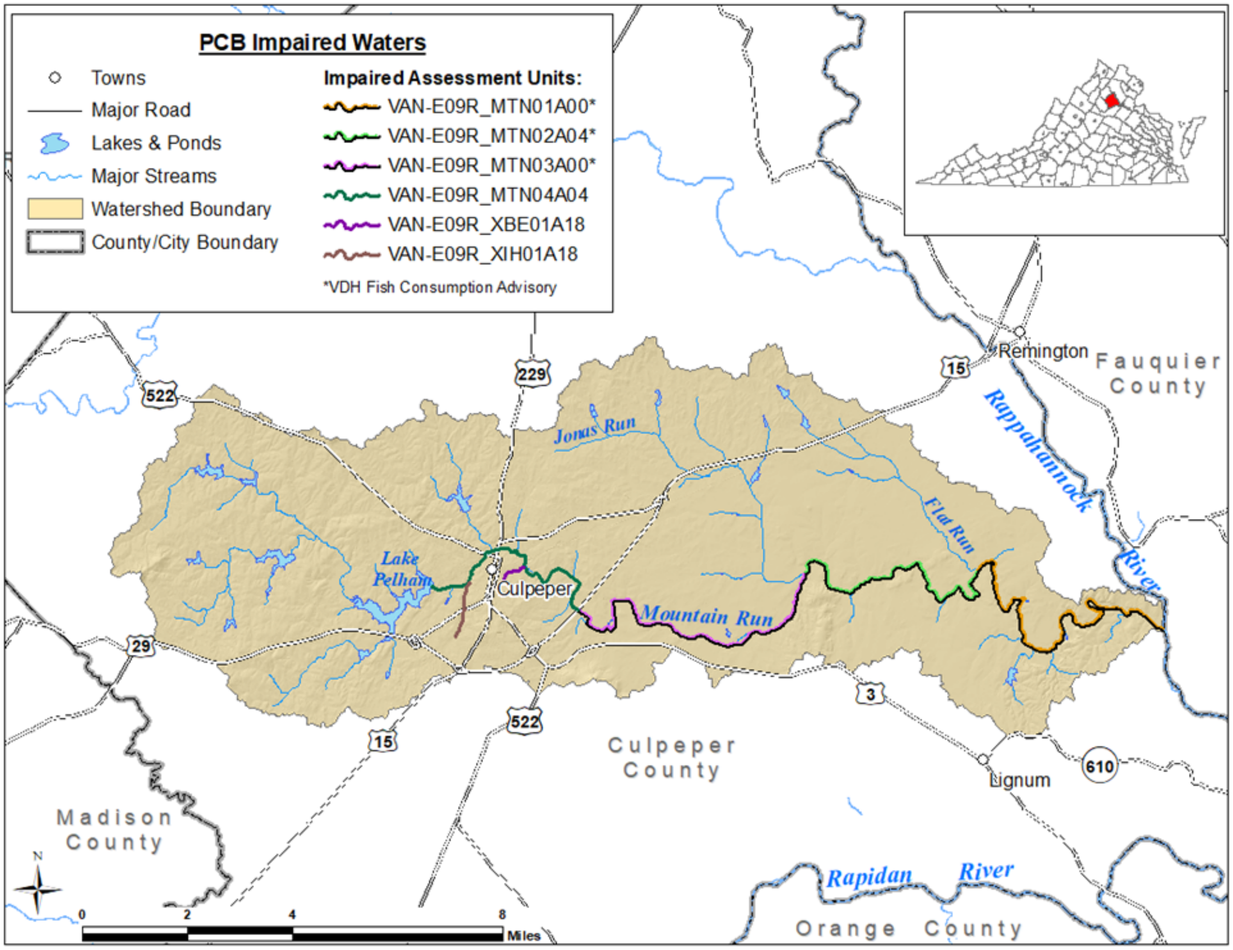

Figure ES-1. PCB impaired segments in the Mountain Run watershed.

Pollutant Sources

PCBs are synthetic compounds that were commonly manufactured in the first half of the 20th century, and were used for industrial processes. Their chemical structure consists of two bonded phenyl rings and at least one chlorine atom. Although banned in the 1970's their chemical properties enable PCBs to persist in the environment. Exposure to PCBs leads to chronic ailments such as endocrine disruption, and they are a suspected carcinogen. Sources of PCBs were characterized throughout the Mountain Run study area. Point sources include several types of permitted facilities in this watershed. Nonpoint sources include known contaminated sites (e.g., former manufacturing facilities, metal recycling facilities, railyards and railway spurs, spills), non-regulated surface sources (the sum of net atmospheric deposition to land, loads from small tributaries that are not explicitly specified in the model, unregulated stormwater runoff, loads from unidentified contaminated sites, and unspecified point source discharges), atmospheric deposition to water surfaces, and PCB-contaminated stream bed sediment.

Modeling

The Hydrological Simulation Program–FORTRAN (HSPF) (Bicknell et al., 2005) was used to simulate the fate and transport of PCBs in the Mountain Run study area. HSPF is a continuous computational model that can represent fate and transport of pollutants on both the land surface and instream. Modeling included hydrology, sediment, and PCB fate and transport. Modeling segments divided the study area into discrete regions, based on PCB sources present and major tributaries. Outputs from each upstream segment became inputs into downstream segments. The hydrologic modeling established the foundation for the Mountain Run PCB TMDL model. Since PCBs are hydrophobic and tend to associate with sediment, a sediment model component was used as well.

The final model also simulated PCB fate and transport. The Mountain Run model was calibrated at each stage of model development, using a “weight-of-evidence” approach. Multiple analyses were used to ensure the simulated outputs adequately reflected the observed data.

Endpoints

The impaired segments of Mountain Run do not support the fish consumption designated use due to exceedances of the VDH’s PCB fish tissue threshold and the Virginia Department of Environmental Quality’s (DEQ) total PCB (tPCBs) fish tissue value (TV) and water quality criterion (WQC). A segment-specific PCB water quality endpoint was calculated using a Bioaccumulation Factor (BAF) approach. The method correlates the localized instream concentrations of PCBs to the concentration of PCBs found within a variety of fish species collected in the same area. As such, the maximum allowable water column tPCB concentration is calculated to ensure the fish tissue thresholds established by either VDH, 100 ng/g (ppb), or DEQ, 18 ng/g (ppb) will be attained. The water column tPCB endpoint (310 pg/L) for Mountain Run was calculated using the BAF approach.

PCB TMDL

Various source reduction scenarios were evaluated to identify implementable scenarios that meet the TMDL endpoint. Load reduction allocation scenarios were generated using meteorological data for the harmonic mean flow year (HMFY) using the USGS flow gage on the Rappahannock River at Remington, VA (USGS 01664000) since there are no active continuous USGS flow gages on Mountain Run. The HMFY is the observed flow year whose harmonic mean flow best corresponds to the harmonic mean flow of the entire observed flow data period at a given gage. An analysis of Rappahannock River flow data determined that the HMFY was 2008.

The modeled PCB loads correspond to anticipated and permitted future conditions for Mountain Run. For Mountain Run, the goal of the allocation scenarios is to meet the TMDL endpoint. Equation ES-1 was used to calculate the loadings shown in Table ES-3.

$$TMDL = WLA_{Total} + LA + MOS \qquad \textbf{Eq. ES-1}$$

Where:

WLA_{Total} = waste load allocation (point source contributions, future conditions which account for point source facilities inadvertently excluded from TMDL);
LA = load allocation (nonpoint source contributions); and
MOS = margin of safety.

Table ES-3. Annual and daily PCB loadings for the TMDL.

Impaired Segment (Harmonic Mean Flow Year)	Units	WLA_{Total}[1]	LA[2]	MOS[3]	TMDL
Mountain Run	mg/yr	2,775	57,574	3,176	63,525
(HMFY: 2008)	mg/day	18	463	26	507

[1] WLA_{Total} includes future conditions.
[2] The LA is the remaining loading allowed after the MOS and WLA_{Total} are subtracted from the TMDL as determined for the downstream end/outlet of the impaired segment.
[3] Explicit MOS (5%).

Margin of Safety

In order to account for the uncertainty of the relationship between the pollutant loads and the quality of the receiving waters, a margin of safety (MOS) was implemented. For Mountain Run, an explicit MOS of 5% was included in the TMDL.

Allocation Scenario

The proposed TMDL allocation scenario requires load reductions from point and nonpoint sources of PCBs. The difference between the TMDL and the existing annual load represents the necessary level of PCB reduction. The recommended reduction scenario from nonpoint sources that will meet the TMDL endpoint of 310 mg/L for Mountain Run is listed in Table ES-4.

Table ES-4. PCB nonpoint source allocation scenarios for Mountain Run.

Required PCB Loading Reductions to Meet the TMDL Endpoint of 310 pg/L (%)		
Loads from Unregulated Surface Sources[1]	**Loads from Contaminated Sites[2]**	**Loads from Streambed Sediments**
55	99	0

[1] Unregulated surface sources represent PCB loads supported by the observed data whose specific location have yet to be identified.
[2] Contaminated sites include Jim's Liquid Wastes site, railyards and spurs, electrical substations, and PREP spills.

Table ES-5 provides a summary of the existing loads, WLAs, LAs, and percent reduction by source category. The LAs and existing loads for the nonpoint sources are the average annual loads based on the source contribution to instream PCB concentration at the outlets of the impaired segments. The WLA is calculated at the outlets of the permitted areas. Existing loads for nonpoint sources are back calculated from the final TMDL. The row for WLA Future Conditions in Table ES-5 accounts for point source PCB dischargers that may have been inadvertently excluded from the TMDL and are equal to 0.25% of the TMDL for Mountain Run.

Table ES-5. Average annual tPCB loads for Mountain Run source categories.

Source Category	Existing Load (mg/yr)	WLA (mg/yr)	LA (mg/yr)	Reduction (%)
Municipal Dischargers[1]	2,364	2,616		-
Industrial Stormwater General Permits	109			55
WLA Future Conditions[2]		159		
Contaminated Sites	7,558		76	99
Unregulated Surface Sources[3]	65,546		29,496	55
Streambed Sediments	27,960		27,960	0
Atmospheric Deposition (water surface)	43		43	0
TOTAL	**103,580**	**2,774**	**57,575**	**42%**

[1]A tPCB load reduction for Municipal Dischargers does not apply as the existing load is less than the WLA.
[2]WLA Future Conditions account for permitted facilities that may come on-line in the future and are equal to 0.25% of the TMDL for Mountain Run.
[3] Unregulated surface sources are the sum of net atmospheric deposition to land surfaces, loads from small tributaries that are not explicitly specified in the model, stormwater runoff, loads from unidentified contaminated sites, and unspecified point source discharges.

Implementation

The goal of the TMDL program is to establish a three-step path that will lead to reasonable assurance that attainment of the applicable WQSs will be achieved. The first step in the process is to develop TMDLs that will meet targeted water quality goals. This report represents the culmination of that effort for the PCB impairments in Mountain Run. The second step is to develop a TMDL implementation plan, which can include the use of available PCB data to “fingerprint” source areas, perform additional investigation of uncharacterized nonpoint sources, and to recommend the implementation of best management practices (BMPs) where practical or remediate hot spots. The final step is to initiate recommendations outlined in the TMDL implementation plan, and to monitor stream water quality to determine if fish tissue thresholds and WQSs are being attained. Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan in the future. Implementation plan development will be supported by DEQ’s regional and local offices and other cooperating agencies.

Public Participation

Public participation was elicited at every stage of the TMDL development in order to receive inputs from stakeholders and to apprise the stakeholders of the progress made. The first Technical Advisory Committee (TAC) meeting was held on Tuesday, January 12, 2021, and was conducted virtually through an online webinar platform due to the Covid-19 State of Emergency. Presentations included an overview of the Mountain Run PCB TMDL project including problem identification, PCB monitoring results and prospective sources. As a part of their contract with DEQ to develop the Mountain Run PCB TMDL, Virginia Tech's department of Biological Systems Engineering (BSE) presented the modeling process and the PCB sources that were considered. This virtual meeting was attended by 11 stakeholders (four representatives of non-governmental organizations, two representatives of local government, one representative of state government, three representatives of Virginia Pollutant Discharge Elimination System (VPDES) permitted facilities, and one representative of Virginia Association of Municipal Wastewater Agencies and Virginia Municipal Stormwater Association).

The first PCB Public Meeting was held on Wednesday, January 13, 2021, also held virtually through a webinar platform. The meeting hosted by DEQ staff included background information on PCBs and related human health concerns, long term PCB monitoring data from Mountain Run, and an overview of the TMDL process that will be used in the Mountain Run watershed. Virginia Tech BSE presented details on the PCB modeling process for determining PCB pollutant fate and transport. Fourteen stakeholders registered for this virtual meeting. The comment period for the first public meeting ended February 16, 2021.

The second TAC meeting was held on Tuesday, July 26, 2022 at the Culpeper County Library. The primary focus of the meeting was to review the draft PCB sources allocation scenarios. This meeting was attended by three stakeholders (two representatives of state government and one representative of a VPDES permitted facility).

The second and final Public Meeting to present the draft PCB TMDL report for Mountain Run was held on September 6, 2023, and four people attended the meeting at the Culpeper County Board of Supervisors conference room. The public comment period for the second public meeting ended October 6th, 2023, and a single comment was received.

Chapter 1: Introduction

1.1 ***Background***

1.1.1 **TMDL Definition and Regulatory Information**

Section 303(d) of the Federal Clean Water Act and the U.S. Environmental Protection Agency's (EPA) Water Quality Planning and Management Regulations (40 CFR Part 130 and 131) require states to identify water bodies that violate state water quality standards (WQSs) and to develop Total Maximum Daily Loads (TMDLs) that are established at levels necessary to attain narrative and numerical WQSs. A TMDL reflects the total pollutant loading a water body can receive and still attain and maintain the applicable numerical criterion. A TMDL establishes the maximum allowable pollutant loading from both point and nonpoint sources for a water body, allocates the load among the pollutant contributors, and provides a framework for taking actions to restore water quality.

1.1.2 **PCB Impairment Listing**

In the 2020 Water Quality Assessment Integrated Report (2020IR)[1], Mountain Run is included on the Section 303(d) list as impaired for the fish consumption use for polychlorinated biphenyls (PCBs). The impairment begins at the outlet of Lake Pelham and extends downstream 24.53 miles through the Town of Culpeper to the confluence of Mountain Run and the Rappahannock River. The PCB impairments are based on exceedances of the Virginia Department of Environmental Quality's (DEQ) human health water quality criterion (WQC) based fish tissue value (TV) for PCBs in fish tissue and for exceedances of the WQC in the water column. The portion of Mountain Run from the Route 15/29 bridge in Culpeper downstream to the confluence with the Rappahannock River is considered impaired due to a Virginia Department of Health (VDH) fish consumption advisory for PCBs (VDH, 2004). Additionally, two unnamed tributaries to Mountain Run are impaired for PCBs in the water column; these small tributaries total 1.72 stream miles. The tributaries of Flat Run and Jonas Run were assessed as

[1] The 2022 Water Quality Assessment Integrated Report (2022IR) was approved by EPA on October 21, 2022. The 2022IR did not include significant changes to the PCB assessment described in this report. The 2022IR can be accessed at https://www.deq.virginia.gov/water/water-quality/assessments/integrated-report

supporting based on PCBs in the water column with observed effects noted based on fish tissue PCB data.

Fish consumption advisories, exceedances of the water quality criterion-based fish tissue values for PCBs, and exceedances of the human health criteria for PCBs in the water column mean a TMDL is required. The impaired segments, descriptions of their extent, and initial listing years are provided in Table 1-1, and the fish consumption advisory is described in Table 1-2. Figure 1-1 shows the locations of the PCB impaired segments within the Mountain Run watershed study area in Virginia.

Table 1-1. PCB impaired segments from the 2020 303(d) list addressed in this TMDL report (DEQ, 2020).

Impaired Water	Assessment Unit (AU) ID	Segment Length (miles)	Initial Listing Year (PCBs in Fish Tissue/Water Column)	AU Location Description	Cause Group Code
Mountain Run	VAN-E09R_MTN01A00	7.58	2006 / 2020	Begins at the confluence with Flat Run, continuing downstream to the confluence with Rappahannock River.	E09R-01-PCB
	VAN-E09R_MTN02A04	5.67	2006 / 2020	Begins at the confluence with Jonas Run, continuing downstream to the confluence with Flat Run.	E09R-01-PCB
	VAN-E09R_MTN03A00	6.65	2006 / 2018	Begins at the Route 15/29 bridge continuing downstream to the confluence with Jonas Run.	E09R-01-PCB
	VAN-E09R_MTN04A04	4.63	2016 / 2018	Begins at Lake Pelham outlet, downstream to Route 15/29 bridge.	E09R-02-PCB
Unnamed Tributaries to Mountain Run	VAN-E09R_XBE01A18	0.6	– / 2020	Segment begins at the perennial headwaters near E. Chandler St., continuing downstream to the confluence with Mountain Run.	E09R-03-PCB
	VAN-E09R_XIH01A18	1.12	– / 2020	Segment begins at the perennial headwaters near Sunset Lane, continuing downstream to the confluence with Mountain Run.	E09R-03-PCB

Table 1-2. Mountain Run water bodies with PCB Fish Consumption Advisories from the VDH.

Water Body and Affected Boundaries	Affected Localities	Initial Advisory Year	Species	Advisories/ Restriction
Mountain Run extending from Route 15/29 bridge in Culpeper downstream to the confluence with Rappahannock River. *	Culpeper County	2004	American Eel	No more than two meals/month

*The VDH Fish Consumption Advisory applies to 2020IR Cause Group Code E09R-01-PCB (Assessment Unit IDs VAN-E09R_MTN01A00, VAN-E09R_MTN02A04, and VAN-E09R_MTN03A00).

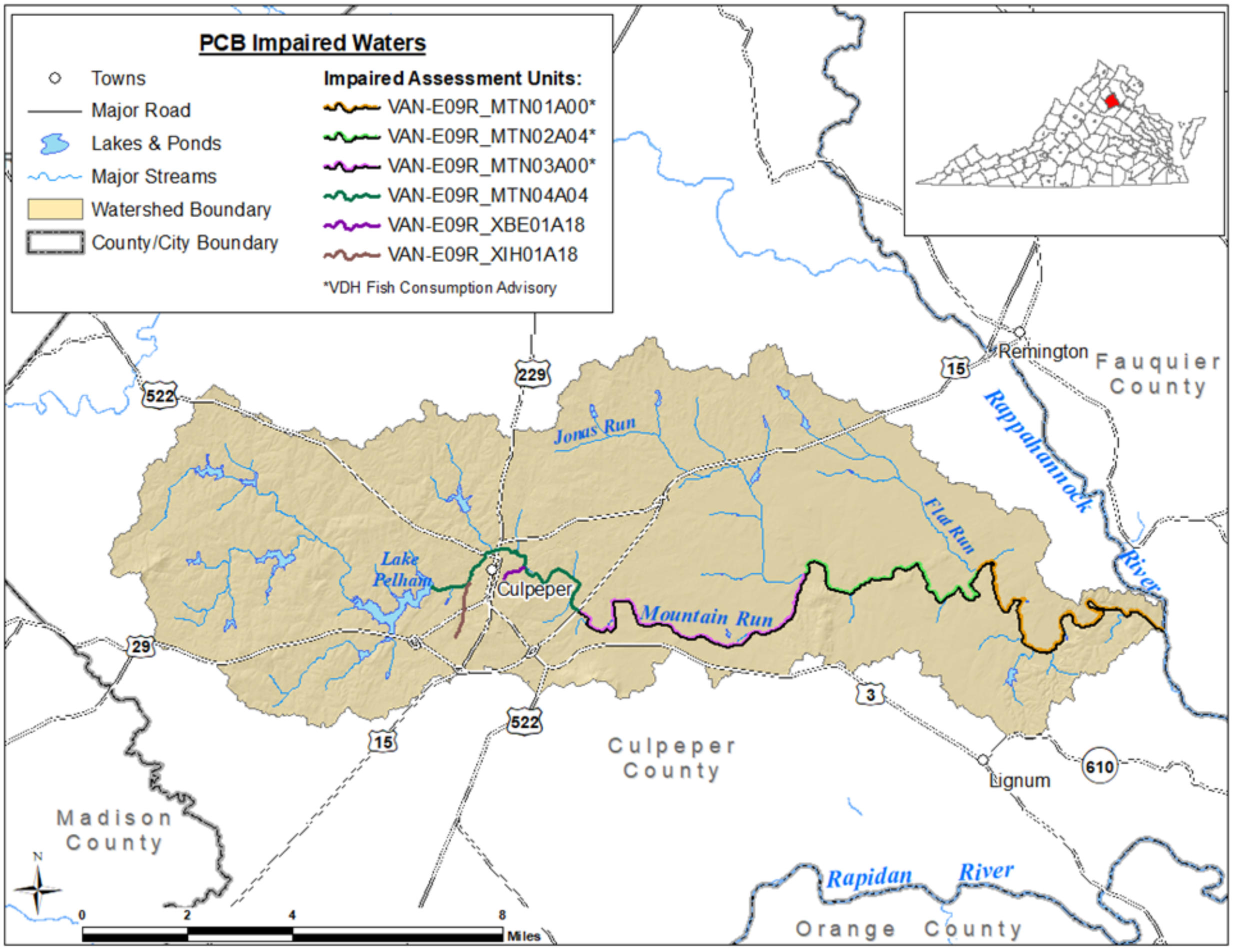

Figure 1-1. PCB impaired segments in the Mountain Run watershed.

1.1.3 **Study Area Location and Description**

The Mountain Run watershed study area is located in Culpeper County Virginia, encompassing an area of approximately 58,401 acres (91 mi^2) (Figure 1-2). Mountain Run flows through the town of Culpeper to its confluence with the Rappahannock River, which eventually drains to the Chesapeake Bay. Portions of Mountain Run and its tributaries are impaired due to PCB contaminants found in fish tissue and water column samples that indicate the stream exceeds water quality criteria.

The Mountain Run watershed is located east of the Blue Ridge Mountains in Piedmont Ecoregions. The watershed is predominantly forest (45%) and agricultural land use (39%), with developed land (residential, commercial and industrial) making up

16% of the study area. The watershed study area is characterized in more detail in Chapter 2.

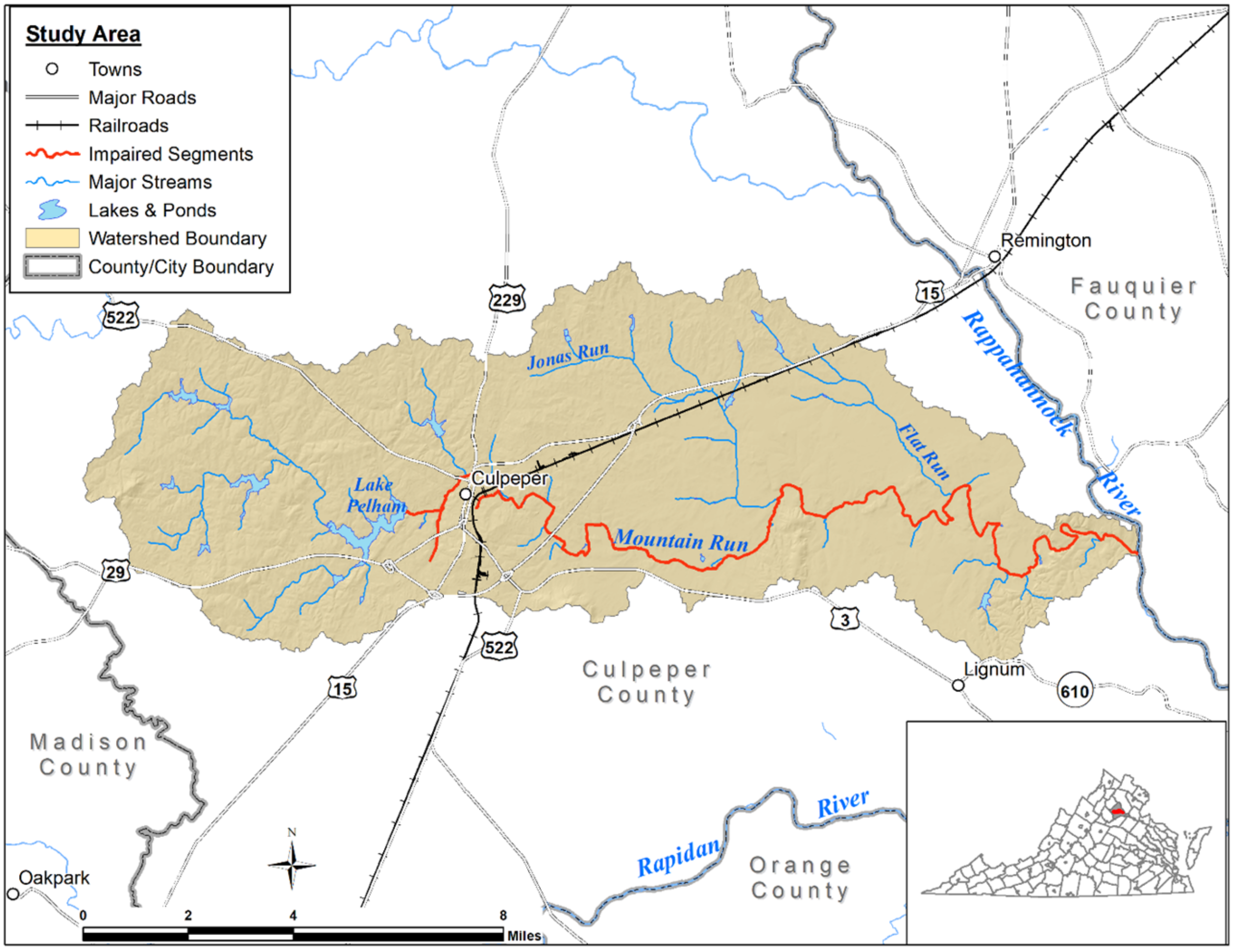

Figure 1-2. Mountain Run watershed study area showing PCB impaired stream segments.

1.1.4 **Pollutant of Concern**

The TMDL pollutant of concern is polychlorinated biphenyl (PCB) contamination. PCBs are synthetic compounds that were commonly manufactured in the first half of the 20th century. The chemical structure consists of two bonded phenyl rings with at least one chlorine atom bonded to one of ten positions on the perimeter of the rings (Figure 1-3). There are 209 unique PCB formulations, or congeners, of which chlorine atom(s) are substituted at different positions on the rings. Congeners are grouped by the number of chlorine atoms, irrespective of their position on the phenyl rings, into ten homologs (e.g. monochlorobiphenyl, di-, tri-...deca-). PCBs are very resistant to degradation and persist in the environment. They are relatively insoluble in water, dielectric, and flame-resistant. As a result, PCBs were commonly used in industrial processes and were often found in oils used in machinery such as transformers. The anti-degradation properties that made PCBs valuable to industrial and manufacturing processes also made them an environmental hazard.

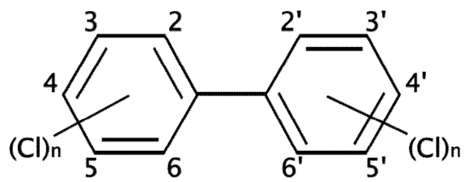

Figure 1-3. Chemical structure of polychlorinated biphenyls (PCBs) (Wikimedia, 2006)

PCB production and usage were banned in the late 1970’s. However, PCBs may still be found in legacy machinery that fall under the exceptions to EPA regulations such as train locomotives. Given their persistence, PCBs are still commonly found in the atmosphere, in the water column and sediment of rivers, streams, lakes, and estuaries, and in the soil, especially soil at contaminated sites. While the concentrations of PCBs in the environment are typically small relative to other pollutants addressed by TMDLs, PCBs bioaccumulate in fish at low concentrations, and considering their known high toxicity and risk to human health, even in small quantities of PCBs in the environment is a concern. The common units used in this report to denote concentrations and loads of PCBs are listed in Table 1-3.

Table 1-3. Common PCB concentration and load units used in this report.

Media/Measure	Units	Parts-per
Fish Tissue	nanograms per gram, ng/g	parts-per-billion, ppb
Sediment	nanograms per gram, ng/g	parts-per- billion, ppb
Water Column (PCB Concentration)	picograms per liter, pg/L	parts-per-quadrillion, ppq
Annual PCB Load	milligrams per year, mg/yr	–

In its 1999 Final Rule: Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants; States’ Compliance—Revision of Polychlorinated

Biphenyls (PCBs) Criteria (USEPA 1999), the EPA determined that the major pathway of human exposure to PCBs is fish consumption. When PCBs enter into a water body, they may contaminate fish tissue at very low levels through bioaccumulation. Fish are exposed to PCBs via different pathways such as uptake through the gills and/or skin, exposure can be affected by different feeding strategies, and are known to increase in concentration through trophic transfer within a food chain (i.e., biomagnification). Humans that consume PCB-contaminated fish may contract a multitude of chronic ailments. PCB exposure in humans can result in endocrine system disruption and weakened immune systems. Acute symptoms of PCB contamination may include fatigue, headaches, coughs, and rashes. The children of women exposed to PCBs during or before pregnancy have been found with compromised immune systems and intellectual impairments (Jacobson and Jacobson, 1996). PCBs are also a suspected carcinogen in humans. Although food is the major cause of PCB exposure for humans, exposure can also occur by breathing contaminated air and via skin contact.

1.2 *Designated Uses and Applicable Water Quality Standards*

1.2.1 **Designation of Uses (9 VAC 25-260-10 A)**

"All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish" (SWCB, 2019). Mountain Run does not support the fish consumption designated use as VDH made the determination for restrictions on fish consumption to protect human health from PCB contamination. DEQ also included Mountain Run as not meeting the "fishable" component of the general standard and subsequently listed it in the 303(d) impaired waters list for PCBs due to PCB contaminant exceedances in fish tissue and in the water column.

1.2.2 **Applicable Water Quality Standards**

The VDH and DEQ have PCB fish tissue thresholds, and DEQ has a water quality criterion (WQC) designed to be protective of the "fishable" use (Table 1-4). VDH provides alerts on unsafe fish consumption when contaminants like PCBs are detected in fish tissue and their quantity in the sampled tissue exceeds the level of concern. In 2012, VDH revised the threshold level from 50 ng/g (ppb) to 100 ng/g (ppb) (VDH, 2012). DEQ's WQC for total PCBs (tPCB), as listed in 9 VAC-25-260-140, was derived by following EPA's guidelines to protect human health from toxic effects through drinking water and the consumption of fish. The WQC, adopted by the Virginia State Water Control Board in January 2010, was derived using a risk-based approach whereby 1) a bioconcentration factor (BCF) was used as the denominator of the risk-based equation to translate the value into an acceptable concentration in water (e.g., WQC), and then 2) an acceptable fish tissue threshold concentration was determined by removing the BCF from the equation. DEQ's criterion-based fish screening threshold was originally 54 ng/g (ppb), but with the application of updated risk-based assumptions, the threshold was decreased to 20 ng/g (ppb) in 2010 (DEQ, 2010), and then again in 2021 to 18 ng/g (ppb) (DEQ, 2021a). The VDH's revised value and DEQ's fish TV are different because they serve different purposes. VDH consumption advisories seek to mitigate human health risks once a waterbody has become contaminated. DEQ's fish screening value is designed to mitigate the risk of excess contamination in all of Virginia's waters.

Table 1-4. Applicable Fish Tissue Thresholds and Water Quality Criterion for PCBs

Agency	Fish Tissue Threshold (ng/g, ppb)	Water Quality Criterion (pg/L, ppq)
Virginia Department of Health (VDH)	100 (Fish Consumption Advisory)	–
Virginia Department of Environmental Quality (DEQ)	*18 (Fish Tissue Value)	**580

*DEQ's Tissue Value when this TMDL was developed.
** WQS Footnote: Human health criteria are based on the assumption of average amount of exposure on a long-term basis.

Considering the fact that fish have different exposure pathways to PCBs, the use of DEQ's fish tissue value (TV) and a segment-specific Bioaccumulation Factor (BAF) adds additional assurance to the prospects of restoring the "fishable" designated use. The benefit to using a segment-specific BAF approach was established during the development of the multi-jurisdictional PCB TMDL for the Potomac River (ICPRB, 2007) the Roanoke River PCB TMDL (DEQ, 2009), and the New River PCB TMDL (DEQ, 2018). By adhering to the guidelines from the aforementioned studies, a PCB water quality target for the Mountain Run study area was determined through the derivation of a segment-specific endpoint using local fish tissue/river water monitoring data.

A BAF quantifies the ratio between the pollutant concentrations in a stream to the pollutant concentration found in fish tissue. This methodology improves upon the BCF approach as it accounts for multiple pathways of exposure in fish including uptake from water, food, and sediment. The final BAF value uses DEQ's fish TV of 18 ppb to derive the water quality endpoint. Of note, the fish TV is an equivalent concentration to the water based WQC and is consistent with the most up-to-date threshold level as described in the 2022 Water Quality Assessment Guidance Manual (DEQ, 2021a).

1.2.3 **Targeted Water Quality Goals**

After the water quality endpoint was derived from the final BAF, it was compared against the applicable WQC of 580 pg/L. The more protective (smaller) value of the two (310 pg/L) was used as the final water quality (WQ) target/TMDL endpoint. Appendix A details the process of calculating and selecting a TMDL endpoint. Provided in the appendix is an explanation of the BAF calculation, how the fish tissue thresholds were used, and the conditions for selecting a suitable endpoint.

Chapter 2: Watershed Characterization

2.1 *Selection of Subwatersheds*

The Mountain Run watershed was subdivided into twenty-eight subwatersheds as illustrated in Figure 2-1. Subwatersheds were delineated based on a number of factors: continuity of the stream network, similarity of land use distribution, and proximity to water quality monitoring stations. The stream network used to help define the subwatersheds was obtained from the National Hydrography Dataset (NHD) (USGS, 2019). Subwatershed outlets were located at or near a monitoring station, so that simulated outputs could be calibrated to observed monitoring data (to be discussed in Chapter 5). Table 2-1 lists the Mountain Run subwatersheds and their acreage.

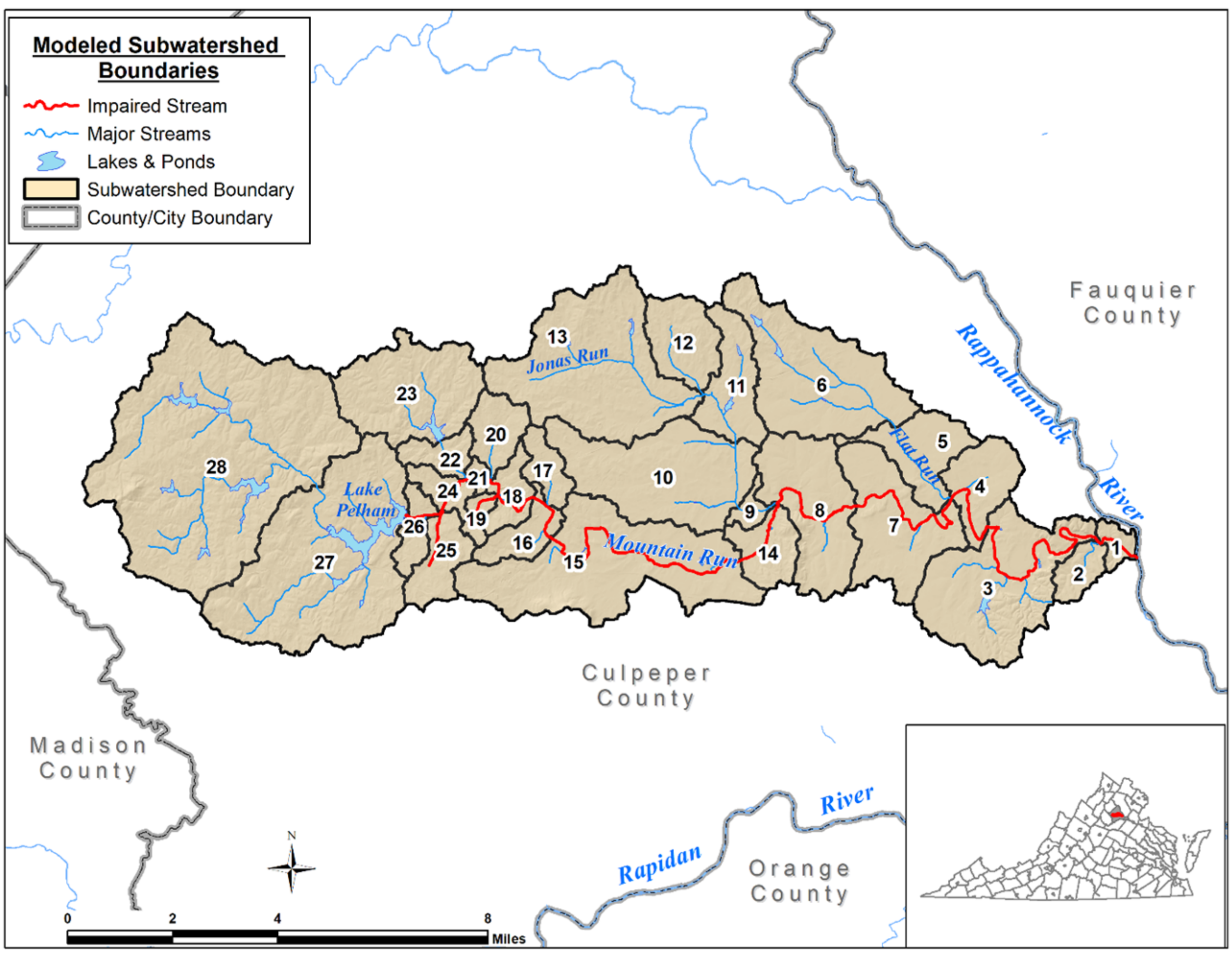

Figure 2-1. Subwatershed boundaries used in the Mountain Run watershed model.

Table 2-1. Mountain Run subwatersheds area (ac) .

Subwatershed ID	Area (ac)
1	301
2	514
3	3,758
4	1,194
5	1,370
6	3,712
7	2,590
8	2,582
9	253
10	3,646
11	1,396
12	1,286
13	4,815
14	931
15	4,918
16	726
17	573
18	619
19	259
20	809
21	142
22	553
23	2,798
24	455
25	912
26	541
27	6,406
28	10,342
TOTAL	**58,401**

2.2 *General Watershed Characteristics*

2.2.1 **Water Resources**

The Mountain Run watershed is located within the Rapidan-Upper Rappahannock River basin USGS Hydrologic Unit Code (HUC) 02080103, and within Virginia hydrologic unit boundaries RA19, RA20, and RA21. The main stem of Mountain Run is joined by the tributaries Jonas Run and Flat Run before it flows to the Rappahannock River. Flowing southeast, these waters are joined by the Rapidan River and eventually feed into the Chesapeake Bay, where the final outlet is the Atlantic Ocean.

2.2.2 **Ecoregion**

The Mountain Run watershed is part of the Piedmont (45) and Northern Piedmont (64) Level III Ecoregions (Woods *et al.*, 1999). Figure 2-2 illustrates the portions of the study area in each ecoregion, which is further subdivided into Level IV regions with disparate geologic properties that influence the hydrology of the area. The watershed is underlain by Level IV sub-ecoregions consisting of the Northern Inner Piedmont (45e), Triassic Lowlands (64a), Diabase and Conglomerate Uplands (64b), and Piedmont Uplands (64c). These regions reflect ecosystems with similar biotic and abiotic characteristics of physiography, geology, soils, climate, vegetation, species distribution, and hydrology.

Much of the study area is nestled within the transitional area between the mountainous slopes of the Blue Ridge and the Piedmont regions. Piedmont geology consists of a mix of metamorphic, igneous, and sedimentary rock that form a terrain of low rolling hills and ridges. The western, hillier portion of Mountain Run has relatively high local relief providing moderate stream gradients that promote fish habitat and diversity. To the east, lower stream gradients are common.

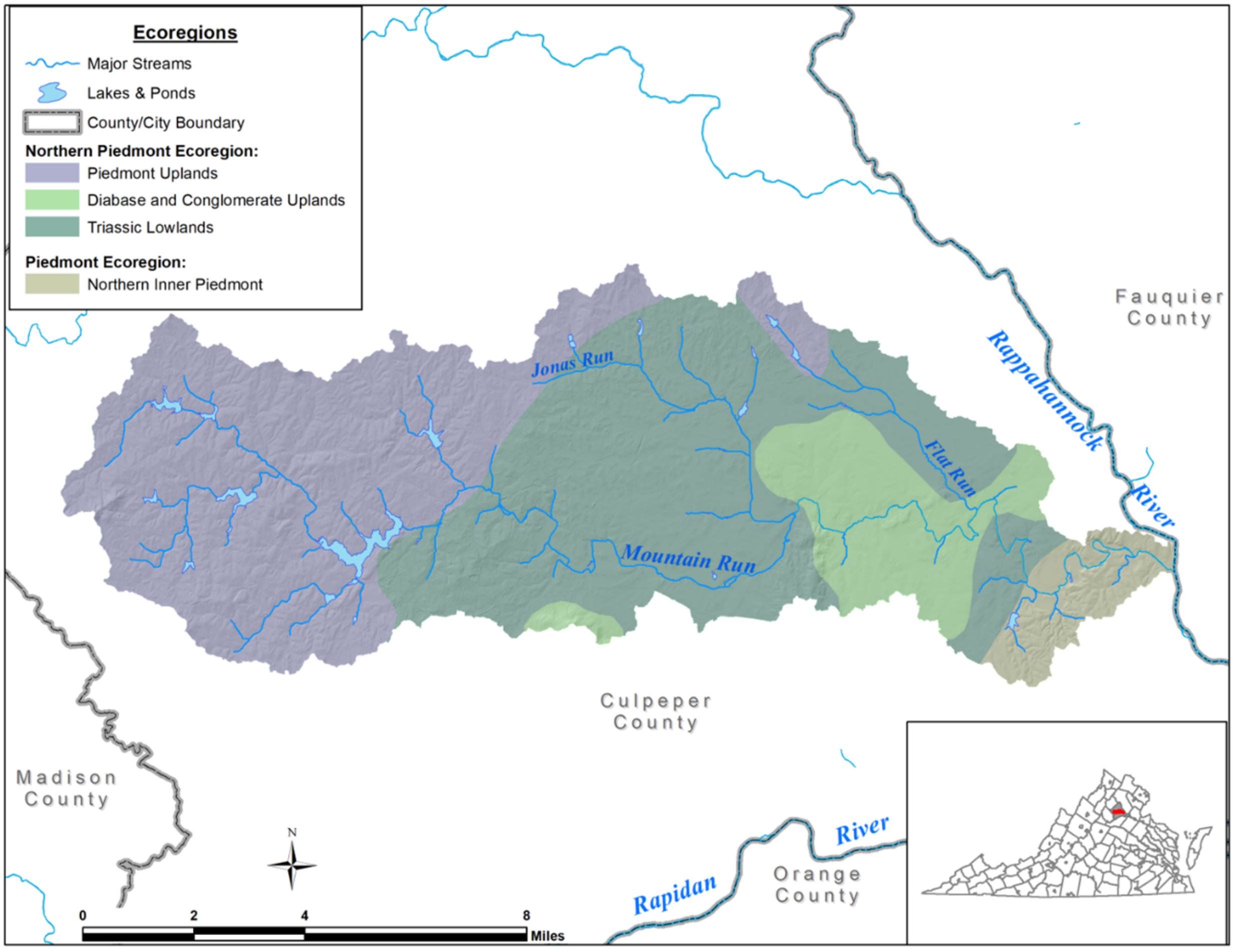

Figure 2-2. Ecoregions of the Mountain Run watershed. Legend labels areas by [Ecoregion III, Ecoregion IV].

2.2.3 **Soils**

The Soil Survey Geographic (SSURGO) dataset was used to characterize the soils in the watershed. Hydrologic soil groups were the primary soil property used. Soil groups provide a basis for estimating surface runoff and infiltration rates. For example, soils in hydrologic group “A” pass a larger proportion of rainfall through to ground water than soils in hydrologic group “B.” Conversely, soils in hydrologic group “D” inhibit infiltration such that a large proportion of rainfall contributes to surface runoff and therefore a more direct path to stream channels. These soil properties impact pollutant fate and transport (USDA-NRCS, 2019). Figure 2-3 presents the distribution of the soil groups in the Mountain Run watershed. Hydrologic group “C” soils dominate the watershed with 47% of the entire area. Hydrologic groups “B”, and “D” cover 18% and 17% of the study area, respectively. A low proportion of the study area contain hydrologic groups “B/D” (8% of the study area), “C/D” (6%), and “A” (4%). Note, there is no “A/D” hydrologic group in the study area.

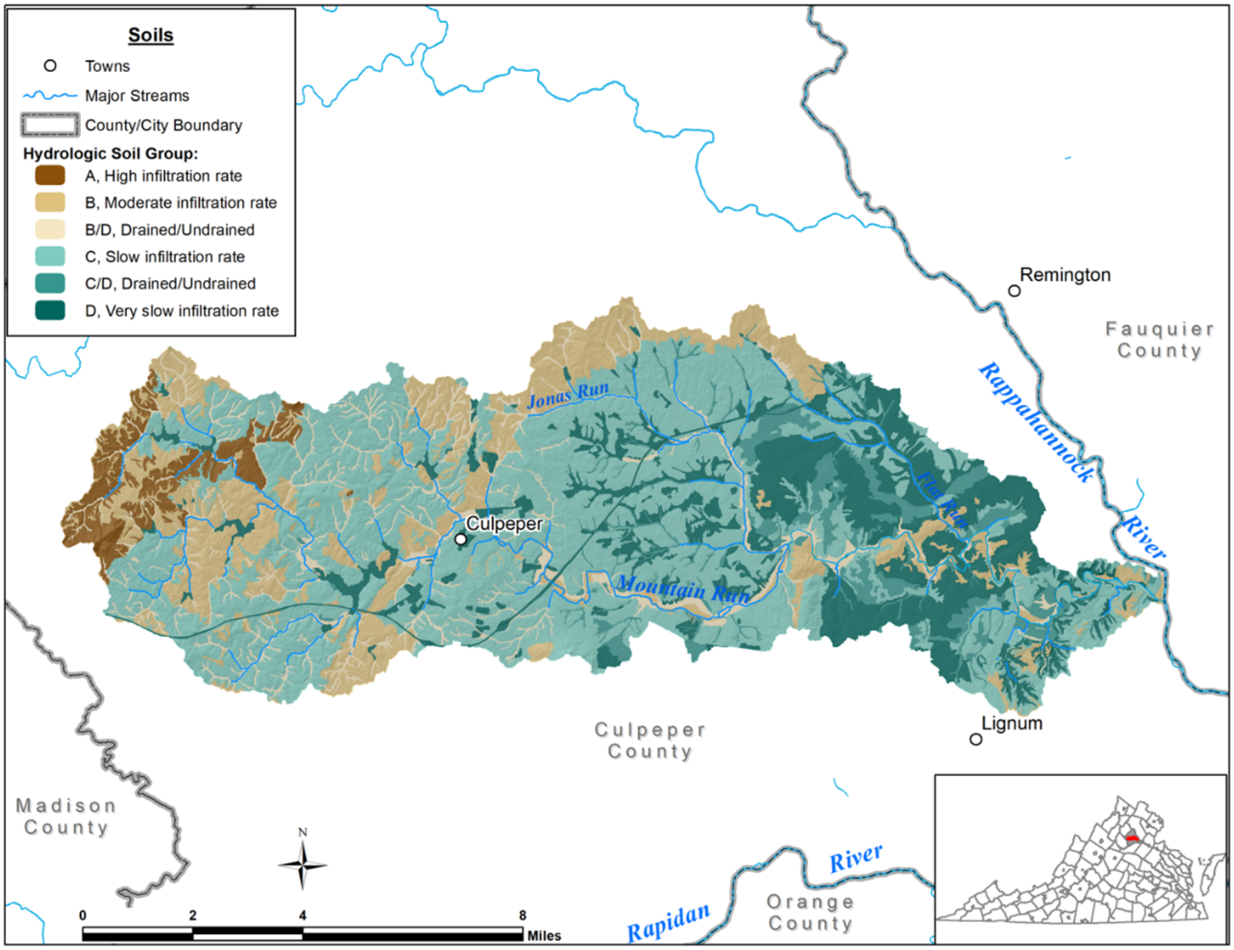

Figure 2-3. Distribution of soil types by hydrologic soil group in the Mountain Run watershed.

2.2.4 **Climate**

The climate of the Mountain Run watershed study area was characterized using meteorological observations acquired at weather stations from the National Centers for Environmental Information (NCEI) located within or near the watershed (NCEI, 2019; Table 2-2). Locations of the meteorological stations are mapped in Figure 2-4. These stations were selected based on distance to the study area, orographic influence, and completeness of the datasets.

Table 2-2. Meteorological stations and the parameter data used from each station.

Meteorological Station Locations	Station ID	Meteorological Parameters
Boston 4 SE, VA	USC00440860	Precipitation Minimum Daily Temperature Maximum Daily Temperature
Rixeyville 2.5 N, VA	US1VACP0002	
Piedmont Research Station, VA	USC00446712	
Sperryville, VA	USC00447985	
Culpeper Regional Airport, VA	723098 93798	Dew Point Temperature
Orange County Airport, VA	722167 03718	
Charlottesville Albemarle Airport, VA	USW00093736	Average Wind Speed
Washington Dulles International Airport, VA	USW00093738	
Lynchburg Regional Airport, VA	USW00013733	Percent Sun

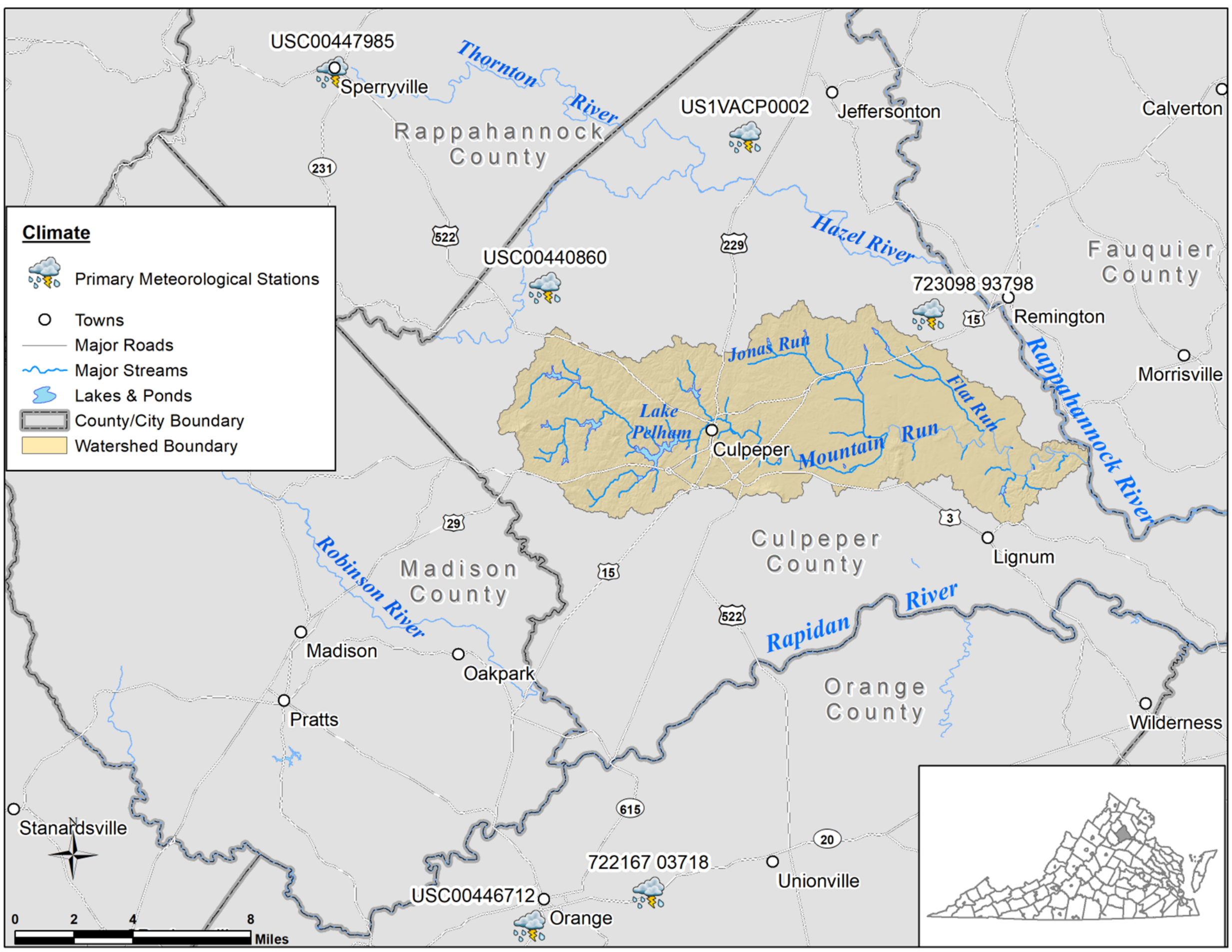

Figure 2-4. Meteorological stations used for the Mountain Run watershed. *Not shown: Charlottesville, Lynchburg, and Washington Dulles International airports.*

Table 2-2 lists the NCEI stations used to collect the main meteorological data for model input: precipitation, minimum and maximum temperature. These four stations were proximal to the study area, and together were used to compile a complete dataset needed for modeling purposes. The majority of data consisted of daily observations obtained from Global Historical Climatology Network – Daily (GHCN-Daily) meteorological stations. Two stations with Global Summary of Day (GSOD) data were located at Culpeper Regional Airport (WBAN ID: 93798), and Orange County Airport (WBAN ID: 03718). Additional stations listed in Table 2-2 provided the observed meteorological data: dew point temperature, average wind speed, and percent sun. These parameters are less commonly recorded, and past experience from developing TMDLs has revealed that water quality models are less sensitive to these weather inputs. Data from multiple stations near and far from the watershed, located at airports, were used to complete datasets for these parameters.

2.2.5 **Topography**

Topography governs the types of streams and degree of stream gradient that may be present in a watershed, and also influences weather patterns and determines hydrological behavior. Within the Mountain Run watershed elevation data is available as a 10-meter grid resolution Digital Elevation Model (DEM), which is a highly detailed topographic dataset derived from the United States Geological Survey (USGS) 3D Elevation Program (USGS, 2019). DEMs were used to delineate subwatersheds and calculate average land surface slopes. Figure 2-5 provides a visualization of the elevation distribution in the study area. Mountain Run watershed is nestled east of the slopes of the Blue Ridge mountains. Elevations in the Mountain Run watershed range approximately from 60 to 250 meters (197 to 820 feet) above mean sea level.

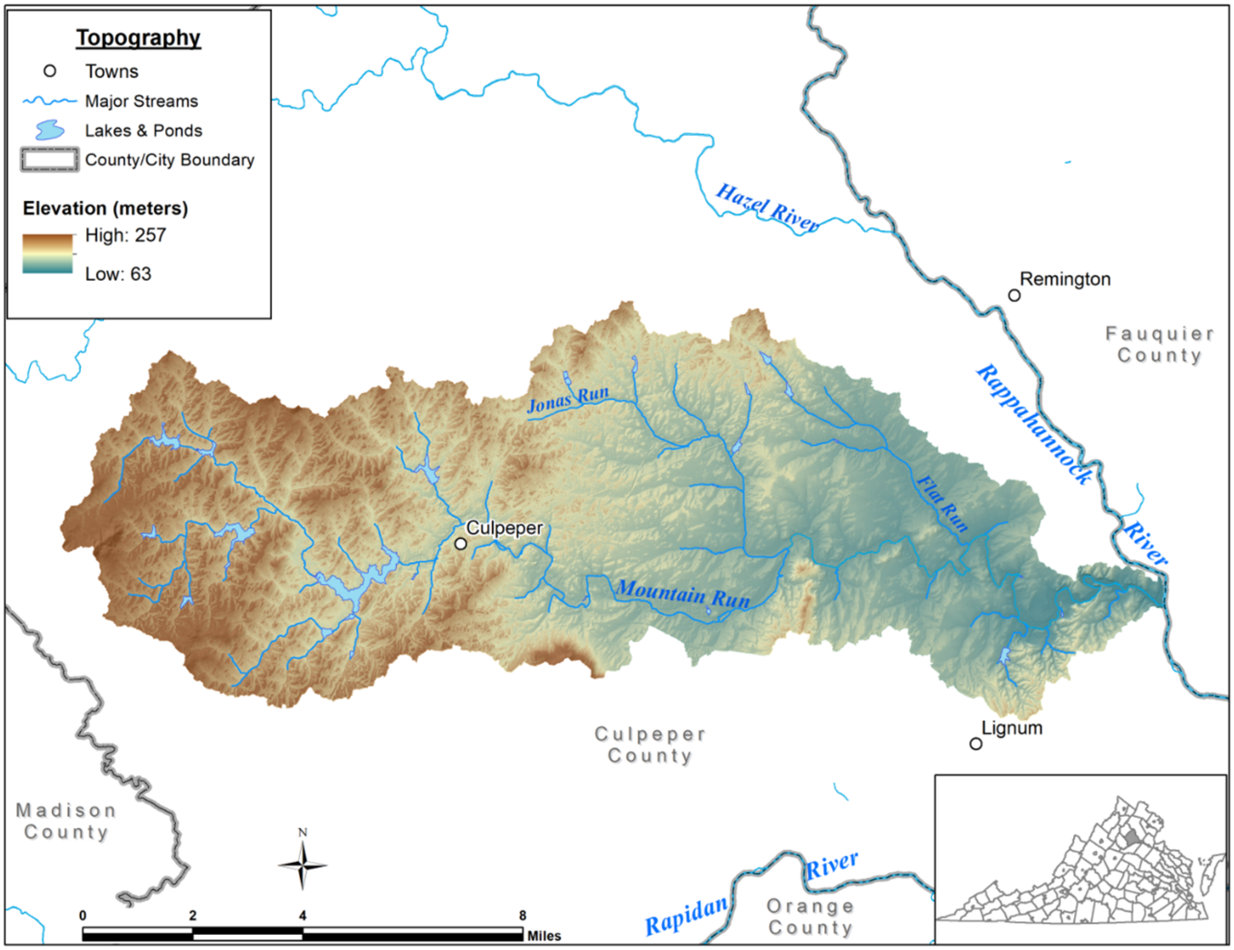

Figure 2-5. Topography of the Mountain Run watershed. Elevation is in meters.

2.2.6 **Land Use**

The Virginia Land Cover Dataset (VLCD), completed in 2016, was used to characterize land use in the study area (VGIN, 2017). The VLCD consists of 1-meter resolution digital land classes derived from base map aerial imagery. The land cover classes in the Mountain Run watershed were grouped into six major land use categories based on similarities in hydrologic features and runoff potential (Table 2-3). Pervious and impervious percentages were assigned to the land use categories for use in the watershed model. VLCD land features classified as 'Impervious' tend to represent a 'constructed' landscape that includes buildings, paved lots, roads, and railroad corridors (VITA 2016, VGIN 2017). Land cover with VLCD impervious classifications were reclassified as either 'Residential' or 'Commercial'. Areas dominated by high concentrations of impervious features were identified, and these land features were assigned to the 'Commercial' category. The modeled land use categories for the

Mountain Run watershed are presented graphically in Figure 2-6 and their distribution summarized in

Table 2-4.

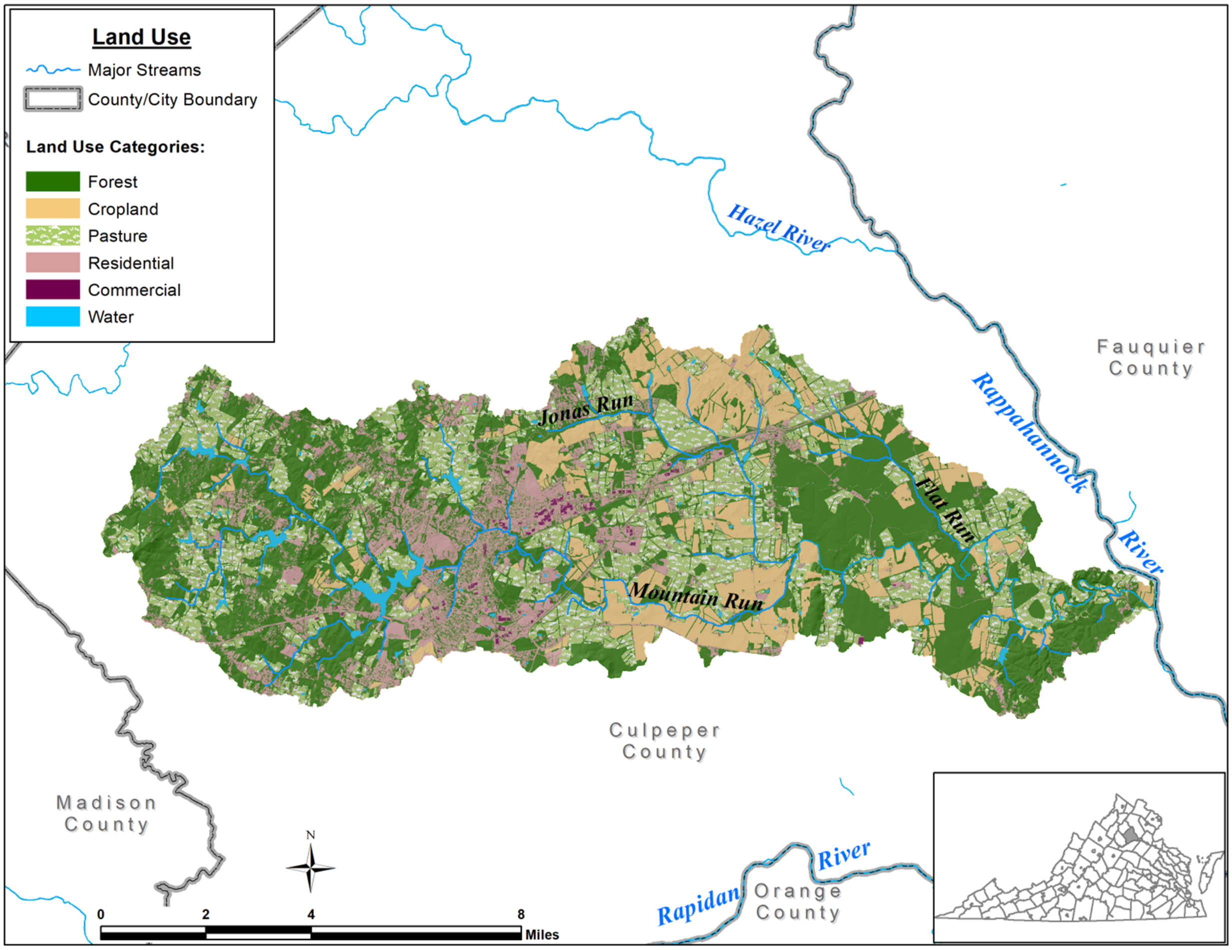

Figure 2-6. Land use distribution in the Mountain Run watershed.

Table 2-3. TMDL land use category, percent perviousness and corresponding Virginia Land Use Dataset land use class.

TMDL Land Use Categories	Pervious/Impervious (Percentage)	VLCD Land Use Classes (Gridcode)
Cropland	Pervious (100%)	Cropland (82)
Pasture	Pervious (100%)	Pasture (81)
Residential	Pervious (35%); Impervious (65%)	Impervious-extracted (21) Impervious-local datasets (22)
	Pervious (100%)	Turfgrass (71)
Commercial	Pervious (10%); Impervious (90%)	Impervious-extracted (21) Impervious-local datasets (22)
Forest	Pervious (100%)	Barren (31) Forest (41) Tree (42) Scrub/Shrub (51) Harvested/Disturbed (61) National Wetland Inventory/Other (91)
Water	Pervious (100%)	Hydro (11)

Table 2-4. Mountain Run watershed land use distribution.

	Forest	Cropland	Pasture	Residential	Commercial	Water	Total
Total Acres	26,146	8,443	14,129	8,673	203	807	58,401
% of Total	45%	15%	24%	15%	< 1%	1%	100%

2.3 *Stream Flow Monitoring Data*

When developing the hydrologic component of a watershed model, observed flow data collected by the United States Geological Survey (USGS) is typically used for modeling purposes. The USGS operates numerous flow gages throughout the United States that continuously measure the depth of the water level (stage) in the stream. The stream stage is then converted into a discharge using a stage-discharge curve. The USGS reports flow rates as daily averages (cubic feet per second, cfs).

Utilizing observed flow data was important for calibrating the hydrologic model, as well as for analyzing PCB and sediment concentration trends across flow regimes. Since there are no active continuous stream flow gages on Mountain Run, this project used model hydrology parameters from a previous Mountain Run TMDL study that addressed a bacteria impairment (BSE, 2001). Chapter 5 provides additional discussion of model development.

2.4 ***Suspended Sediment Concentration (SSC) Monitoring Data***

Since PCBs are hydrophobic and tend to attach to soil and sediment particles, an integral part of modeling PCBs is understanding the fate and transport of sediment. DEQ collected water column samples in the Mountain Run watershed from 2013-2019. These samples were analyzed to determine the suspended sediment concentration (SSC) in mg/L, and those data were used to calibrate the sediment component of the Mountain Run PCB TMDL model. SSC sample locations are shown in Figure 2-7. Appendix B.2 includes the SSC data used in the Mountain Run PCB TMDL model calibration. Sediment calibration used a “weight-of-evidence” approach that compared the simulated outputs with the observed data using multiple analyses. The multiple analyses, weight-of-evidence approach offered a systematic comparison of the simulated and observed data and ensured that an adequate model was developed with the available samples. The process of calibrating the sediment component of the Mountain Run PCB TMDL model is further explained in Appendix D.

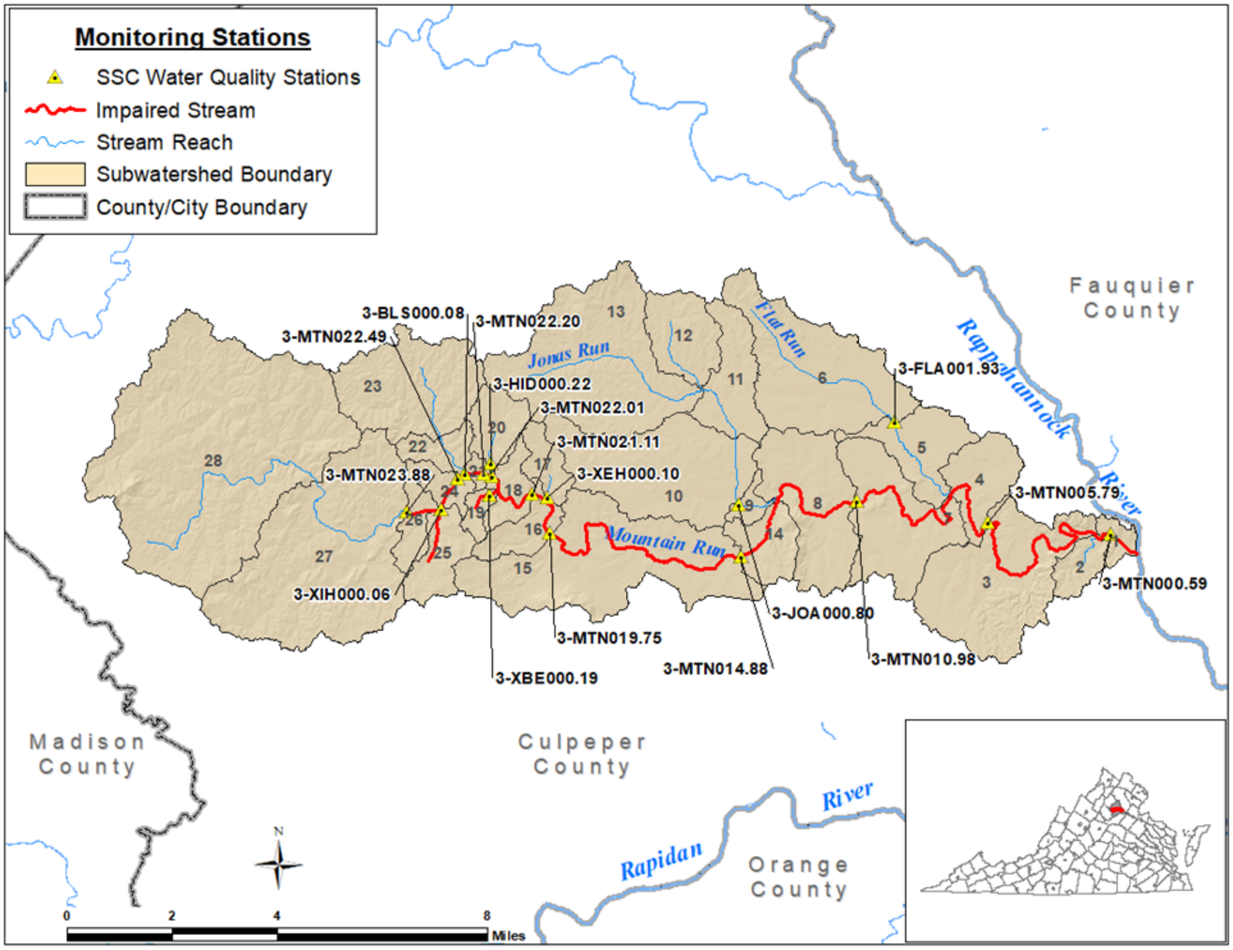

Figure 2-7. Suspended sediment concentration (SSC) water quality stations in the Mountain Run watershed. These stations were used to conduct the sediment model calibration.

2.5 *Total Organic Carbon (TOC) Data*

Water samples collected in Mountain Run were also analyzed for Total organic carbon (TOC). TOC may consist of decaying natural organic matter originating from plant fragments, algal blooms, bacteria, etc. and was reported as a concentration, mg/L. Samples were also analyzed for dissolved organic carbon (DOC), which is a measurement of the quantity of organic carbon dissolved in the water column sample. TOC, DOC, and particulate organic carbon (POC), which is derived from subtracting DOC from TOC, were important water quality constituents used to calculate BAFs and TMDL endpoints (Appendix A). TOC was also used to calculate model parameters that were used for PCB fate and transport modeling Appendix E. Appendix B.3 tabulates the TOC data used to develop the Mountain Run PCB TMDL.

2.6 ***PCB Concentration Monitoring Data***

Three types of tPCB data were collected by DEQ and were used to develop the Mountain Run PCB TMDL: Fish tissue were collected over several years and were analyzed for PCBs, river bottom sediment samples were analyzed for attached PCBs, and Mountain Run river water collected and analyzed for the combined particulate and dissolved PCB phases at several locations.

2.6.1 **Fish Tissue PCB Concentration Data**

DEQ collected fish species during 1999, 2001, 2006, and 2013 and tested the tissue for PCBs. Figure 2-8 shows the locations of the DEQ water quality stations where fish tissue samples were collected and assessed for PCBs. The primary human PCB exposure pathway of concern is consumption of contaminated fish. The units of PCB concentration are ng (nanograms, 10^{-9} g) of PCBs per gram of fish tissue. This unit is equivalent to parts-per-billion, ppb. Fish tissue PCB concentration data collected from Mountain Run were used to calculate BAFs and a site-specific TMDL endpoint. The findings from DEQ’s fish tissue monitoring can be found in Appendix B.4.

Fish tissue data were plotted to visualize the temporal and spatial distribution of PCB concentrations from upstream to downstream in the Mountain Run watershed (Figure 2-9). The y-axis of the graph is PCB concentration, and the x-axis shows the various fish species sampled at each river mile station ID, grouped by sample year. Also plotted are the VDH fish consumption advisory level (100 ng/g) and the DEQ fish tissue screening value (18 ng/g).

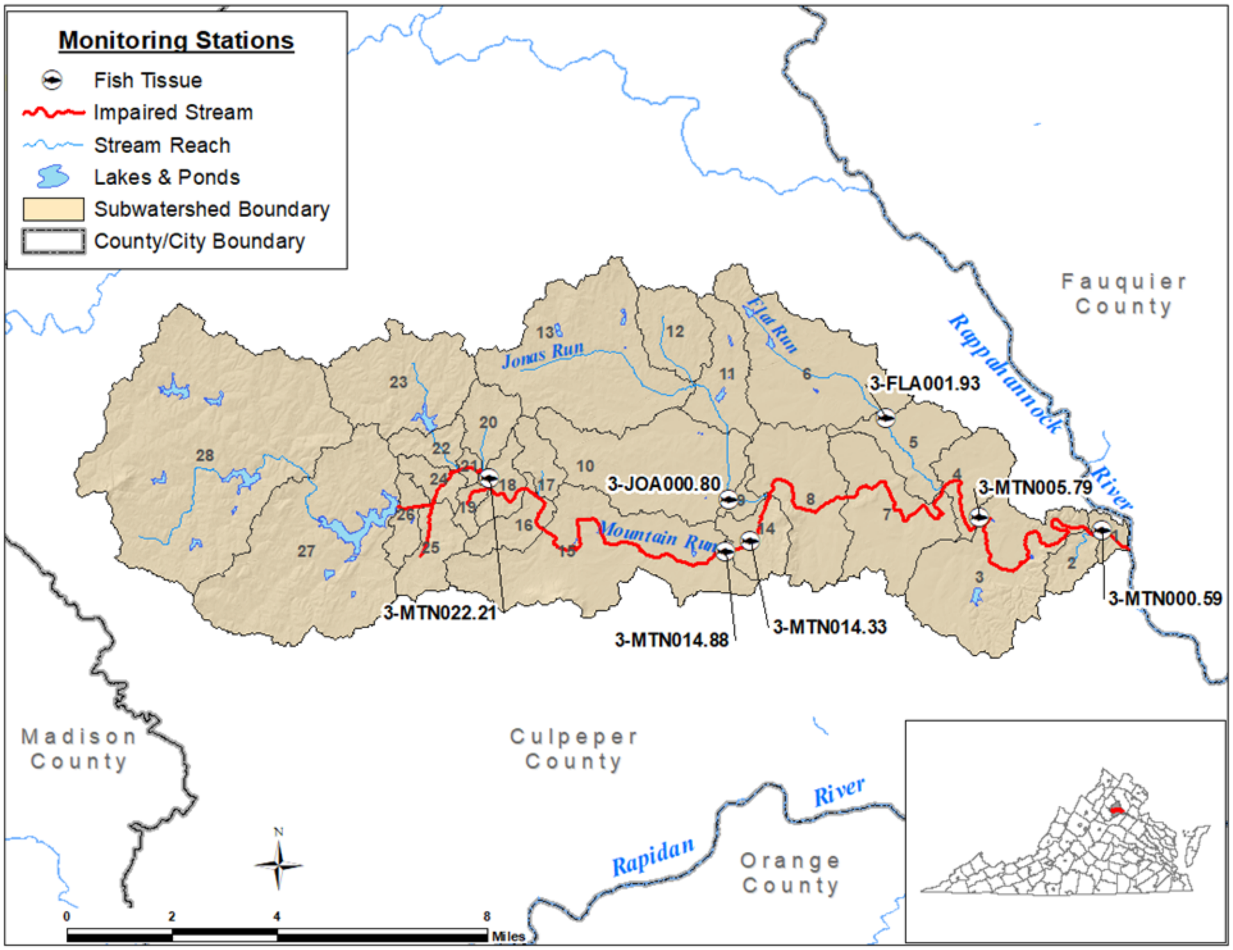

Figure 2-8. Water quality stations with fish tissue PCB concentration data in the Mountain Run watershed. These stations were used to calculate the bioaccumulation (BAF) and PCB endpoint values.

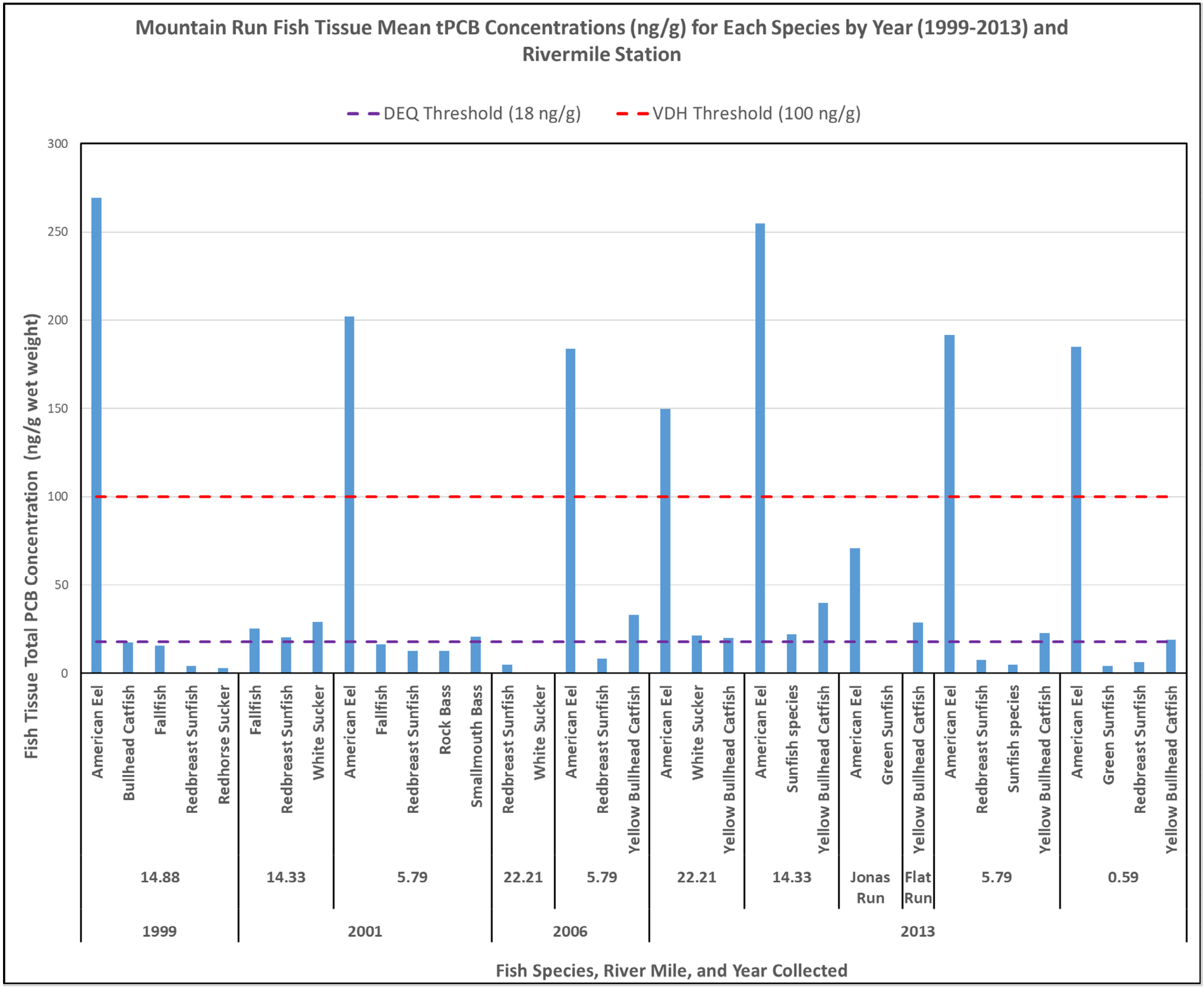

Figure 2-9. Fish tissue PCB concentrations (ng PCB/g fish tissue) from DEQ sampling in Mountain Run. Observed data are partitioned by station, fish species, year and graphed from upstream to downstream (left to right).

2.6.2 **Sediment-Associated PCB Concentration Data**

DEQ collected instream sediment samples to determine the quantity of sediment-attached PCBs. Figure 2- illustrates the locations of the DEQ water quality stations where samples were collected. Appendix B.5 tabulates the findings from DEQ's monitoring (years 2014–2015, and 2021). The units of sediment-associated PCB concentration are ng (nanograms, 10^{-9} g) of PCBs per gram of sediment (ppb). Sediment-associated PCB concentration data were used for initializing simulated sediment PCB concentrations at the beginning of the modeling period. The data were also used to confirm that the general trend of simulated sediment PCB concentrations over time (increasing or decreasing) corresponded with the observed data.

Figure 2-11 is a graphical representation of the sediment-associated PCB concentrations throughout the Mountain Run watershed. In general, PCB concentrations increase from upstream to downstream, moving from left to right on the graph. There is no maximum threshold for sediment-associated PCB concentration although sediment screening thresholds identified in DEQ's PCB strategy (DEQ, 2005a) range from 1.8 ng/g to 49 ng/g and are based on Biota Sediment Accumulation Factors (BSAFs).

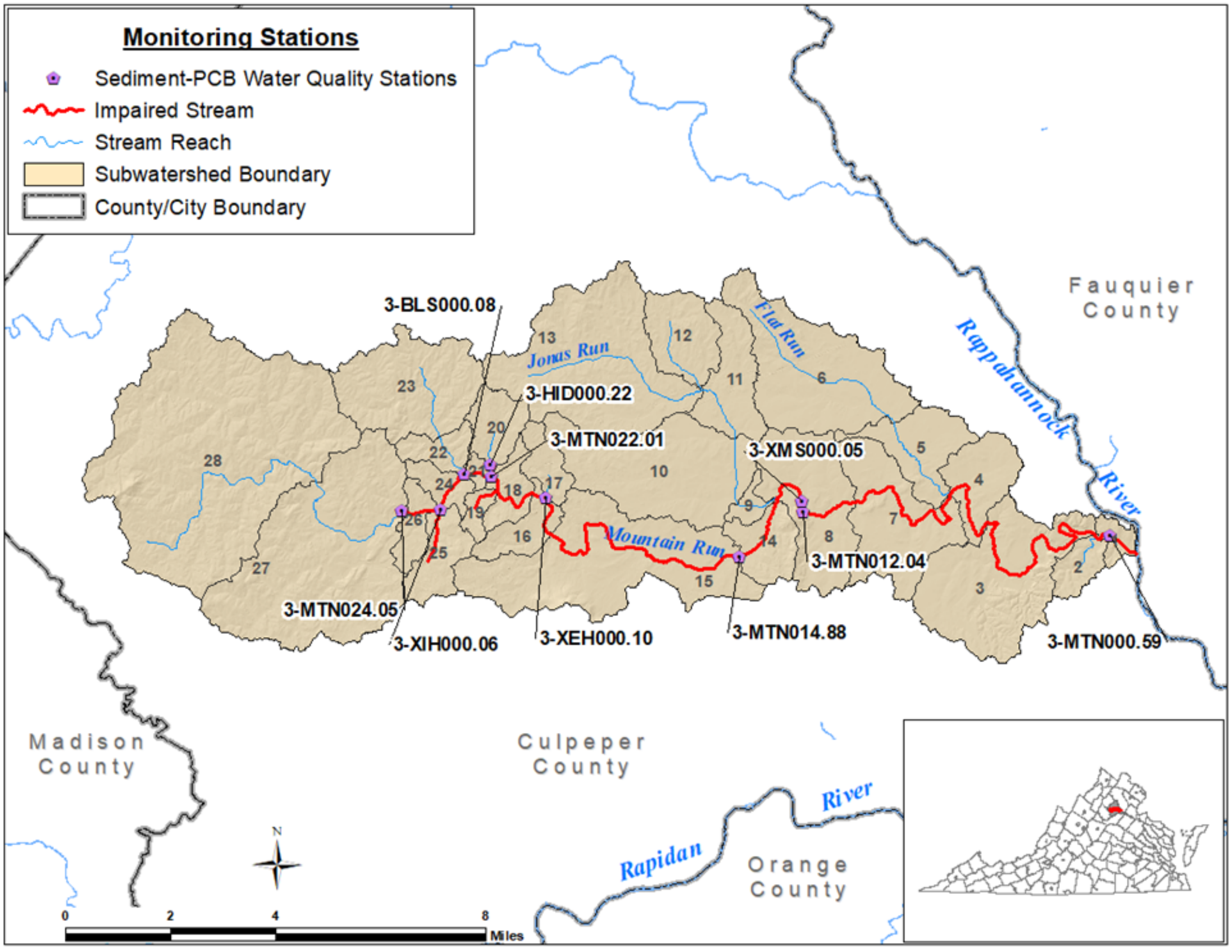

Figure 2-10. Selected sediment-associated PCB water quality stations in the Mountain Run watershed. At these stations, sediment samples were collected and tested for sediment-attached PCB concentrations. The observed data from these stations were used to calculate PCB model parameters and assess model trends.

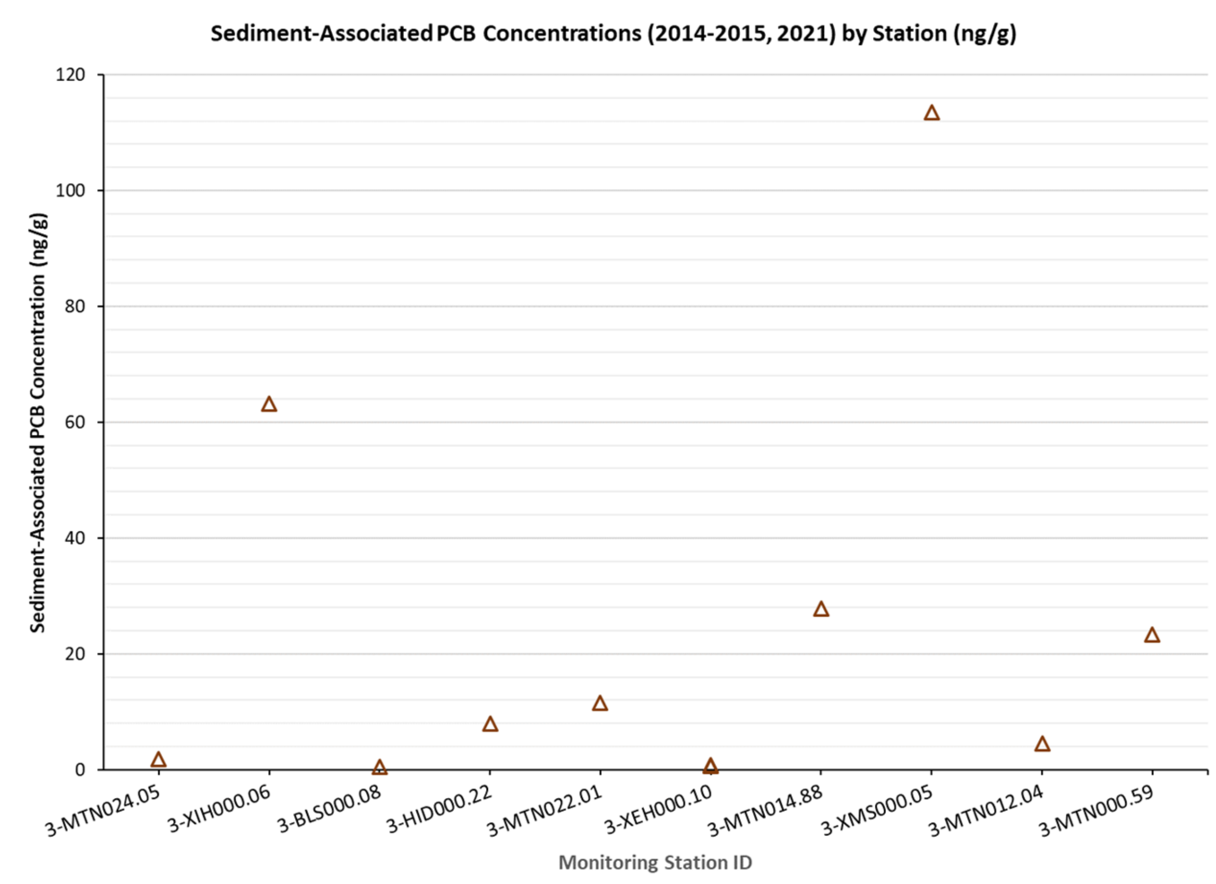

Figure 2-11. Sediment-associated PCB concentrations (ng PCBs/g sediment) in selected DEQ sediment monitoring stations used in the Mountain Run PCB model. Observed data are graphed from stations upstream to downstream (left to right).

2.6.3 **Water Column tPCB Concentration Data**

DEQ collected water column samples in 2013-2015, 2018, and 2021 and analyzed those samples for aqueous tPCB concentrations. The water column tPCB concentration includes the quantification of PCBs associated with suspended particulate matter as well as “dissolved” PCBs in the ambient water column, i.e. PCBs that are freely available in the water and are not sediment associated. Figure 2-12 illustrates the locations of the DEQ water quality stations where these samples were collected, and the results tabulated in Appendix B.6. The units are pg (picograms, 10^{-12} g) per liter of water and is equivalent to parts-per-quadrillion, ppq. For each water quality sample, DEQ summed the concentration from all detected PCB congeners to calculate tPCBs. DEQ also provided the concentration of each homolog.

Figure 2-13 shows the 2013-2021 water column tPCB sampling. On the y-axis is the water column tPCB concentrations and the station IDs are on the x-axis. The stations are arranged from left to right going from upstream to downstream. Also included is a dashed line for the Mountain Run TMDL endpoint. Table 2-5 quantifies the number of samples from each monitoring station that exceeds the TMDL endpoint. Observed PCB concentrations generally increase from upstream to downstream.

The tPCB concentration from the water column was used to calibrate the PCB fate and transport component of the Mountain Run PCB TMDL model. Two or fewer samples were collected in a single year at some water quality stations. Model calibration was accomplished using a “weight-of-evidence” approach that compared the simulated outputs with the observed data using multiple analyses and professional knowledge of the study area. Model calibration is detailed in Appendix E.

The Mountain Run PCB TMDL project utilized sediment concentration (SSC) and water column PCB data that were collected 2013-2018. Using similar calibration periods for the sediment and PCB components of the model and employing observed sample data that were collected on the same day meant the PCB component of the Mountain Run model could be built on the sediment component for the same climatic conditions.

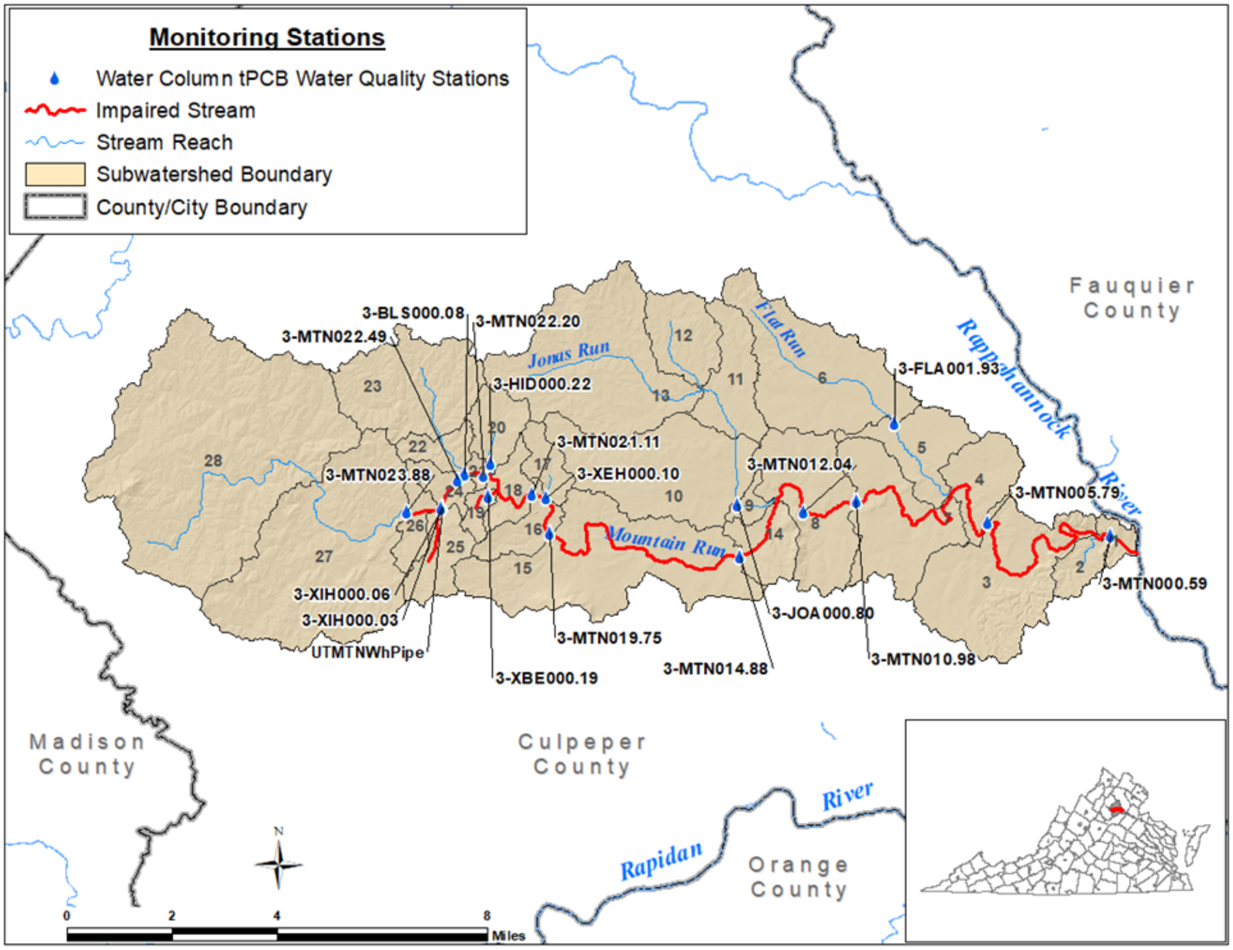

Figure 2-12. Water column tPCB water quality stations in the Mountain Run watershed. These stations were used to conduct the PCB model calibration.

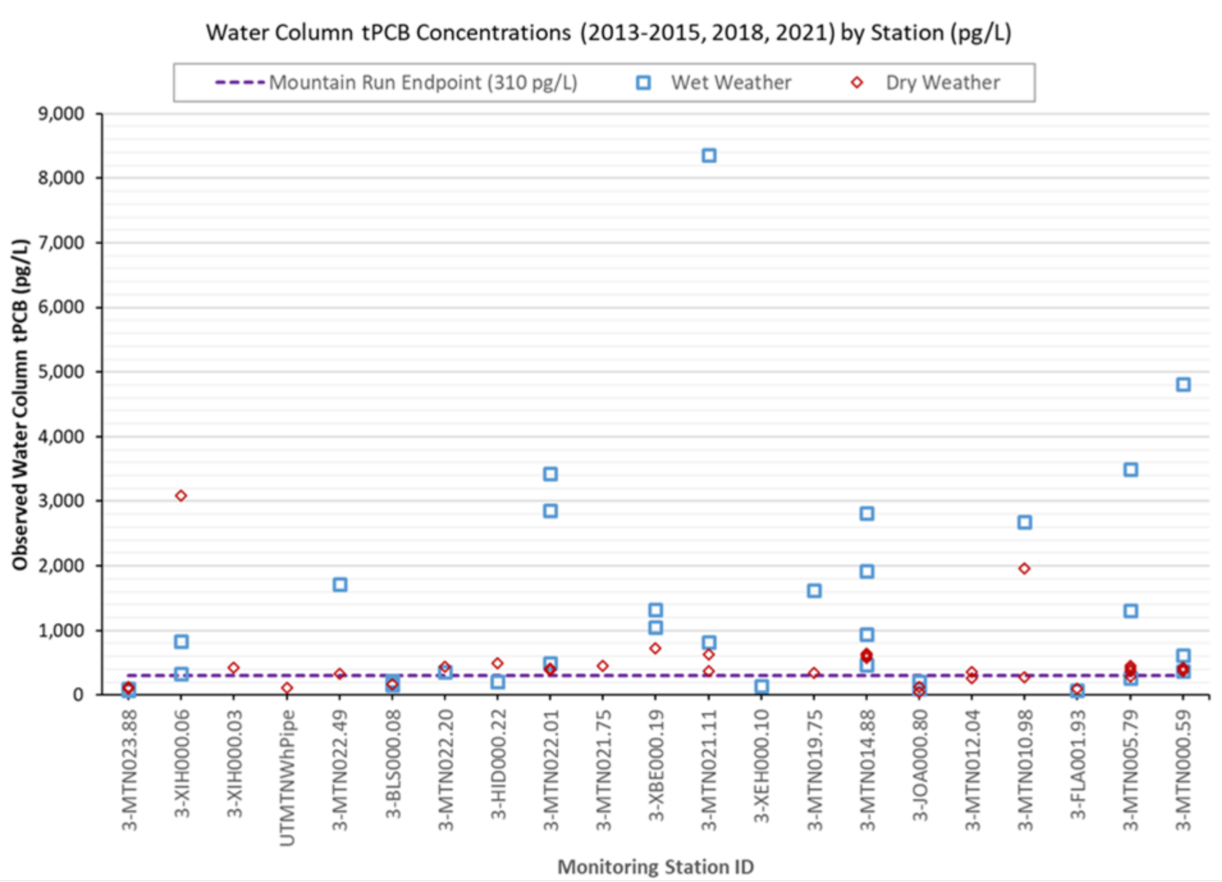

Figure 2-9. Water column tPCB concentrations (pg PCB/L water) from DEQ monitoring stations used in the Mountain Run PCB model. Observed data are graphed from stations upstream to downstream (left to right), as collected during wet or dry weather conditions. The dashed line represents the TMDL endpoint (310 pg/L).

Table 2-5. Number of water quality samples exceeding the TMDL endpoint (310 pg/L).

Monitoring Station	No. of Samples	No. of Samples Exceeding Endpoint	Percent Exceedance (%)
3-MTN000.59	6	6	100
3-MTN005.79	7	5	71
3-FLA001.93	2	0	0
3-MTN010.98	3	2	67
3-MTN012.04	2	1	50
3-JOA000.80	4	0	0
3-MTN014.88	8	8	100
3-MTN019.75	2	2	100
3-XEH000.10	1	0	0
3-MTN021.11	4	4	100
3-XBE000.19	3	3	100
3-MTN021.75	1	1	100
3-MTN022.01	5	5	100
3-HID000.22	3	1	33
3-MTN022.20	2	2	100
3-BLS000.08	4	0	0
3-MTN022.49	2	2	100
3-XIH000.06	3	3	100
3-XIH000.03	1	1	100
3-UTMTNWhPipe	1	0	0
3-MTN023.88	4	0	0
Total	**68**	**46**	**68%**

Chapter 3: Source Assessment

The source assessment chapter describes the currently available data on the sources of PCBs in the Mountain Run PCB TMDL study area. Please refer to Appendix C for detailed information. Point- and nonpoint- sources contribute to the PCB loadings found in the impaired segments of Mountain Run. Permitted point sources (e.g., those that are regulated in the Virginia Pollutant Discharge Elimination System (VPDES)), include municipal wastewater treatment plants, and other permitted facilities from industrial or commercial activities that have been identified by DEQ as potentially contributing PCB loadings. Nonpoint sources include: known and suspected runoff (e.g., runoff from contaminated sites, railyards and railway spurs, electrical substations and pollutant spills); less certain sources are categorized as non-regulated surface sources and include uncharacterized sources that contribute background PCBs to the land and water surfaces; atmospheric deposition; and sediment within the channel stream bottom. This chapter describes the types of PCB sources and how they were included in the Mountain Run PCB TMDL model. Detailed information regarding the estimation of PCB loads for each of the sources found in Mountain Run can be found in Appendix C.

3.1 ***Permitted Sources***

This section lists the specific permitted facilities that have been identified as possible sources of PCBs. The Mountain Run watershed contains permitted point sources that operate under individual permit including municipal wastewater treatment plants (WWTP), and those that operate under a general permit that are identified as industrial storm water facilities (ISWGP). Both types of facilities operate under the Virginia Pollutant Discharge Elimination System (VPDES) permitting process. There are no municipal separate storm sewer systems (MS4s) in this watershed, and based on the lack of evidence for large industrial facilities located in the watershed and operated under an individual permit, or small domestic wastewater facilities, they are not considered to be PCB sources.

All permitted dischargers with potential for PCB source contribution were modeled as point sources, Appendix C. Table 3-1 lists the WWTP and ISWGP facilities in the Mountain Run study area with the mean PCB concentration. For those instances where PCBs were not collected in advance of developing the Mountain Run PCB TMDL, default tPCB concentrations were used from a statewide dataset that are applicable to municipal and industrial outfalls (DEQ, 2016). The endpoint of 310 pg/L for the Mountain Run point source dischargers is based on calculated, segment-specific BAFs.

Table 3-1. Permitted PCB point source discharges located in the Mountain Run watershed.

Facility Type	PCB Impaired Waterbody	Facility Name	Permit ID	Mean tPCB Concentration (pg/L)
Municipal WWTP	Mountain Run	Town of Culpeper WWTP	VA0061590	285.5
Industrial Stormwater	Mountain Run, UT*	TE Connectivity - Culpeper Plant	VAR050855	458.6
	Mountain Run, UT	Bingham and Taylor Corp	VAR050900	1,100.0
	Mountain Run, UT	Culpeper Municipal Power Plant	VAR051573	619.4
	Mountain Run	Wise Services and Recycling LLC	VAR051878	2,223.8
	Jonas Run, UT	Culpeper Recycling	VAR051928	314.3
	Mountain Run	Culpeper Towing and Salvage Incorporated	VAR051952	1,169.7
	Jonas Run, UT	AMRF Incorporated	VAR052293	2,218.6

* UT, unnamed tributary

3.2 ***Nonpoint Sources***

Nonpoint sources included contaminated sites, stormwater runoff from unregulated surface sources (including unregulated stormwater, unidentified contaminated sites, loads from small tributaries, atmospheric deposition to land surfaces, and unspecified point sources) atmospheric deposition to the surface water, and streambed sediment. Table 3-2 lists the nonpoint sources considered in the Mountain Run PCB TMDL.

Table 3-2. Mountain Run nonpoint sources and estimated PCB loads.

Nonpoint Sources	PCB Load
Contaminated Sites	
Volunteer Remediation Program Sites	Varies by site
Railyards and Railway Spurs	7.02×10^{10} pg PCB/ton of sediment
Electrical Substation	1.29×10^{12} pg/PCB/ton of sediment
Pollution Response Program (PREP) Spills	Varies by Spill
Surface Sources	
Unregulated Surface Sources[1]	Varies by land use category
Atmospheric Deposition	8.90×10^{3} pg/m^2/year
Streambed Sediment	Varies by stream segment

[1] Unregulated surface sources represent PCB loads supported by the observed data whose specific location have yet to be identified.

3.2.1 **Contaminated Sites**

The PCB load for contaminated sites is modeled as a potency factor that estimates the mass of PCBs washed off per ton of sediment runoff from the contaminated site. Contaminated sites with the potential for long-term contamination of the soil, such as former manufacturing facilities, railyards, and electrical substations, were assigned “contaminated” land use categories that are similar hydrologically, pedologically and geophysically to the existing land use types (e.g., Forest, Cropland, Pasture, Residential, etc.). Since the location of Pollution Response Program (PREP) spills have been recorded in VDEQ’s PREP database, these PCB sources are also identified as loads from contaminated sites. However, because a PREP spill is an isolated incident, PREP PCB spills were modeled as direct inputs into the stream or as deposition onto the land surface as a “one-time” event based on the recorded date of the spill.

3.2.2 **Unregulated Surface Sources**

Unregulated surface source is a term that collectively describes PCB loadings from uncertain origins that drain to Mountain Run during runoff events. This source category represents PCB load concentrations observed in instream water column samples, but whose specific location have yet to be identified. The term “direct drainage” was used in the Potomac River PCB TMDL to describe unregulated stormwater runoff, unidentified contaminated sites, and unspecified point source discharges (ICPRB, 2007). The Roanoke River PCB TMDL referred to these as “urban background/unidentified sources” (DEQ, 2009) whereas these source types were recognized as “uncharacterized sources” in the New River PCB TMDL (DEQ, 2018). Sources in the Mountain Run PCB TMDL study area that are recognized as contributing to the land surface category include loads from unidentified contaminated sites, unregulated stormwater runoff from commercial land use areas, atmospheric deposition to land surfaces, loads from small tributaries that are not explicitly specified in the model, and unspecified point source discharges. Unregulated surface sources were modeled as a load applied to all land area not part of the contaminated sites, railyards, electrical substations, or PREP spills. DEQ will continue to search for these unaccounted sources that contribute to the PCB impairment as part of TMDL implementation and upon identification, will identify mechanisms to target load reductions.

3.2.3 **Atmospheric Deposition**

Atmospheric deposition is due to aerosolized PCBs that settle out of the atmosphere. This source was applied on all water surfaces in the Mountain Run watershed at a constant rate throughout the year.

3.2.4 **Streambed Sediment**

The streambed sediment source accounts for legacy PCBs that are present in the aquatic environment and are adsorbed to sediment.

3.2.5 **Biosolids**

One VPDES Municipal WWTP is considered as a potential source of PCBs to Mountain Run and is allocated a load. Whether legacy or from more recent sources, PCBs originate from unknown areas within municipality collection systems where conveyance to the treatment plants occurs. After treatment, a small percentage can be released with the effluent. Observations have shown that PCB concentrations entering WWTPs via influents are typically elevated when compared to the concentrations that exit the facilities. Given PCBs extreme hydrophobicity, the tendency is for PCBs to adsorb to available solids. WWTPs, operating properly, can remove 80-99% of solids from the

WWTP effluent. Given this, it is reasonable to conclude that most PCBs are settling out of WWTP's in sewage sludge.

When treated and used for agronomic purposes, sewage sludge is referred to as biosolids, and requires a permit administered under the Virginia Pollution Abatement (VPA) permit program (9VAC25-32-10 et. seq.) or the VPDES permit program (9VAC25-31-10 et seq.). When biosolids are land applied, regulations require treatment to significantly reduce pathogens and vector attraction. Regulations also include pollutant concentration limits for heavy metals and PCBs. Section 9VAC25-32-317 of the VPA permit program requires that PCBs be monitored within sewage sludge and are considered acceptable for application only when the concentration is less than 50 mg/Kg (ppm) of total solids (dry weight basis). Permit regulations also require spreading according to sound agronomic requirements with consideration for topography, hydrology, and the use of appropriate setbacks depending on site-specific conditions.

While it has been the practice to apply biosolids at numerous fields within the study area, application sites are likely insignificant sources of PCBs in the Mountain Run watershed. Samples collected from fields located in other watersheds in Virginia that have received biosolids applications show an arithmetic mean concentration of 0.15 mg/Kg, well below the allowed 50 mg/Kg. Further, with adherence to the agronomic requirements specified in the VPA regulations, prospective loadings derived from stormwater runoff from this source would be considered *de minimis.*

Chapter 4: TMDL Technical Approach

A key component in developing a TMDL is establishing the relationship between pollutant loadings (both point- and nonpoint-source) and instream water quality conditions. Once this relationship is developed, options for reducing pollutant loadings to streams can be assessed. In developing a TMDL, it is critical to understand the processes that affect the fate and transport of the pollutants that are impairing the waterbody of concern. Pollutant transport to water bodies is evaluated using a variety of tools, including monitoring, geographic information systems (GIS), and mathematical, computer simulation models.

4.1 *Critical Considerations*

PCBs exist in the environment in many different forms, i.e., as an airborne contaminate, as a freely available (“dissolved”) water column constituent, as an attached constituent that is adsorbed to suspended particulate in the water column, as a constituent attached to sediment deposited on the streambed, and as a constituent associated with soil (e.g., contaminated sites). Understanding the PCB concentrations found in each of these forms requires an understanding of the fate and transport of PCBs within a watershed. Developing a hydrologic representation (computational model) of the watershed is an important initial step in assessing the fate and transport of PCBs in the environment. A well-calibrated hydrologic model creates a foundation upon which the model’s pollutant fate and transport components can be developed.

A critical assumption when developing a pollutant fate and transport model is that the water quality grab samples collected by DEQ are completely representative of the stream cross section. While this is likely not the case due to incomplete mixing, continuous sampling across the entire cross section of every stream and tributary is unfeasible. Thus, the assumption that the stream is a completely mixed medium is necessary. To account for this and other assumptions and uncertainties inherent in pollutant fate and transport modeling, a conservative modeling approach was used to ensure that the model did not underestimate the PCB concentration. Additionally, an explicit margin of safety (MOS) of 5% was incorporated into the TMDL.

4.2 ***Modeling Framework***

The TMDL development process often relies on the use of a mathematical watershed-based model that integrates both point and nonpoint sources and simulates instream hydrologic and water quality processes. The Hydrological Simulation Program–FORTRAN (HSPF) version 12 (Bicknell *et al.*, 2005) was used to model sediment and PCB transport and fate in the Mountain Run watershed. The HSPF model is capable of modeling overland and instream hydrologic and pollutant fate and transport processes, making it an appropriate choice for this application.

HSPF simulates nonpoint source runoff and pollutant loadings, performs flow routing through streams, and simulates instream water quality processes. HSPF estimates runoff from both pervious and impervious parts of the watershed and stream flow in the channel network. The sub-module PWATER (water budget pervious) within the module PERLND (pervious land) simulates runoff, and hence, estimates the water budget, on pervious areas (e.g., agricultural land). Runoff from impervious areas is modeled using the IWATER (water budget impervious) sub-module within the IMPLND (impervious land) module. The simulation of flow through the stream network is performed using the sub-modules HYDR (hydraulic behavior) and ADCALC (advection of fully restrained constituents) within the module RCHRES (stream reaches and reservoirs). While HYDR routes the water through the stream network, ADCALC calculates variables used for simulating convective transport of the pollutant in the stream.

Fate and transport of PCBs on pervious and impervious land segments is simulated using the SEDMNT (sediment production and removal) and PQUAL (quality constituents pervious) sub-modules within the PERLND module, and SOLIDS (solids accumulation and removal) and IQUAL (quality constituents impervious) sub-modules within the IMPLND module. Fate and transport of PCBs in stream water is simulated using the sediment transport (SEDTRN) sub-module and general constituent pollutant (GQUAL) sub-module within the RCHRES module. Each component of HSPF contains a series of parameters that control hydrologic and constituent behavior. During calibration, model parameters and pollutant sources are adjusted. The simulated outputs were analyzed against the observed data, and if an adequate calibration is not achieved, parameters and source loads are further adjusted in an iterative cycle until the model is calibrated. Model development is discussed in more detail in Chapter 5 and Appendices D and E.

Chapter 5: Model Setup for PCB TMDL Development

The Mountain Run PCB TMDL model was developed in two phases. In the first phase, watershed characterization relevant meteorological, hydrological and constituent (sediment and PCBs in this study) source data were compiled, processed, and converted into variables and parameters required for the model. The second phase, calibration, entailed comparing the model outputs with observed data and adjusting model parameters and variables until the model adequately simulated what the observed data showed. This chapter offers a summary of the steps involved during model development.

5.1 *Watershed Segmentation*

One of the first steps in the watershed characterization process was delineating the watershed into subwatersheds in order to capture the diversity in hydrology and geomorphology. Dividing the study area into subwatersheds allowed for more detailed and representative modeling. Rather than assuming the entire watershed is hydrologically homogenous, each subwatershed featured different parameters and proportions of land use types. Subwatersheds were delineated based on the stream network, hydrologic and land use variability, and the locations of PCB sources and DEQ water quality monitoring stations. Where possible, subwatersheds were delineated so that DEQ water quality monitoring stations were located at a subwatershed outlet. This ensured better comparability of simulated and observed data since model results were simulating pollutant fate and transport from the same area of land represented in the collected samples. Figure 2-1 shows the relative position of the subwatersheds within the Mountain Run watershed. Table 2-1 shows the respective area for each subwatershed.

5.2 *Input Data Requirements*

5.2.1 **Land Use, Soils, and Topography Data**

Land use, soils, and topographic data were used for estimating various model parameters. Soils data were used to estimate hydrologic parameters that determine surface, interflow, and groundwater patterns, ultimately impacting the water balance.

Land use data were used to determine the percentage of pervious and impervious surface area. Stream network data from the high-resolution National Hydrography Dataset (NHDPlusHR) were used to identify perennial streams and the primary stream network (USGS, 2019). Topography was assessed using seamless 10-meter resolution digital elevation models from the USGS 3D Elevation Program (USGS, 2019) and were the basis for subwatershed delineation and calculating terrain slopes. Additional detail about the data discussed here is provided in Chapter 2.

5.2.2 **Meteorological Data**

Meteorological data (e.g., precipitation, temperature, wind speed, dew point temperature, percent sun) drive mass-balance, water quality models like HSPF. The Mountain Run model was developed using meteorology measurements from weather stations that are monitored and quality controlled by the NCEI (NCEI, 2019). The data from these stations were accessed to generate time series inputs for meteorological variables which were then used to calculate the water balance. Generally, the data provided by the NCEI were recorded in daily intervals. Since the model simulated at hourly time steps, an HSPF supplemental application called WDMUtil was used to disaggregate the daily meteorological data into hourly data.

5.2.3 **Hydrologic Withdrawals**

DEQ obtained data from facilities permitted to withdraw water within the Mountain Run watershed. The facilities report the source and estimated average monthly quantity of withdrawals. Water withdrawals were identified in the Mountain Run study area that potentially influence stream flow rate over time (Table 5-1). The average monthly withdrawal amounts were evenly distributed to estimate hourly withdrawal rates for the listed facilities. These withdrawals were simulated using hourly time series applied to the relevant reach within each subwatershed.

Table 5-1. Withdrawal rates used in modeling the Mountain Run study area.

Facility	Stream Name	Subwatershed	Withdrawal Rates (mgd)[1]
Culpeper Wood Preservers	Reservoir	10	0.21 – 4.11
The Country Club of Culpeper Golf Course	Lake Pelham	27	0 – 3.10
Town of Culpeper WTP[2]	Lake Pelham	27	0 – 80.30

[1] million gallons per day
[2] Water Treatment Plant

5.3 ***Representation of Sources***

The Mountain Run PCB model simulates the fate and transport of sediment and PCBs through the watershed. This section describes how the loads for both constituents are categorized and input into the model. Loads are input into the model as point sources or rainfall-runoff driven nonpoint sources.

5.3.1 **Sediment Sources**

5.3.1.1 ***Surface Runoff***

Instream sediment is part of a healthy ecosystem and serves an important role in the environment. When modeling sediment sources for this TMDL, the goal to develop an understanding about the fate of this primary PCB transport vector from surface detachment, to runoff, to instream suspended sediment. One significant source of PCBs in the study area is contaminated land areas (both known and unknown areas). Since PCBs have a high affinity for sediment, the sediment washoff from PCB-contaminated areas can contaminate the stream network. Sediment is washed off the land surface through a two-step process: detachment and removal. Within the model, soil and sediment are detached and “stored” on the land surface via raindrop impact. Detached, stored sediment is then available for wash off during a runoff event (surface flow). When runoff occurs, the detached sediment is carried into the stream network. Surface runoff of sediment is modeled as a nonpoint source.

5.3.1.2 ***Channel Bed Sediment Scouring***

When stream velocity is sufficiently high, the streambed will experience increased shear stress. This shear stress can cause bed sediment to be scoured, suspended/resuspended into the water column, carried downstream, and potentially redeposited (Figure 5-1). HSPF simulates scour, transport, and deposition. Channel scouring and sediment resuspension is considered a nonpoint source of sediment because it occurs throughout the stream and is generally an issue after major precipitation events.

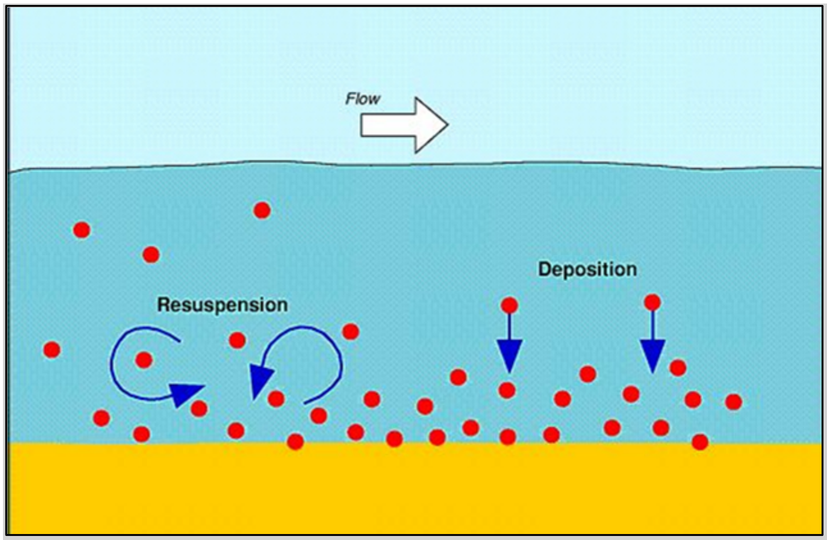

Figure 5-1. Scouring/resuspension and deposition of sediment in a stream (OzCoasts, 2021).

*5.3.1.3 **Permitted Sediment Sources***

Permitted point sources are also a source of sediment. Effluent from permitted facilities such as wastewater treatment plants (WWTPs) and industrial plants are monitored for total suspended solids (TSS). The loads from these facilities contribute to the instream suspended sediment concentrations (SSC). They are input into the model with a single point of entry into the stream network. Table 5-2 details the mean monthly flow rate and the mean monthly TSS concentrations of the permitted sources for the sediment modeling period January 2008 to June 2019.

Table 5-2. Permitted TSS point sources in the Mountain Run study area.

Facility Type	PCB Impaired Waterbody	Facility Name	Permit ID	Mean Monthly Flow (mgd)[1]	Mean TSS (mg/L)	Period of Record
Municipal WWTP	Mountain Run	Town of Culpeper WWTP	VA0061590	3.006	16.75	2008-2019
	Mountain Run, UT[2]	Camp Red Arrow WWTP	VA0092452	0.003	0.03	2010-2019

Industrial	Jonas Run, UT	Culpeper Wood Preservers	VA0059145	0.463	–	2008-2019

[1] million gallons per day, [2] Unnamed tributary.

5.3.2 **PCB Sources**

5.3.2.1 ***Point Source Dischargers***

The Mountain Run watershed contains two categories of VPDES permitted point source dischargers that are modeled as point sources for PCBs: municipal wastewater treatment plants (WWTP), and industrial storm water general permitted facilities (ISWGP). DEQ provided flow and mean tPCB concentration information for permitted point sources of PCBs (Table 5-3). The mean flows for Municipal Wastewater Treatment Facilities are calculated from the Discharge Monitoring Reports (DMR) for the period January 2008 to June 2019. Mean flows for ISWGPs were calculated from the facility drainage areas. As noted in the table, the mean tPCB concentration for a single point source is based on a statewide Standard Industrial Classification (SIC) default value (DEQ, 2016) since it had not been screened for PCBs during TMDL development.

Table 5-3. Permitted PCB point sources in the Mountain Run study area

Facility Type	PCB Impaired Waterbody	Facility Name	Permit ID	Mean Monthly Flow (mgd)[1]	Mean tPCB Concentration (pg/L)
Municipal WWTP	Mountain Run	Town of Culpeper WWTP	VA0061590	3.006	285.5
Industrial Stormwater	Mountain Run, UT*	TE Connectivity - Culpeper Plant	VAR050855	0.069	458.6
	Mountain Run. UT	Bingham and Taylor Corp	VAR050900	0.017	1,100.0
	Mountain Run. UT	Culpeper Municipal Power Plant	VAR051573	0.007	619.4
	Mountain Run	Wise Services and Recycling LLC	VAR051878	0.009	2,223.8
	Jonas Run, UT	Culpeper Recycling	VAR051928	0.045	314.3
	Mountain Run	Culpeper Towing and Salvage Incorporated	VAR051952	0.001	1,169.7[2]
	Jonas Run, UT	AMRF Incorporated	VAR052293	0.002	2,218.6

[1] million gallons per day
[2] Default tPCB concentration based on a statewide Standard Industrial Classification (SIC) dataset (DEQ, 2016)

5.3.2.2 ***Nonpoint Sources***

Nonpoint source pollution is driven by runoff. Nonpoint sources of PCBs are those that do not have a defined entry point into the stream network. These sources include known contaminated sites and unregulated surface sources. Known contaminated sites can include former manufacturing facilities, railyards and rail spurs, and electrical substations. They may also include PCB spills if the spill occurred on the land surface and was not directly released into the stream. Within the model, nonpoint sources are assigned a washoff potency factor (pg/ton) that defines the quantity of PCBs (pg) per ton of sediment washed off the land surface. Higher potency factors indicate elevated contamination and more PCB washoff during a storm event. When watershed surface areas are assigned a washoff potency factor, sediment surface runoff becomes a primary contamination pathway. Table 5-4 lists the “long-term” contaminated sites in the Mountain Run watershed. PREP PCB spills were modeled as direct inputs into the stream or as deposition onto the land surface as a “one-time” event based on the recorded date of the spill. Appendix C identifies the occurrences of potential PCB spills reported to DEQ.

Table 5-4. Contaminated sites in the Mountain Run watershed.

Source	Site Description	Subwatershed	Estimated Area (ac)
Volunteer Remediation Program Sites	VRP00647: Cintas Culpeper (former Rental Uniform Service site)	18	12.8
	VRP00024: Jim’s Liquid Wastes site	8	67.0
Railyard/Railway Spur	Railway Spur #1	15	4.4
	Railway Spur #2	15, 16	1.1
	Railway Spur #3	18, 19	0.9
	Railway Spur #4	18	1.6
	Railway Spur #5	17	1.1
	Railway Spur #6	6, 11	0.8
Electrical Transformers	Electrical Substation #1	16	2.1
	Electrical Substation #2	19	0.4
	Electrical Substation #3	19	1.0

When simulated PCB data were compared with water quality samples, the results suggested that there are PCB sources in the Mountain Run study area that were not being accounted for in the model. Even with all known sources input into the model, including those from contaminated sites, atmospheric deposition, and streambed sediment, the model underestimated the instream PCB concentration during high flow events beyond an acceptable margin of error. This under prediction is consistent with results from similar PCB TMDL studies recently completed in Virginia (DEQ, 2009;

DEQ, 2018) and indicates that additional PCB loading to Mountain Run is occurring. As a result, an unregulated surface source category was added to account for PCB sources in the Mountain Run study area that have yet to be identified. Because the location of the contributing surface sources are unknown, the unregulated source category was applied to all land surfaces that are not within a contaminated site. Additional details on how the unregulated surface sources are input into the PCB fate and transport model and how its load was calculated during calibration can be found in Appendix E.

5.3.3.3 ***Legacy Sources***

Two legacy sources of PCBs are atmospheric deposition and streambed sediment. PCBs that were released into the atmosphere during industrial manufacturing persist. Over time, these PCBs may settle out from the atmosphere and deposit on the ground. Research has shown that PCB atmospheric deposition may be elevated near urban areas, manufacturing facilities, or contaminated sites (Totten *et al.*, 2006). However, because data were not available to quantify varying atmospheric deposition rates within the Mountain Run study area, it was assumed that PCB atmospheric deposition was uniform over the study area. PCBs from atmospheric deposition to land were considered as a component of the unregulated surface source category. The ability of PCBs to persist in the environment also means streambed sediment that was contaminated years prior may continue to release PCBs back into the water column if disturbed. PCBs are considered uncontrollable when in the atmosphere or once released to waterbodies and ubiquitously deposited in the streambeds. Consequently, PCBs within the streambed sediment were not considered for reduction when allocating PCBs, but in the interest of developing a representative model, they were included as PCB sources.

5.4 ***Model Calibration and Validation***

Model calibration is the iterative process of selecting model parameters, producing simulated outputs, comparing the outputs with observed data, adjusting the model parameters, and repeating the process. The goal is to develop a model that provides a reasonably accurate representation of the system being modeled. This section, details the procedures used to calibrate the HSPF model used to develop the Mountain Run PCB TMDL.

5.4.1 **Hydrology**

Since there are no active continuous USGS stream flow gages with complete datasets for Mountain Run, hydrologic model parameters from the Mountain Run Bacteria TMDL (BSE, 2001) were used to develop the hydrology model component. As a result, detailed hydrology calibrations are not included in this report. For information on the hydrology calibration for Mountain Run PCB TMDL model, refer to the bacteria TMDL final report, available by request from DEQ. There are no observed flow data from DEQ water quality monitoring stations. It should be reiterated that an observed flow-PCB concentration graphical comparison could not be completed for Mountain Run due to the lack of observed flow data.

5.4.2 **Sediment**

Sediment model calibration was conducted in two phases. The first phase simulated the detachment and removal/wash off of sediment from the land surface. The second simulated the instream sediment processes such as bed sediment scouring/resuspension, transport, and deposition. In both phases, the calibration involved qualitative, graphical, and quantitative analyses.

Unlike typical water quality calibrations, there were no observed data for sediment storage and removal available for model calibration. Measuring the quantity and removal (wash off) of sediment from a land surface would be a laborious and expensive task, and include a high degree of uncertainty. As a result, model calibration involved adjusting selected parameter values, e.g., the rate of sediment detachment from the land surface and the removal of detached, stored sediment. Target ranges for these parameters are available in EPA BASINS Technical Note 8 (USEPA, 2006). Model calibration involved plotting the time series of simulated sediment storage and removal and comparing those plots to expected trends. In a watershed, sediment storage is expected to increase gradually over time and decrease after precipitation events due to spikes in removal rate (i.e., wash off).

The second phase of sediment model calibration involved comparing instream SSC data DEQ with simulated instream sediment concentrations across a range of flows. Figure 2-7 marks the locations of the seven DEQ water quality monitoring stations in the Mountain Run watershed that were used during sediment calibration. SSC and TSS are slightly different water quality measurements. Whereas the methodology for measuring TSS was originally created for analyzing wastewater samples, SSC is more commonly used for natural water samples (Gray *et al.*, 2000). For the purpose of this study, it was appropriate to use SSC and TSS data interchangeably. Model parameters were adjusted until simulated outputs were representative of the observed data and could produce the expected sediment concentrations given specific flow conditions. Additional details about the sediment calibration process and results can be found in Appendix D.

5.4.3 **PCBs**

PCBs were modeled as a pollutant that could exist in two states, sediment-associated and "dissolved." Sediment-associated PCBs were simulated as runoff from the land surface and as suspended instream particulate. "Dissolved" PCBs involved modeling PCBs in instream (i.e., in the water column). HSPF is capable of modeling pollutants as both sediment-associated and dissolved, and the proportion at which they exist in each state is dependent on adsorption/desorption model parameters. Figure 2- maps the locations of the twenty-one DEQ water quality monitoring stations where PCB data were collected.

PCB sources were placed in one of two categories, sources with a known load and sources with an uncertain load. Sources with a known load included any sources where the load has been quantified, such as known contaminated sites (i.e., spills), and streambed sediment where specific measurement has been completed. Sources with an uncertain load included unregulated surface sources, i.e., the sum of net atmospheric deposition to land and water surfaces, loads from small tributaries that are not explicitly specified in the model, unregulated stormwater runoff, loads from unidentified contaminated sites, and unspecified point source discharges. Appendix E provides additional details regarding PCB model calibration.

5.5 ***Existing Conditions***

The existing conditions model run was used to prioritize sources for reduction during the allocation phase. Table 5-5 gives a general overview of the contribution from each source type to the instream PCB concentration at the outlet of Mountain Run. Detailed tables with the PCB concentration and load magnitude are presented in Appendix E. Note Table 5-5 is not comparable to the source breakdown load tables presented in the Executive Summary nor the tables in Chapter 6. This relative daily contribution table was calculated by sequentially toggling on and off single sources within the model and outputting the mean daily concentration at the outlet. This information is valuable in understanding the relative impact the different sources have on the instream PCB concentrations once transport factors are considered. The source breakdown load tables are calculated as a back calculation of the TMDL.

Table 5-5. Relative contributions of different PCB sources to the overall instream PCB concentration for existing conditions in the Mountain Run watershed.

Relative Daily Contribution by Source				
Contaminated Sites	Unregulated Surface Sources[1]	Permitted	Streambed Sediment	Atmospheric Deposition
3%	57%	<1%	39%	<1%

[1] Unregulated surface sources represent PCB loads supported by the observed data whose specific location have yet to be identified.

Chapter 6: TMDL Allocations

The objective of a TMDL is to allocate allowable pollutant loads among different sources so that the appropriate control actions can be taken to achieve WQSs (USEPA, 1991a).

6.1 ***Background***

The objective of the PCB TMDL for Mountain Run was to determine what reductions in PCB loadings from point and nonpoint sources are required to meet state WQSs. The state water quality standard for PCBs is 580 pg/L unless the fish-tissue PCB threshold is exceeded. If the fish-tissue PCB threshold is violated, a more protective, segment-specific BAF-calculated endpoint is often necessary to support the fish consumption designated use. The TMDL is an estimate of the maximum allowable PCB load that Mountain Run can assimilate and still meet the applicable WQSs, and the PCB sources are separated into point- and nonpoint-sources, Eq. 6-1. A TMDL accounts for critical conditions, seasonal variations, future conditions, and must include a margin of safety (MOS) in accordance with EPA regulations [CWA §303(d)(1)(C), 40 C.F.R. §130.7(c)(1)].

$$TMDL = WLA_{Total} + LA + MOS$$ **Eq. 6-1**

Where:

WLA_{Total} = waste load allocation (point source contributions, future conditions i.e. growth; accounts for point source facilities inadvertently excluded from TMDL);
LA = load allocation (nonpoint source contributions); and
MOS = margin of safety.

The Virginia Department of Environmental Quality has introduced a new PCB water quality standard (WQS) that sets the instream PCB water quality criteria (WQC) at 580 pg/L and determines compliance with that “human health” criteria by relying on the assumption of [an] “average amount of exposure on a long-term basis.” As the revised WQC may not always meet the goal of restoring the consumption use when applying a long-term average exposure, a BAF-calculated water column tPCB endpoint which is lower than the WQC was used as the final TMDL endpoint. The procedure for determining the pollutant allocation to meet the instream concentration TMDL endpoint is summarized here, with results from this procedure/analysis for Mountain Run presented in Table 6-1.

- Using meteorological inputs from the appropriately determined harmonic mean flow year (HMFY), analyze the resulting modeled, 365 daily average instream PCB concentrations to determine which specific statistic of central tendency of that modeled output that should be evaluated against the TMDL endpoint.
- Determine whether the TMDL calibration model output is normal/lognormal or whether the distribution is neither.
  - If the model output is normally distributed, select the arithmetic mean as the measure of central tendency for aggregating model output over the simulation period.
  - If the model output is lognormally distributed, select the geometric mean as the measure of central tendency for aggregating model output over the simulation period.
  - If model output distribution is neither normal nor lognormal, a median of the model output will need to be the measure of central tendency for aggregating model output over the simulation period.
- If the **mean** of model output is **greater than** the endpoint (310 pg/L):
  - Use the upper 95% confidence limit (CL) of the mean as the basis for reductions.
- If the **mean** of model output is **less than** the endpoint (310 pg/L) and the:
  - Upper 95% confidence limit of the mean (arithmetic, Eq. 6-2 or geometric, Eq. 6-3) is *greater than* the endpoint, use this statistic as the basis for reductions. If the upper 95% CL is *less than* the endpoint, find the daily value closest to the upper 95% CL that is above the endpoint but is less than the 90^{th} percentile of a normal curve composed from the mean and standard deviation of the model output. Use this value as the basis for reductions.
- If the **median** of model output is **greater than** the endpoint (310 pg/L):
  - Use the upper 95% CL of the median (Eq. 6-4) as the basis for reductions.

- If the **median** of model output is **less than** the endpoint (310 pg/L) and the:
  - Upper 95% CL of the median (Eq. 6-4) is *greater than* the endpoint, use this statistic as the basis for reductions. If the upper 95% CL is *less than* the endpoint, find the daily value closest to the upper 95% CL that is *greater than* the endpoint but no greater than the 90th percentile of the model output dataset. Use this value as the basis for reductions.

Upper 95% confidence limit of the arithmetic mean	=	Arithmetic Mean + 1.96 x (standard deviation of daily averages) ÷ sqrt(count of daily averages)	**Eq. 6-2**
Upper 95% confidence limit of the geometric mean	=	exp(arithmetic mean of log-transformed daily values) + 1.96 x exp(standard deviation of log-transformed daily averages) ÷ sqrt(count of daily averages)	**Eq. 6-3**
Upper 95% confidence limit of the median[1]	=	365 * 0.5 + 1.96*sqrt(365* 0.5*(1-.05))	**Eq. 6-4**

[1]Assumes one has 365 modeled, daily-average instream PCB concentration. Round result up to the nearest whole number.

Table 6-1. Arithmetic mean and median statistics for existing conditions for Mountain Run impaired segment.

Arithmetic Mean Modeled Output Statistic	Existing Conditions PCB concentration (pg/L)		Median Modeled Output Statistic	Existing Conditions PCB concentration (pg/L)
Mean	669		Median	329
Upper 95% CL	781		Upper 95% CL	330
90th percentile	1,230		90th percentile	1,230

6.2 *Accounting for Critical Conditions and Seasonal Variations*

Current EPA regulations [40 CFR 130.7(c)(1)] require TMDLs to consider critical conditions for stream flow, loading, and water quality parameters. Such an approach provides additional assurance that TMDLs, when implemented, will not result in WQS exceedances across a range of flow regimes that affect PCB concentrations.

6.2.1 **Selection of Representative Modeling Period**

The model calibration period of record (2013 – 2019) was selected to include the available PCB monitoring data. For allocation purposes, data corresponding to a harmonic mean flow year (HMFY) were used to drive the model. A HMFY is frequently used to account for critical flow conditions when developing TMDLs for contaminants that impact human health on a lifetime exposure scale (USEPA, 1991b). Unlike arithmetic and geometric means, a harmonic mean is more influenced by small values more than large values, and out of the three measure of central tendency, the harmonic mean is the smallest. Using the HMFY data for allocation purposes, prioritizes low flow conditions, which can lead to high pollutant concentrations. The modeled PCB loads from nonpoint sources generally do not fluctuate from year to year but do fluctuate with precipitation events, with higher flows yielding lower instream concentrations, but higher pollutant loads. Point sources contribute a consistent PCB load of that is a function of both discharge flow and concentration. Using the HMFY data as the allocation period ensures that the TMDL addresses critical, low flow conditions.

Since there are no active continuous USGS flow gages in the Mountain Run watershed, the HMFY was calculated using the full record of observed flow data from the nearest USGS gage (USGS 01664000, Rappahannock River at Remington, VA). The following equation calculates harmonic mean flow:

$$H = \frac{n}{\sum(1/Q_i)} \qquad \textbf{Eq. 6-5}$$

Where:

H = harmonic mean flow, cfs;
n = number of observations; and
Q_i = daily mean flow for day i.

The harmonic mean flow for that gage was then compared with the annual harmonic mean flows from most recent 20 years (post-2001) of flow data. The year with the harmonic mean flow that was closest to the harmonic mean flow from the full flow record was selected as the HMFY and allocation modeling period. The harmonic mean flow year allocation period for the Mountain Run PCB TMDL was 2008.

6.2.2 **Seasonal Variability**

The Mountain Run PCB TMDL model reflects seasonal variations present in the meteorological data used to drive the model and selected parameters that vary by season. Seasonal variability was also addressed during the monitoring phase of the project. DEQ collected water column PCB concentration samples, sediment-associated PCB concentration samples, fish tissue samples, and SSC samples across seasons.

The HMFY allocation period encompasses an entire calendar year. Using a full continuous calendar year as the allocation period and daily simulated PCB outputs for TMDL development further ensures that seasonal variability is considered. The TMDL was developed using a PCB endpoint that applies throughout the year. The purpose of this TMDL project is to address water quality impairments due to high levels of PCBs in fish tissue. Since PCBs bioaccumulate, it is also worth noting that seasonal variations may not be as important as long-term annual variations (USEPA, 2011).

6.3 ***Margin of Safety (MOS)***

A Margin of Safety (MOS) is factored into a TMDL to account for various sources of uncertainty. Typically, a TMDL MOS can be either explicit (some fraction of the allocated TMDL load) or implicit. In accordance with past Virginia PCB TMDLs, an explicit MOS of 5% was used in this study. The explicit MOS is subtracted from the TMDL total when calculating the LA (DEQ, 2009). In addition to the explicit MOS, an additional implicit MOS was incorporated by using conservative assumptions for selected model parameters and variables. A sample of conservative assumptions and approaches taken during model development include:

- When conducting model PCB calibration, the unregulated surface source load was created to include sources in the watershed that were not identified. When calibrating the load rate from this source, a more conservative estimate was used to ensure that allocation reductions would sufficiently address the unidentified sources.
- The decay rate of PCBs was not modeled. In a watershed, PCBs decay at an extremely slow rate. Since this was not modeled it provides a more conservative estimate of instream PCB concentrations.
- During allocation, if a scenario output simulated values within 5% of the TMDL endpoint, further PCB load reductions were made.

Developing a TMDL with conservative modeling measures helps to ensure that no WQS exceedances will occur if the TMDL pollutant allocation reductions are achieved.

6.4 ***Waste Load Allocation (WLA)***

6.4.1 **Future Conditions**

The production of PCBs was banned in the late 1970's, although a "newly identified" or contemporary source that can contribute PCB loads includes "inadvertent production" (DEQ, 2016). While it may be a reasonable assumption that any increase in population, human or otherwise, in the Mountain Run watershed will not lead to a substantial rise in the PCB load, an allocation for a future condition is included to account for facilities that are not currently regulated under a VPDES permit but may require a permit in the years to come. The WLA Future Conditions for the Mountain Run PCB TMDL is 0.25% of the TMDL endpoint load. While this is not considered "future growth", the inclusion of this allocation is consistent with the future growth concept (DEQ, 2014a). It is possible that future land use changes will lead to different sediment loading scenarios from current conditions, but based on professional judgement, it was assumed that such changes would have a negligible impact on PCB loads.

6.4.2 **Permitted Sources**

The Waste Load Allocation (WLA) specified the maximum allowable PCB load from permitted sources without exceeding the TMDL endpoint. To calculate a WLA for each permitted discharger, the TMDL endpoint concentration was applied using the appropriate flow. For municipal facilities, the design flow was used. For stormwater outfalls, the contributing outfall drainage area was used to estimate flow.

Permitted municipal wastewater treatment facilities in the Mountain Run study area are shown in Table 6-2. A "NA" (i.e., not applicable) in the % reduction column means the permitted facility is currently generating a load that is less than the WLA. Table 6-3 shows the industrial stormwater general permit facilities (ISWGP). Each table identifies the total existing PCB load from each permit, the WLA presented on an annual and daily basis, and the percent reduction necessary. The approach used to generate daily loads is presented in Section 6.7.2 below.

Table 6-2. Existing total PCB load and waste load allocations form of Municipal Wastewater Treatment Facilities in the Mountain Run study area.

Waterbody	Facility Name	Permit ID	Existing tPCB Load (mg/yr)	WLA tPCB (mg/yr)	WLA tPCB (mg/d)	% Reduction
Mountain Run	Town of Culpeper WWTP	VA0061590	2,363.9	2,566.8	17.0	NA

NA - tPCB load reduction does not apply as the existing effluent load calculated using actual tPCB results is less than the WLA.

Table 6-3. Existing total PCB Loads and Waste Load Allocations of Industrial Stormwater General Permit Facilities in the Mountain Run study area.

Waterbody	Facility Name	Permit ID	Existing tPCB Load (mg/yr)	WLA tPCB (mg/yr)	WLA tPCB (mg/d)	% Reduction
Mountain Run, UT*	TE Connectivity – Culpeper Plant	VAR050855	20.2	13.7	0.110	32
Mountain Run. UT	Bingham and Taylor Corp	VAR050900	26.7	7.5	0.060	72
Mountain Run. UT	Culpeper Municipal Power Plant	VAR051573	6.3	3.2	0.026	49
Mountain Run	Wise Services and Recycling LLC	VAR051878	26.9	3.7	0.030	86
Jonas Run, UT	Culpeper Recycling	VAR051928	19.7	19.4	0.156	2
Mountain Run	Culpeper Towing and Salvage Incorporated	VAR051952	1.7[a]	0.4	0.004	76
Jonas Run, UT	AMRF Incorporated	VAR052293	7.1	1.0	0.008	86
		ISWGP Total	**108.6**	**48.9**	**0.394**	**55**

*Unnamed tributary.
[a] Existing tPCB load based on a default tPCB concentration taken from a statewide Standard Industrial Classification (SIC) dataset (DEQ, 2016).

The Total Waste Load Allocation ($WLA_{Subtotal}$) was calculated for the Mountain Run PCB impairments and represents the sum of the WLAs for all permitted point source facilities in the study area. The $WLA_{Subtotal}$ does not include the WLA Future Conditions load which is included later in this chapter. Table 6-4 lists the $WLA_{Subtotal}$ for Municipal Wastewater Treatment and Industrial Stormwater General Permit Facilities in the Mountain Run watershed.

Table 6-4. Estimated annual $WLA_{Subtotal}$ for Mountain Run.

Total Municipal WLA[1] (mg/yr)	Total ISWGP WLA[2] (mg/yr)	$WLA_{Subtotal}$ (mg/yr)
2,566.8	48.9	***2,615.7***

[1] Total Waste Load Allocation for Municipal Wastewater Treatment Facilities in given impaired segment.

[2] Total Waste Load Allocation for Industrial Stormwater General Permit Facilities in given impaired segment.

6.5 *Load Allocation (LA)*

The Load Allocation (LA) quantifies the maximum allowable PCB load from non-permitted sources (primarily nonpoint sources). Nonpoint sources include known contaminated sites (e.g., former manufacturing facilities, metal recycling facilities, railyards and railway spurs, spills), non-regulated surface sources (the sum of net atmospheric deposition to land, loads from small tributaries that are not explicitly specified in the model, unregulated stormwater runoff, loads from unidentified contaminated sites, and unspecified point source discharges), atmospheric deposition to water surfaces, and PCB-contaminated stream bed sediment. For many other pollutants, natural background is included as a source within the LA component of a TMDL. However, since PCBs are man-made, there is no natural background PCB load and it was not included in the PCB LA for Mountain Run.

Reductions are typically not assigned to streambed sediments. Realistically, given the difficulty and cost associated with removing contaminated streambed sediment, any reduction called for from this 'source' category would be unattainable. Unless there are significantly contaminated streambed sediments in localized depositional areas (e.g., immediately upstream from a dam), it is generally impractical and cost prohibitive to remediate this source of PCBs. For PCB spills, it was assumed that the areas and tributaries affected by PCB spills would be 100% cleaned up. As such, contaminated sites and direct drainage sources were the primary targets of the load reductions.

6.6 *Allocation Scenarios*

Using the calibrated HSPF Mountain Run PCB TMDL model, several PCB allocation scenarios were evaluated.

6.6.1 **PCB Allocation Approach**

PCB allocation scenarios for the Mountain Run study area include permitted sources (waste load allocation, WLA) and nonpoint sources (load allocation, LA).

Allocations to meet the TMDL focused on reducing both the permitted (WLA) and nonpoint source (LA) loads.

The Mountain Run PCB TMDL model generates hourly PCB concentrations at the watershed outlet. The segment-specific BAF-calculated PCB TMDL endpoint, for the revised WQS scenario detailed in Section 6.1 is 310 pg/L.

The allocation process starts with “Existing Conditions” (that is, the calibrated model uses all currently estimated PCB loadings, including those from permitted sources). Then a “Baseline Conditions” run is completed, wherein nonpoint sources are not changed, but permitted point sources are modeled using their permitted WLAs. In the case of Mountain Run, this includes VPDES dischargers such as Municipal and General Stormwater facilities. The “TMDL” scenario, is one in which permitted sources are modeled using the WLAs and reductions needed to achieve the TMDL allocation load are applied to the nonpoint sources.

All of the allocation scenarios assume that any spill of PCBs will be completely cleaned up. Reductions were applied to sources from known contaminated sites first. If a 100% reduction from known contaminated sites did not achieve the TMDL endpoint, reductions were applied to unregulated surface sources from commercial land use. The Mountain Run watershed contains railyards and rail spurs, electrical substations, and other identified contaminated sites detailed in Chapter 3 and Appendix C.

Since there are no active continuous USGS stream flow gages on Mountain Run, the USGS gage located on Rappahannock River at Remington, VA (USGS 01664000) was used to identify the harmonic mean flow year (HMFY). Comparing calendar year harmonic mean flows for the most recent 20 years (2002 – 2021), calendar year 2008 was selected as the allocation period since the annual harmonic mean flow in year 2008 (168 cfs) most closely matches the long-term harmonic mean flow (163 cfs) for the period of record from 10/1/1942 through the present.

The segment-specific BAF-calculated PCB TMDL endpoint is 310 pg/L. Based on the procedure presented in Section 6.1, since the median of model output is greater than the endpoint, the reductions shown in Table 6-5 are based on the upper 95% CL of the median.

Table 6-5. PCB allocation scenarios for Mountain Run impaired segment with a TMDL endpoint of 310 pg/L.

Allocation Scenario	Required PCB Loading Reductions to Meet the TMDL Endpoint of 310 pg/L (%)					Exceedance of 580 pg/L (%)	Daily Mean tPCB concentration (pg/L)	Daily Median tPCB concentration (pg/L)
	Loads from Permitted Sources	Loads from Known Contaminated Sites	Loads from Nonregulated Surface Sources	Loads from Streambed Sediments	Spills			
Existing Conditions	0	0	0	0	0	14	669	329
Allocated Conditions[1]	-	99	55	0	100	12	440	294

[1] daily simulated PCB concentration less than the upper 95% CL of the median (330 pg/L).

6.7 *Summary of the TMDL Allocation Scenario for PCBs*

A TMDL that addresses PCB impairments in the Mountain Run watershed was developed. That TMDL addresses the following issues:

1. Simulated, allocated average daily PCB concentrations in Mountain Run do not exceed upper 95% CL of the existing conditions modeled median of 330 pg/L.
2. PCBs are a hydrophobic pollutant that tend to associate with soil and sediment. Instream PCB concentrations were simulated using a multilayered, calibrated model that simulated hydrology and sediment and PCB fate and transport.
3. The TMDL was developed considering all known, characterized sources (contaminated sites, permitted, and legacy sources) as well as less well-characterized unregulated surface sources.
4. An explicit margin of safety (MOS) of 5% of the TMDL load was used.
5. A future conditions load is included to account for facilities that may come on-line in the years to come and/or those that may increase their permitted flow. The Future Conditions WLA load is set at 0.25% of the TMDL endpoint load. Table 6-6 lists the future conditions load for Mountain Run. The WLA_{Total} is equal to the $WLA_{Subtotal}$ plus the $WLA_{Future\ Conditions}$.
6. Critical flow conditions were considered by using data from a harmonic mean flow year (2008) to drive the model used to develop the TMDL. Using data corresponding to a harmonic mean flow year is recommended by the USEPA

when the human health impact due to a pollutant is considered over a lifetime exposure period (USEPA, 1991b).

7. The TMDL accounts for seasonal effects by using time-varying data to drive the TMDL model and by incorporating various model parameter values that vary by month.

Table 6-6. WLA for Future Conditions for Mountain Run and percent of TMDL.

Impaired Segment	$WLA_{Future\ Conditions}$ (mg/yr)	Percent of TMDL (%)
Mountain Run	159	0.25

Using Equation 6-1, a summary of the Mountain Run PCB TMDL allocation scenario is given in Table 6-7. The TMDL equation was developed using the HMFY allocation period (2008).

Table 6-7. Maximum annual PCB loadings (mg/yr) at the outlet of Mountain Run.

Impaired Segment	WLA_{Total} (mg/yr)[1]	LA[2] (mg/yr)	MOS[3] (mg/yr)	TMDL (mg/yr)
	Equation to Meet the TMDL Endpoint of 310 pg/L			
Mountain Run	2,775	57,574	3,176	63,525

[1] WLA_{Total} includes future conditions.
[2] The LA is the remaining loading allowed after the MOS and WLA_{Total} were subtracted from the TMDL as determined for the downstream end/outlet of the impaired segment.
[3] Explicit MOS (5%).

6.7.1 **Source Category Breakdown**

Table 6-8 summarizes the annual existing load, WLA, LA, and percent reduction based on the TMDL allocation by source category. The table includes WLA Future Conditions to account for point source PCB dischargers that may be regulated under a VPDES permit in the future and are equal to 0.25% of the TMDL. The LA and existing loads for the nonpoint sources are the average annual loads based on each source’s contribution to the instream PCB concentration at the Mountain Run watershed outlet. The existing loads are not to be used as accurate estimates of the current nonpoint source load. Rather they provide guidance and an estimation of how much that load needs to be reduced to meet the TMDL.

Table 6-8. Average estimated annual PCB load at the outlet of Mountain Run expressed by source category.

Source Category	Existing Load (mg/yr)	WLA (mg/yr)	LA (mg/yr)	Reduction (%)
Municipal Dischargers[1]	2,364	2,616		-
Industrial Stormwater General Permits	109			55
WLA Future Conditions[2]		159		
Contaminated Sites	7,558		76	99
Unregulated Surface Sources[3]	65,546		29,496	55
Streambed Sediments	27,960		27,960	0
Atmospheric Deposition (water surface)	43		43	0
TOTAL	**103,580**	**2,774**	**57,575**	**42%**

[1]A tPCB load reduction for Municipal Dischargers does not apply as the existing load is less than the WLA.
[2]WLA Future Conditions account for permitted facilities that may come on-line in the future and are equal to 0.25% of the TMDL for Mountain Run.
[3] Unregulated surface sources are the sum of net atmospheric deposition to land surfaces, loads from small tributaries that are not explicitly specified in the model, stormwater runoff, loads from unidentified contaminated sites, and unspecified point source discharges.

6.7.2 **Daily Loads**

A court ruling by the U.S. Court of Appeals for the District of Columbia Circuit in the case Friends of the Earth, Inc. v. EPA, et al., resulted in requirements for daily maximum load calculations, in addition to the average annual load tabulated in the previous section (Friends of the Earth, Inc. v. Environmental Protection Agency, et al., 2006). Setting a *maximum daily* load will help ensure that the annual loads given in Table 6-7 are appropriately distributed such that on any given day the PCB water quality standard will be met. The loadings in the annual load tables, being of a longer-term, will more directly assure compliance with the TMDL endpoint.

Daily loads are expressed as Maximum Daily Limit (MDL) and were derived using the approach found in the USEPA Technical Support Document For Water Quality-based Toxics Control (USEPA, 1991b). The following equation was used.

$$MDL = LTA \times e^{[z\sigma - 0.5\sigma^2]} \quad \textbf{Eq. 6-3}$$

Where:

MDL = maximum daily limit (mg/day);
LTA = long-term average (mg/day);
z = 97th percentile of standard normal probability distribution (z-score);

σ^2 = ln(CV^2+1); and
CV = Coefficient of variation of daily instream concentration.

The LTA is the annual WLA divided by the number of days in the year (365). The CV is a measure of the instream variability of the initial condition for PCBs and is calculated by dividing the standard deviation by the mean of the distribution of daily PCB concentrations. The 97th percentile was selected as the probability of occurrence, for consistency with limits set in VPDES permits. By using the 97th percentile, the MDL can be expected to be exceeded no more than 3% of the time.

A CV was calculated specifically for Mountain Run to account for the variability in PCB concentrations that are affected by the direct impacts of stormwater on the stream hydrology. Table 6-9 includes the CV, the z score, and the calculated multiplier used to convert the LTA to an MDL.

Daily loads were calculated for VPDES permits in a different manner depending on whether stormwater was an influencing factor in determining their PCB loads. The LTA-to-MDL multiplier calculated for Mountain Run as presented in Table 6-9, was used to convert the annual WLA to a daily load for stormwater-based permits. The permit types for this approach included Industrial Stormwater (under General Permits). To simplify the conversion, the average annual WLA for any industrial stormwater facility in Mountain Run, as an example, was multiplied by 0.0160 (i.e., 5.85/365) to yield a daily load expressed as mg/d.

For Municipal WWTPs, the same approach was applied but utilized a CV of 0.6 as recommended by EPA guidance (1991b). The rationale for applying this approach is based on the minimal impact of stormwater to these outfalls. The z-score set at the 97th percentile was also used (z-score = 1.88; LTA-to-MDL multiplier = 2.43; conversion from mg/yr to mg/d 2.43/365 = 0.0067).

The multiplier included in Table 6-9 was also used to convert the LA and MOS elements of the TMDL equation for Mountain Run. As another example of a simplistic conversion, the average annual Load Allocation (LA) for the Mountain Run PCB TMDL is reported as 34,152 mg/yr which is multiplied by 0.0160 (i.e., 5.85/365) to yield 547 mg/d. The resulting watershed wide daily maximum loadings are shown in Table 6-10.

Table 6-11 summarizes the estimated daily existing load, WLA, LA, and percent reduction based on the TMDL allocation by source category.

Table 6-9. Components of Maximum Daily Load Calculations for Stormwater VPDES and LAs.

Impaired Segment	CV	z-score (97th percentile)	LTA-to-MDL multiplier
Mountain Run	106.11	1.88	2.94

Table 6-10. Maximum daily PCB loadings (mg/day) at the impaired segment outlet in the Mountain Run watershed.

Impaired Segment	WLA_{Total} (mg/day)[1]	LA[2] (mg/day)	MOS[3] (mg/day)	TMDL (mg/day)
	Equation to Meet the TMDL Endpoint of 310 pg/L			
Mountain Run[4]	18	463	26	507

[1] WLA_{Total} includes future conditions.
[2] The LA is the remaining loading allowed after the MOS and WLA were subtracted from the TMDL as determined for the downstream end/outlet of the impaired segment.
[3] Explicit MOS (5%).
[4] Concentration used to develop the TMDL depended on simulated average daily PCB concentration. When simulated average daily PCB concentration was less than or equal to the segment-specific endpoint, the endpoint concentration was used in place of the simulated average daily concentration. Simulated average daily PCB concentrations were used when greater than the segment-specific endpoint.

Table 6-11. Average estimated daily PCB load at the outlet of Mountain Run expressed by source category.

Source Category	Existing Load (mg/day)	WLA (mg/day)	LA (mg/day)	Reduction (%)
Municipal Dischargers[1]	16	17		-
Industrial Stormwater General Permits	1			55
WLA Future Conditions[2]		1		
Contaminated Sites	61		1	99
Unregulated Surface Sources[3]	528		237	55
Streambed Sediments	225		225	0
Atmospheric Deposition (water surface)	<1		<1	0
TOTAL	**831**	**18**	**463**	**42%**

[1] A tPCB load reduction for Municipal Dischargers does not apply as the existing load is less than the WLA.
[2] WLA Future Conditions account for permitted facilities that may come on-line in the future and are equal to 0.25% of the TMDL for Mountain Run.
[3] Unregulated surface sources are the sum of net atmospheric deposition to land surfaces, loads from small tributaries that are not explicitly specified in the model, stormwater runoff, loads from unidentified contaminated sites, and unspecified point source discharges.

Chapter 7: TMDL Implementation and Reasonable Assurance

The PCB TMDL developed for the Mountain Run watershed is designed to achieve the selected water quality endpoint. Once this TMDL has been approved by EPA, measures must be taken to reduce pollution levels, with an emphasis on those sources with the greatest relative impact on the applicable designated use impairments. The following sections outline the framework used in Virginia to provide reasonable assurance that the required pollutant reductions can be achieved.

7.1 *Water Quality Management Planning*

After DEQ approves the TMDL study staff will present the study to the State Water Control Board (SWCB) and request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9 VAC 25-720), in accordance with §2.2-4006A.14 and §2.2-4006B of the Code of Virginia. DEQ's public participation procedures relating to TMDL development can be found in DEQ’s Guidance Memo No. 14-2016 (DEQ, 2014b).

7.2 *Staged/Adaptive Implementation*

In general, Virginia intends for the required control actions, including appropriate best management practices (BMPs), to be implemented in a staged or iterative process that places emphasis on those known sources with the largest impact on water quality. The iterative implementation of pollution control actions in the watershed has several benefits:

1. Enables tracking of water quality improvements following implementation through follow-up stream monitoring;
2. Provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. Provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;
4. Helps ensure that the most cost-effective practices are implemented first;
5. Allows for the evaluation of the adequacy of the TMDL in achieving WQSs.

7.3 ***Implementation of Waste Load Allocations***

Federal regulations require that all new, revised, and reissued National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the assumptions and requirements of any applicable TMDL WLA (40 CFR §122.44 (d)(1)(vii)(B)). Permits should be submitted to EPA for review, as applicable.

To implement the WLA component of the TMDL, DEQ utilizes the VPDES Program under the authority delegated by EPA. Requirements of the permit process should not be duplicated in the TMDL process as, depending on the type and nature of a point source discharge, the WLA component is to be addressed solely through the discharge permit. Federal regulations allow permits to use best management practices (BMPs) in lieu of numeric effluent limitations under certain conditions (40 CFR 122.44(k)). The regulation, in subsections 3 and 4, states that BMP-based water quality based effluent limits (WQBELs) can be used where "Numeric effluent limitations are infeasible; or [t]he practices are reasonably necessary to achieve effluent limitations and standards or to carry out the purposes and intent of the CWA." Because BMPs are appropriate and reasonably necessary to achieve water quality standards and to carry out the goals of the Clean Water Act for the Mountain Run watershed, DEQ will use non-numeric WQBELs to comply with the WLA provisions of the TMDL. BMPs will be implemented through Pollutant Minimization Plans (PMPs) as the primary PCB reduction strategy.

There may be circumstances where a VPDES facility with the potential for discharging PCBs may have been excluded from the development of this TMDL. A small percentage (0.25%) of the PCB TMDL has been set aside as "Future Conditions" to account for these situations. For these occurrences, Permit Special conditions may be incorporated into relevant VPDES facilities that were excluded during TMDL development.

7.3.1 **Wastewater Treatment Plants**

Effluent from municipal Waste Water Treatment Plants (WWTP) are asked to meet the BMP-based WQBELs for total PCB concentrations at the point of discharge as stipulated in the VPDES permit. The discharge concentration BMP-based WQBELs serve as an effective surrogate to demonstrate that permittees are meeting established PCB waste load allocations. Direct measurement of PCB effluent concentrations compared against TMDL end-points, or when appropriate Virginia's WQC, is the expected method for demonstrating that permitted discharges are consistent with the assumptions and requirements of this TMDL.

7.3.2 **Stormwater**

DEQ regulates stormwater discharges associated with industrial activities through its VPDES program and regulates stormwater discharges from municipal separate storm sewer systems (MS4s) through the Virginia Stormwater Management Program (VSMP). While covered by different regulations, permits allowing the discharge of industrial stormwater and stormwater from MS4s are administered through VPDES permits. While there are no MS4s in the Mountain Run watershed, all new or revised stormwater permits must be consistent with the assumptions and requirements of any applicable TMDL WLA.

Industrial Stormwater. Discharges from industrial stormwater are derived from precipitation, as opposed to process wastewaters. In the Mountain Run study area industrial stormwater discharges are regulated under VPDES general permits. Discharge concentration BMP-based WQBELs serve as an effective surrogate to demonstrate that permittees are meeting established PCB waste load allocations. Direct measurement of PCB effluent concentrations and evaluation against TMDL end-points, including Virginia's WQC where applicable, is the expected method for demonstrating permitted discharges are consistent with the assumptions and requirements of this TMDL.

Municipal Separate Storm Sewer Systems – MS4s. The Mountain Run watershed currently does not have any MS4 stormwater discharges.

7.3.3 **Insignificant Dischargers**

Waste load allocations are assigned to permittees considered to be significant dischargers of PCBs. Significant discharges of the PCBs have reasonable potential to cause or contribute to the instream impairment. Conversely, incidental or insignificant discharges of the PCBs may occur but not at levels considered to cause or contribute to the impairment, therefore not necessitating the establishment of waste load allocations for these dischargers. For example, there may be residual PCB loads coming from a small permitted wastewater treatment sewage discharge or from industrial sites where PCBs have not been used and reflect background conditions. However, discharges of PCBs from these sources are considered to be negligible and are therefore not included in the TMDL and assigned a WLA.

7.3.4 **TMDL Modifications for New (Previously Unknown Sources) or Expanding Dischargers**

Permits issued for facilities with WLAs developed as part of a TMDL must be consistent with the assumptions and requirements of these WLAs, per EPA regulations. In cases where a new permit from a previously unknown source of PCBs or proposed permit modification occurs in a TMDL watershed and is therefore affected by a TMDL WLA, permit and TMDL staff will coordinate to ensure that new or expanding discharges meet this requirement. In 2014, DEQ issued Guidance Memorandum No. 14-2015 describing the available options and the process that should be followed under those circumstances, including public participation, State Water Control Board actions, EPA approval, and coordination between permit and TMDL staff (DEQ, 2014a).

7.4 ***Implementation of Load Allocations***

The TMDL program does not impart new implementation authorities. Therefore, DEQ intends to use existing programs to the fullest extent in order to attain its water quality goals. The measures for unregulated nonpoint source reductions are implemented in an iterative process using a wide array of BMPs.

7.4.1 **Implementation Plan Development**

A TMDL implementation plan must address, at a minimum, the requirements specified in the Code of Virginia, Section 62.1-44.19.7. State law directs the State Water Control Board to “develop and implement a plan to achieve fully supporting status for impaired waters. The implementation plan “shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments.” EPA outlines the minimum elements of an approvable implementation plan in its 1999 “Guidance for Water Quality-Based Decisions: The TMDL Process.” The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain WQSs, monitoring plans, and milestones for attaining WQSs.

In order to qualify for other funding sources, such as EPA’s Section 319 grants, additional plan requirements may need to be met. The detailed process for developing an implementation plan has been described in the “TMDL Implementation Plan Guidance Manual,” available at:

https://www.deq.virginia.gov/home/showpublisheddocument/6849/637511609521170000.

Watershed stakeholders will have opportunities to provide input and to participate in the development of a TMDL implementation plan. Regional and local offices of DEQ, DCR, and other cooperating agencies are technical resources that can assist in this endeavor.

With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

7.4.2 **Staged Implementation Scenarios**

The purpose of the staged implementation scenarios is to identify one or more combinations of implementation actions that will result in the reduction of controllable sources to the maximum extent practicable using cost-effective, reasonable BMPs for nonpoint source control.

DEQ expects that implementation of this PCB TMDL to occur in stages, and that full implementation of the TMDL is a long-term goal with the overall timeline to be defined by key stakeholders including property owners of contaminated sites. An example of an initial implementation step may include further evaluation of PCB data results as each analytical sample result is comprised of 209 PCB congeners which can be used to provide insight on prospective sources. Depending on the source of the

PCBs to the instream contamination, each PCB result can have a unique “fingerprint”. Follow-up use of available statistical tools may identify possible source areas that match these “fingerprints”. Watershed areas that contain railyards, for instance, can be further evaluated to determine if they contribute greater PCB loads than indicated by this study. Specific goals for subsequent phases of implementation will be determined based on the results of the source identification process. If previously unknown PCB sources are discovered, subsequent implementation phases can include the installation of BMPs used to control sediment (i.e., contaminated) from entering the waterbody. Methods to reduce PCBs can be part of the implementation plan development.

7.4.3 **Link to Ongoing Restoration Efforts**

Nonpoint source reductions are assigned to sources including known contaminated sites, railyards, historic spills or nonregulated surface sources (the sum of net atmospheric deposition to land surfaces, loads from small tributaries that are not explicitly specified in the model, unregulated stormwater runoff, loads from unidentified contaminated sites, and unspecified point source discharges). Contaminated streambed sediments can also be considered within this category but are not expressed within this TMDL as controllable sources.

Implementation of this TMDL will contribute to on-going water quality improvement efforts in Mountain Run and efforts aimed at restoring water quality. Under the adaptive implementation approach, the Commonwealth intends to use existing programs in order to attain water quality goals. Available programmatic options include a combination of regulatory authorities, such as the Toxics Substances Control Act (TSCA), as well as state programs including the Voluntary Remediation Program (VRP), Toxics Contamination Source Assessment Policy, and the Virginia Environmental Emergency Response Fund (VEERF). The PCB Strategy for the Commonwealth of Virginia, published in October 2004, establishes the general strategy and outlines the regulatory framework and state initiatives that Virginia could use to address PCB impaired waterbodies (DEQ, 2005b).

Atmospheric deposition sources of PCBs can be numerous and difficult to quantify. PCBs enter the air through a variety of pathways, and the deposition of PCBs from the atmosphere to the land surface and the volatilization of PCBs from the land to the atmosphere are not well understood. Atmospheric deposition studies may help identify these pathways, and efforts to remediate contaminated sites can help reduce possible atmospheric contributions.

PCBs in streambed sediments are contributing to the system through the dynamic relationship between the sediment and water processes. This occurs through sediment resuspension and/or partitioning from sediment through desorption. To address contaminated bed sediments where localized hot spots exist (e.g., depositional area behind a dam), mechanical or vacuum dredging could be explored as an option to permanently remove PCBs from the system.

7.4.4 **Implementation Funding Sources**

Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans". Potential sources for implementation may include Virginia Environmental Emergency Response Fund (VEERF), EPA Section 319 funds (applicable to BMPs used to reduce upland soil erosion), the Virginia State Revolving Loan Program, the Virginia Water Quality Improvement Fund, and landowner contributions. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

7.4.5 **Follow-up Monitoring**

Following the development of the TMDL, DEQ will continue to monitor the PCB impaired waterbodies for 1) the possible detection of uncharacterized sources, and 2) to measure progress in reducing PCBs to the impaired waters as established by fish tissue meeting the restoration goal. As funding is available, and as identified by the "fingerprinting" source identification approach, it is recommended that monitoring of streambed sediments, soil, and water column be continued by DEQ through special studies. A follow-up study to determine progress made to restore the fish consumption use will also be performed in accordance with the Statewide Fish Tissue and Sediment

Monitoring Program. The purpose, location, parameters, frequency, and duration of the special studies monitoring will be determined by the DEQ staff, in cooperation with stakeholders. The follow-up fish tissue monitoring station(s) will be in similar locations as the listing stations and should be representative of the original impaired segments. The details of the follow-up monitoring will be outlined in the annual Fish Tissue and Sediment Monitoring Plan prepared by DEQ's Water Monitoring and Assessment Program.

7.5 *Attainability of Designated Use*

The goal of a TMDL is to restore impaired waters so that numeric and narrative WQSs are attained. WQSs consist of statements that describe water quality requirements and include three components: 1) designated uses, 2) water quality criteria to protect designated uses, and 3) an antidegradation policy. In the case of this PCB TMDL, pollutant load reductions were developed to lower the instream concentrations in order to protect the fish tissue levels for safe consumption by humans. Implementing cost-effective and reasonable best management practices to reduce PCB loads to the maximum extent practicable will ultimately result in attaining the TMDL. However, in some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use. In order for a stream to be assigned a new designated use, a subcategory of a use, or a tiered use, the current designated use must be removed. To remove a designated use, the state must demonstrate that the use is not an existing use, and that downstream uses are protected. Such uses will be attained by implementing effluent limits required under §301b and §306 of Clean Water Act and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10 paragraph I).

The state must also demonstrate that attaining the designated use is not feasible because of one or more of the following reasons:

1. Naturally occurring pollutant concentration prevents the attainment of the use.
2. Natural, ephemeral, intermittent, or low flow conditions prevent the attainment of the use unless these conditions are compensated by the discharge of

sufficient volume of pollutant discharges without violating state water conservation.

3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place.
4. Dams, diversions, or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate the modification in such a way that would result in the attainment of the use.
5. Physical conditions related to natural features of the waterbody, such as the lack of proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life use protection.
6. Controls more stringent than those required by §301b and §306 of the Clean Water Act would result in substantial and widespread economic and social impact.

This and other information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the WQSs regulations. During the regulatory process, watershed stakeholders and other interested citizens, as well as the EPA, are able to provide comment.

The process to address potentially unattainable reductions based on the above is as follows:

As a first step, measures targeted at the controllable, anthropogenic sources of all pollutants and non-pollutants causing or contributing to the biological impairment will be implemented. In addition, measures should be taken to ensure that discharge permits are fully implementing provisions required in the TMDL. The expectation would be for the reductions of all controllable sources to be to the maximum extent practicable. DEQ will continue to monitor water quality in the impaired streams during and subsequent to the implementation of these measures to determine if WQSs are being attained. This effort will also help to evaluate if the modeling assumptions used in the

TMDL were correct. In the best-case scenario, water quality goals will be met and the stream's uses fully restored using pollution controls and BMPs. If, however, WQSs are not being met, and no additional pollution controls and BMPs can be identified, a UAA would then be initiated with the goal of re-designating the stream for a more appropriate use, subcategory of a use, or tiered use.

A 2006 amendment to the Code of Virginia under 62.1-44.19:7E provides an opportunity for aggrieved parties to present to the State Water Control Board reasonable grounds indicating that the attainment of the designated use for a water is not feasible. The Board may then allow the aggrieved party to conduct a use attainability analysis according to the criteria listed above and a schedule established by the Board. The amendment further states that "If applicable, the schedule shall also address whether TMDL development or implementation for the water shall be delayed.

Chapter 8: Public Participation

Public participation was elicited at every stage of the TMDL development in order to receive inputs from stakeholders and to apprise the stakeholders of the progress made.

A Technical Advisory Committee (TAC) was formed. The TAC included members of the watershed community including representatives of key stakeholder groups (e.g., Piedmont Environmental Council and Friends of the Rappahannock River). The first TAC meeting was held on Tuesday, January 12, 2021, and was conducted virtually through an online webinar platform due to the Covid-19 State of Emergency. Presentations included an overview of the Mountain Run PCB TMDL project including problem identification, PCB monitoring results and prospective sources. Virginia Tech BSE presented the modeling process and the PCB sources that were considered. This virtual meeting was attended by 11 stakeholders (four representatives of non-governmental organizations, two representatives of local government, one representative of state government, three representatives of Virginia Pollutant Discharge Elimination System (VPDES) permitted facilities, and one representative of Virginia Association of Municipal Wastewater Agencies and Virginia Municipal Stormwater Association).

The first PCB Public Meeting was also held virtually on Wednesday, January 13, 2021. The meeting was conducted by DEQ staff, and included background information on PCBs and related human health concerns, long term PCB monitoring data from Mountain Run, and an overview of the TMDL process that will be used in the Mountain Run watershed. Virginia Tech BSE presented details on the PCB modeling process for determining PCB pollutant fate and transport. Fourteen stakeholders registered for this virtual meeting. The comment period for the first public meeting ended February 16, 2021.

The second TAC meeting was held on Tuesday, July 26, 2022 at the Culpeper County Library. The primary focus of the meeting was to review the draft PCB sources allocation scenarios. After a brief recap of the previous TAC meeting, DEQ staff presented the draft allocation scenarios and the TAC selected an allocation scenario to develop the TMDL. This meeting was attended by three stakeholders (two representatives of state government and one representative of a VPDES permitted facility).

The second and final Public Meeting to present the draft TMDL report on the Mountain Run PCB impairment was held on September 6, 2023, at the Culpeper County Board of Supervisors conference room. The public comment period for the second public meeting ended on October 6, 2023, and a single comment was received.

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Glossary of Terms

Atmospheric Deposition
In which a constituent currently suspended in the atmosphere deposits onto the land and water surface either via precipitation (wet deposition) or a gradual settling process not driven by precipitation (dry deposition).

Allocation
That portion of a receiving water's loading capacity that is attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources.

Allocation Scenario
A proposed series of point and nonpoint source allocations (loadings from different sources), which are being considered to meet a water quality planning goal.

Background levels
Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering and dissolution.

BASINS (Better Assessment Science Integrating Point and Nonpoint Sources)
A computer-run tool that contains an assessment and planning component that allows users to organize and display geographic information for selected watersheds. It also contains a modeling component to examine impacts of pollutant loadings from point and nonpoint sources and to characterize the overall condition of specific watersheds.

Best Management Practices (BMP)
Methods, measures, or practices that are determined to be reasonable and cost-effective means for a land owner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.

Bioaccumulation
The accumulation of a chemical in an organism through all source pathways including water, diet, and contaminated sediment.

Calibration
The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.

Calibration Segment
A defined subdivision of a watershed. Calibration segments were used to facilitate modeling. Calibration segments are interconnected meaning the model outputs from some segments serve as inputs for other segments.

Direct nonpoint sources
Pollution sources that are defined statutorily (by law) as nonpoint sources that are represented in the model as point source loadings due to limitations of the model. Examples include: PCB oil spills and atmospheric deposition.

Endpoint
The final goal of the TMDL. Calculated from bioaccumulation factors and VDH and DEQ fish tissue screening thresholds, this value establishes the water column PCB concentration that cannot be exceeded in order to meet the water quality criteria. Endpoints are specific to each calibration segment.

HSPF (Hydrological Simulation Program-Fortran)
A computer-based model that calculates runoff, sediment yield, and fate and transport of various pollutants to the stream. The model was developed under the direction of the U.S. Environmental Protection Agency (EPA).

Hydrology
The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.

Load allocation (LA)
The portion of a receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background.

Margin of Safety (MOS)
A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody. An implicit MOS can be incorporated into the TMDL via various conservative assumptions used to develop TMDLs.

Model
Mathematical representation of hydrologic and water quality processes. Effects of land use, slope, soil characteristics, and management practices are included.

Nonpoint source
Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources include contaminated sites, PCB fluid spills, and railyards and railway spurs. Another nonpoint source are uncharacterized sources, i.e. potential contaminated areas located throughout the watershed that have not yet been identified.

Outfall
The discharge point of a point source into a stream, river, or lake.

Polychlorinated Biphenyls (PCB)
An organic compound chemically defined as two bonded benzene rings with 1 to 10 chlorine atoms substituted around the perimeter of the rings. PCBs are man-made chemicals and were manufactured during the early 20th century for use in heavy machinery. The chemical structure of PCBs allows them to be very stable. As a result, they persist in the environment and are found in soils, streams, and the atmosphere. PCBs also bioaccumulate in fatty tissue. PCBs are an endocrine disruptor which mean they interfere the hormonal system in mammals. They are also a suspected carcinogen. Although, PCB production in the United States was banned by Congress in 1979, their toxicity and longevity mean they continue to be a concern for public health.

Point source
Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.

Pollution
Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.

Reach
Segment of a stream or river.

Runoff
That part of rainfall or snowmelt that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

Sediment-Associated Pollutant
A pollutant with a high affinity for attaching to soil or sediment. If a pollutant is sediment-associated, modeling the fate and transport of sediment through the watershed is a key component of the model development process and provides a more accurate representation of pollutant contamination pathways.

Simulation
The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.

Subwatershed
A subdivision of the calibration segments. Subwatersheds were delineated based on a number of factors: continuity of the stream network, similarity of land use distribution, and monitoring station locations.

Total Maximum Daily Load (TMDL)
The sum of the individual waste load allocations (WLA's) for point sources, load allocations (LA's) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.

Total Organic Carbon (TOC)
A water quality measurement of the total amount of organic carbon in a sample. Carbon in water may be in the form of decaying natural organic matter such as plant fibers.

Urban Runoff
Surface runoff originating from an urban drainage area including streets, parking lots, and rooftops.

Validation (of a model)
Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical process under investigation. This follows the calibration of the model and ensures that the calibrated values adequately represent the watershed.

Waste load allocation (WLA)
The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation.

Water quality standard
Law or regulation that consists of the beneficial designated use or uses of a water body, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular water body, and an anti-degradation statement.

Watershed
A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Appendix A: Setting TMDL Endpoints – Derivation of Water Column PCB Targets for Mountain Run TMDL Development

A.1 Introduction

This Appendix details the procedures and equations used to calculate the TMDL endpoint for Mountain Run. The endpoint was calculated using bioaccumulation factors (BAF) which relate the concentration of a pollutant in a stream to the concentration of pollutant found within each fish species. Fish tissue samples were used to calculate the total PCB (tPCB) TMDL endpoint since ingestion of PCB-contaminated foods is a common exposure pathway for PCB related illness. Figure 2-8 in the main document shows the extent of the impaired stream segments in the Mountain Run Study area and the water quality stations where fish tissue samples were collected. Using the procedure explained here, consideration was given to: 1) fish tissue data set robustness, and 2) the importance of the fish species from a recreational or consumption value. DEQ's fish species selection rationale included:

1. When possible, a mean PCB concentration was calculated using fish sample size ≥ 8 and water concentration (WQ) target ≤ 580 pg/L[1]; if these criteria were not met, then the WQ target was not considered for that species as an individual TMDL endpoint.
2. A WQ target >580 pg/L was not used to avoid skewing results to a level greater than the criterion

In the absence of a site-specific endpoint that is more protective of water quality, the DEQ WQC (580 pg/L or ppq) is considered the default PCB TMDL endpoint and is equivalent to DEQ's 18 ppb fish tissue value (TV) included in the Water Quality Assessment Guidance (DEQ, 2021a). Eqn. A-1 and Eqn. A-2 describe the calculations of Virginia's PCB WQC and fish tissue PCB screening threshold, respectively.

[1] The development of this TMDL coincided with the revision to 9 VAC-25-260-140. Consequently, the numeric WQC (640 pg/L) was revised to 580 pg/L late in the TMDL development process. As the site-specific TMDL endpoint (310 pg/L) derived using the former WQC is more sensitive than the revised WQC, the endpoint was retained without modification.

$$Water\ Quality\ Criterion = \frac{RL\ x\ BW}{CSF\ x\ CR\ x\ BCF}$$ Eqn. A-1

$$Fish\ Screening\ Value = \frac{RL\ x\ BW}{CSF\ x\ CR}$$

Eqn. A-2

Where:

RL = human health criteria at risk level 0.00001 (1 in 100,000 population)
BW = average adult body weight of 70 kg (176.4 lbs.)
CSF = cancer potency factor of 2 (USEPA-IRIS, 1997)
CR = fish consumption rate of 0.0175 kg/day
BCF = USEPA recommended bioconcentration factor of 31,200 (USEPA, 1980)

The equation used to derive the Virginia PCB WQC differs from that used to calculate the fish tissue threshold value by using a Bioconcentration Factor (BCF), which was empirically derived in the 1980's using experimental data that compared the chemical concentrations in the water to fish tissue. When calculating the WQC, the mathematical derivation using the BCF value only considers a single fish exposure pathway to PCBs (i.e., water passing over the gills). The newer BAF approach, recommended by the U.S. Environmental Protection Agency (USEPA) for persistent pollutants like PCBs, considers food and sediment (ingestion/contact) as fish exposure pathways (USEPA 2000; 2003). The Mountain Run site-specific PCB TMDL endpoint was calculated using site-specific BAFs and the fish tissue threshold. Calculated endpoints that are more protective than the WQC (i.e., less than 580 pg/l or ppq) are preferred as long as the data set meets the basic requirements for sample size and the species is of recreational interest (or it serves as a surrogate for recreationally important species). When the calculated endpoint is less protective than the WQC, the WQC may be used as the final segment or watershed-specific endpoint. However, there is another option that can be applied in those instances where the calculated endpoint from one species meets the sample size requirement but exceeds the WQC, when combined with the endpoint from a second, taxonomically similar species that also meets the aforementioned criteria, an arithmetic mean can be derived. An approach such as this would also be considered valid.

A.2 BAF Calculation Approach

The BAF calculation approach described here includes the consideration of multiple fish tissue samples collected in 2001-2013 and the use of available Total Organic Carbon (TOC) and Particulate Organic Carbon (POC) data to estimate Dissolved Organic Carbon (DOC). The entire computational approach is included to provide context.

The Virginia Department of Health (VDH) used an allowable fish tissue total PCB (tPCB) concentration screening threshold of 54 ng/g (ppb) until 2012, when the VDH fish tissue screening value was revised to 100 ppb. Until recently, DEQ used a fish TV of 20 ppb but as described in the 2022 Water Quality Guidance Manual (DEQ, 2021a) lowered it to 18 ppb. The 100 ppb fish tissue screening value from VDH and 18 ppb fish TV from DEQ were considered when calculating site-specific Mountain Run PCB TMDL endpoints.

The site-specific allowable tPCB instream concentration, expressed in pg/L (or parts-per-quadrillion, ppq) for a given fish species may be calculated by dividing the allowable screening threshold concentration considered by a species-specific adjusted total BAF, which has units of liters per kg (L/kg). The instream PCB concentration TMDL endpoint for a given river segment is typically based on the PCB concentration associated with the fish species that poses the greatest risk to humans when the fish is consumed.

Total BAF (TBAF) values represent the ratio of the tPCB concentration in a fish's wet tissue to the tPCB concentration in water. Baseline BAF (BLBAF) values are TBAF values normalized by the fraction of freely dissolved tPCBs in the water column and fish tissue lipid content. BLBAF values are used to identify those species that are most susceptible to accumulating and storing PCBs. BLBAF values are used to calculate adjusted total BAF values which are normalized for comparison among the species within a river segment. The adjusted total BAF value in a given river segment ($ATBAF_{RS}$) is the ratio of tPCB concentration in fish tissue to the tPCB concentration in water normalized across the fish samples within a river segment. The $ATBAF_{RS}$ is calculated using a series of equations, as described in this appendix.

USEPA provides four methods for developing BAF values (USEPA, 2003). Method 1, which uses monitoring data to calculate the BAF values, was applied in this analysis. To provide an accurate TMDL endpoint, a temporal window for recent water quality, sediment, and fish tissue data has been established from the available DEQ data. Water quality data are available from 2013-2021. Fish tissue samples were collected in 1999, 2001, 2006, and 2013 although only tissue results from 2001-2013 were used in conjunction with the water quality data for this BAF analysis. Using data from the different time periods is supported by the temporal consistency of observed fish tissue PCB concentrations. The flow chart included at the end of this appendix (A.6) provides a visual representation of the process used in the example calculation to reach a potential instream TMDL endpoint.

A.2.1 Total BAF values (TBAFHR)

DEQ collects fish tissue samples at specific locations. Fish tissue sample data may be associated with water quality data collected at a given water quality monitoring station that falls within the home range of a given fish species. Home range, defined as the normal distance that a given fish species travels, can range from 1, 2, or 5 miles upstream and downstream of the fish tissue collection site depending on the species. Multiple fish species and multiple fish of the same species may be sampled at a given fish sampling location on a given date. An individual fish tissue sample consists of one or more fish of the same species.

The median tPCB concentration in the water column is calculated for each water quality station using all or some subset of the data collected at that station (note that data from some stations may not be applicable to all species depending on the location of the fish sampling site relative to the water quality monitoring station) (ICPRB, 2007). A species-specific home range total BAF ($TBAF_{HR}$) is calculated using the results from an individual fish tissue sample (note an individual sample result can contain a composite of up to 25 individual fish, e.g. American Eel at station 3-MTN000.59) and the average of the median tPCB values of the water column samples that fall within the home range of that species, Eqn. **A-3** (USEPA 2000; 2003):

$$TBAF_{HR} = \frac{tPCB_{tissue}}{tPCB_{water}} \quad \text{Eqn. A-3}$$

Where:

TBAF

$TBAF_{HR}$ = the tPCB concentration in a given species' fish tissue divided by the average median tPCB concentration in the water column within that species' home range (L/kg)

$tPCB_{tissue}$ = concentration of tPCB in wet fish tissue (ng/g)

$tPCB_{water}$ = average median concentration of tPCB in water (µg/L)

The median $TBAF_{HR}$ values for each species in a river segment was used to determine the median total BAF value for a given river segment ($TBAF_{RS}$) for each species (ICPRB, 2007). The home range of a given species applied to a specific sample represents the area within a stream reach to which that fish (or multiple fish) is exposed and may accumulate PCBs based on the observed water quality. Median $TBAF_{RS}$ values may be used for comparison purposes; however, $TBAF_{HR}$ values, and not the median $TBAF_{RS}$ values, are used to calculate BLBAF and $ATBAF_{RS}$ values. Trophic-level BAF values are determined by pooling the species samples by trophic level and calculating the geometric means (USEPA, 2003).

A.2.2 Baseline BAF values ($BLBAF_{HR}$)

Baseline BAF_{HR} ($BLBAF_{HR}$) values are used to normalize the $TBAF_{HR}$ values using the fraction of freely dissolved tPCBs in the water (F_d) and the fish tissue lipid content. For each species, the tPCB concentration in an individual fish tissue sample is normalized by that fish tissue's measured lipid fraction, and then divided by the average fraction of freely-dissolved tPCBs within the species home range (F_{d-HR}), Eqn. **A**-**4** (USEPA, 2003):

$$BLBAF_{HR} = \left[\frac{TBAF_{HR}}{F_{d-HR}} - 1\right] * \frac{1}{lipid} \quad \text{Eqn. A-4}$$

Where:

$BLBAF_{HR}$ = tPCB concentration in an individual fish tissue sample divided by the average concentration of freely-dissolved tPCB in the species home range, and normalized by that species lipid fraction (L/kg).

$F_{d\text{-}HR}$ = fraction of the species' home range tPCB concentration in water that is freely-dissolved (unitless)
Lipid = fraction of tissue that is lipid (unitless)

A.2.3 Fraction of freely-dissolved tPCB (F_d)

The freely-dissolved tPCB fraction in the water column is a function of dissolved and particulate organic carbon concentrations in the water column. The freely-dissolved fraction ($F_{d\text{-}H}$) of tPCB in the water column for a single homolog is calculated using Eqn. **A-5** (USEPA, 2000; 2003),

$$F_{d-H} = \frac{1}{1 + POC * \mathrm{K}_{OW\_H} + 0.08 * DOC * \mathrm{K}_{OW\_H}} \qquad \text{Eqn. A-5}$$

Where:

$F_{d\text{-}H}$ = dissolved fraction of tPCB in water (unitless) for a single homolog
POC = particulate organic carbon concentration (mg/L)
DOC = dissolved organic carbon concentration (mg/L)
K_{OW_H} = partitioning coefficient for tPCB (L/mg)

There are 209 unique chemical congeners that comprise the tPCB parameter. Octanol-water partitioning coefficients (K_{ow_H}) for specific PCB congeners range over four orders of magnitude. These 209 congeners are uniquely grouped by the total number of chlorine atoms and the position of each chlorine atom on the biphenyl chemical structure into 10 distinct groupings, or homologs. Each homolog has a distinct number of chlorine atoms; however, the location of the chlorine atoms is not taken into account when grouping PCBs by homolog. The octanol-water partitioning coefficient (K_{ow_H}) for each homolog is listed in Table A-1 (ICPRB, 2007). The partitioning coefficient is usually expressed as $\log K_{ow}$, the base 10 logarithm of the water partition coefficient. For example, the partitioning coefficient K_{ow_tri} is expressed as $\log K_{ow\_H}$= 5.425, or $10^{5.425}$ L/kg, in the last column of Table A-1. Homolog-specific partitioning coefficients.. To calculate an $F_{d\text{-}HR}$ representative of tPCBs in the home range of a given fish species, $F_{d\text{-}H}$ must be calculated for each water column sample PCB homolog using Eqn. **A-5**.

Table A-1. Homolog-specific partitioning coefficients.

Homolog	log K_{ow_H}	K_{ow_H} (L/kg)
$K_{ow\_mono+di}$	4.675	47,315
K_{ow_tri}	5.425	266,073
K_{ow_tetra}	6.005	1,011,579
K_{ow_penta}	6.525	3,349,654
K_{ow_hexa}	6.73	5,370,318
K_{ow_hepta}	7.235	17,179,084
K_{ow_octa}	7.6	39,810,717
K_{ow_nona}	7.915	82,224,265
K_{ow_deca}	8.18	151,356,125

Source: ICPRB, 2007

The fraction of freely-dissolved PCBs in the water column ($F_{d\text{-}WC}$) is calculated as the product of individual homolog $F_{d\text{-}H}$ values and observed water column tPCB homolog concentrations, summed over all homologs and divided by the water column tPCB concentration (the sum of all PCB homolog concentrations). This homolog-weighted freely dissolved fraction ($F_{d\text{-}WC}$) is calculated for each water column sample within each fish species home range. The homolog-weighted freely dissolved fraction for each water quality station ($F_{d\text{-}WQ}$) is calculated as the median $F_{d\text{-}WC}$. A species-specific $BLBAF_{HR}$ is calculated using the average of the $F_{d\text{-}WQ}$ values within a species home range ($F_{d\text{-}HR}$) through Eqn. **A-4**. The species-specific baseline BAF for each river segment ($BLBAF_{RS}$) is the median of the species-specific $BLBAF_{HR}$ values in a given river segment.

A.3 River Segment Species-Specific Adjusted Total BAFRS Values (ATBAFRS)

The species-specific $ATBAF_{RS}$ is calculated using Eqn. **A-6**:

$$ATBAF_{RS} = [(BLBAF_{RS} * medianlipid) + 1] * F_{d-RS}$$ Eqn. A-6

Where:

$ATBAF_{RS}$ = $BLBAF_{RS}$ normalized by median lipid content and the fraction of freely dissolved tPCBs in the river segment (L/kg)

medianlipid = median lipid content of a given species for a given river segment (unitless)

$F_{d\text{-}RS}$ = fraction of freely dissolved tPCBs in water for a given river segment (unitless)

For a given species in a given river segment, the median lipid content and $F_{d\text{-}RS}$ are calculated to determine the species-specific $ATBAF_{RS.}$ The median of all species-specific lipid content across fish tissue stations within a river segment is determined and used in Eqn. **A-6**. The fraction of freely dissolved tPCBs in water for a given river segment ($F_{d\text{-}RS}$) is calculated as the median of all $F_{d\text{-}HR}$ values within a single river segment for a given species.

To determine the instream tPCB TMDL endpoints considered for each fish species in a stream reach, each of the fish tissue tPCB screening thresholds cited (18 ppb and 100 ppb) were divided by the $ATBAF_{RS}$.

A.4 Results

A site-specific PCB TMDL endpoint was calculated for each fish species collected from the Mountain Run watershed. When applying DEQ's 18 ppb TV, the site-specific PCB value was derived for all seven fish species. All seven site-specific endpoints are more protective than the state WQC of 580 pg/L, as indicated in Table A-2. The resulting endpoints from all fish species collected in the stream ranged in concentration from 25 pg/L to 580 pg/L.

Two approaches were taken to determine initial target PCB endpoints: 1) an arithmetic mean of all fish species endpoints (240 pg/L); and 2) an arithmetic mean of only predator fish species endpoints, 310 pg/L (American Eel, Fallfish, Rock Bass, and Smallmouth Bass). While a metric including all fish species resulted in a more conservative endpoint, calculating an endpoint from only predatory fish may be appropriate since fish exposure to PCBs can increase in concentration through trophic transfer within a food chain (i.e., biomagnification). Each initial endpoint served as a threshold when running model allocation scenarios, and was used to determine a revised endpoint that achieved a conservative value below the WQC (but not too conservative), and provided a reasonable level of reductions. Note that all endpoint values have been set to two significant figures to be consistent with the application of DEQ's WQS.

A.5 Conclusion

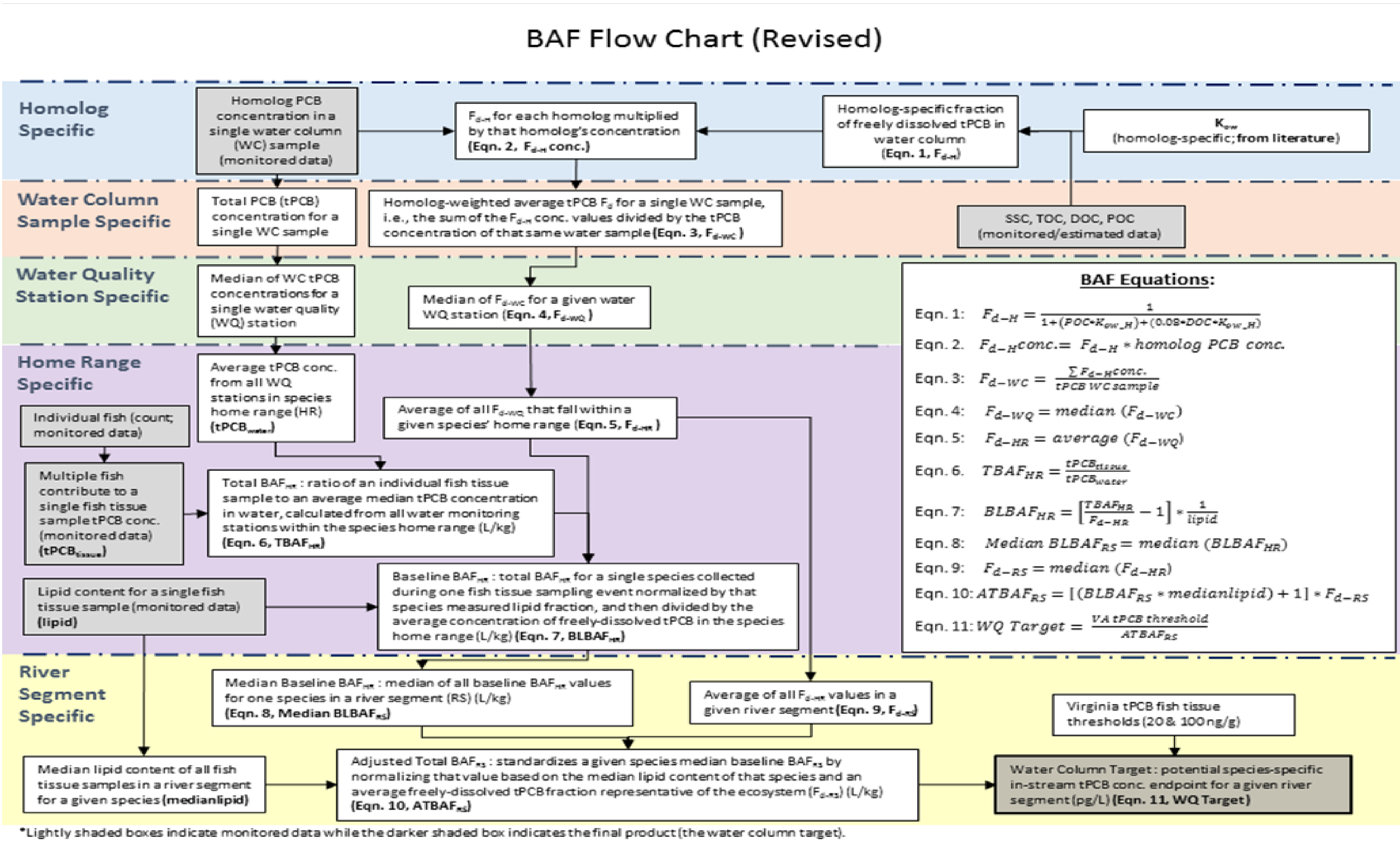
Based on the results of the BAF and site-specific PCB TMDL analyses, the resulting Mountain Run site-specific TMDL PCB endpoint is 310 pg/L. This PCB endpoint is more protective than the Virginia water quality PCB criterion (580 pg/L), and provides a reasonable target goal when considering the 18 ppb fish tissue threshold.

Table A-2. TMDL endpoints calculated for Mountain Run.

	n	**Median $BLBAF_{RS}$**	**$ATBAF_{RS}$**	**WQ Target (pg/L, or ppq)**	
Species	Total Number of Fish	(L/kg)	(L/kg)	**18** ng/g (ppb) tPCB Threshold*	**100** ng/g (ppb) tPCB Threshold
American Eel	11	13,916,055	719	25	140
Fallfish	2	18,785,878	63	290	1,600
Rock Bass	1	18,995,425	31	580	3,200
Sunfish sp.	10	14,543,972	71	250	1,400
Smallmouth Bass	1	30,014,634	50	360	2,000
White Sucker	3	7,870,636	170	110	590
Yellow Bullhead	7	35,241,604	323	56	310

*All fish species, $\bar{x}$ = 240 pg/L; Predator species, $\bar{x}$ = 310 pg/L

A.6 BAF Flow Chart



A.7 References

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Appendix B: Observed Water Quality Data Inventory

B.1 United States Geological Survey (USGS) Streamflow Gages

Table B-1. No active USGS streamflow gages with complete datasets currently exist in Mountain Run.

TMDL Watershed	USGS Stream Gage Station
Mountain Run	None currently active*

*Since there were no active continuous stream flow gages on Mountain Run, parameters from a previous TMDL study were used for the hydrology component of the model (BSE, 2001).

B.2 Suspended Sediment Concentration (SSC) Data and Total Organic Carbon (TOC) Data

Table B-2. Observed SSC (mg/L) and TOC (mg/L) data for the Mountain Run TMDL Watershed.

Subwatershed	Sample Date	Station	Observed SSC (mg/L)	Observed TOC (mg/L)
1	5/7/2013	3-MTN000.59	9.07	–
1	7/18/2013	3-MTN000.59	4.06	–
1	7/27/2015	3-MTN000.59	0.46	3.33
1	8/21/2015	3-MTN000.59	40.10	6.14
1	4/16/2018	3-MTN000.59	274.00	18.10
1	7/11/2018	3-MTN000.59	1.27	3.83
4	5/7/2013	3-MTN005.79	5.74	–
4	7/18/2013	3-MTN005.79	4.64	–
4	7/27/2015	3-MTN005.79	0.33	3.27
4	8/3/2015	3-MTN005.79	1.07	3.91
4	8/21/2015	3-MTN005.79	40.40	7.27
4	4/16/2018	3-MTN005.79	176.00	13.80
4	7/11/2018	3-MTN005.79	0.48	3.82
6	5/7/2013	3-FLA001.93	76.60	–
6	7/18/2013	3-FLA001.93	17.30	–
8	4/16/2018	3-MTN010.98	136.00	12.50
8	7/11/2018	3-MTN010.98	1.88	3.68
10	5/7/2013	3-JOA000.80	112.00	–
10	7/18/2013	3-JOA000.80	1.17	–
10	4/16/2018	3-JOA000.80	36.70	13.50
10	7/11/2018	3-JOA000.80	0.50	3.80
15	5/7/2013	3-MTN014.88	272.00	–
15	7/18/2013	3-MTN014.88	9.10	–
15	7/2/2014	3-MTN014.88	3.64	–
15	8/12/2014	3-MTN014.88	1.69	–

Subwatershed	Sample Date	Station	Observed SSC (mg/L)	Observed TOC (mg/L)
15	7/27/2015	3-MTN014.88	5.08	3.64
15	8/3/2015	3-MTN014.88	2.64	3.29
15	8/21/2015	3-MTN014.88	9.90	5.31
15	4/16/2018	3-MTN014.88	113.00	8.92
15	7/11/2018	3-MTN014.88	2.55	3.61
16	7/2/2014	3-MTN019.75	0.37	–
16	8/12/2014	3-MTN019.75	73.30	–
17	9/30/2015	3-XEH000.10	15.20	4.34
18	7/2/2014	3-MTN021.11	2.44	–
18	8/12/2014	3-MTN021.11	486.00	–
18	7/27/2015	3-MTN021.11	0.00	2.83
18	8/3/2015	3-MTN021.11	0.82	2.64
18	9/30/2015	3-MTN021.11	52.40	7.27
19	9/30/2015	3-XBE000.19	585.00	6.17
19	4/16/2018	3-XBE000.19	5.62	5.47
19	7/11/2018	3-XBE000.19	3.17	1.66
20&21	7/11/2018	3-MTN021.75	2.74	4.59
20&21	7/2/2014	3-MTN022.01	3.75	–
20&21	8/12/2014	3-MTN022.01	70.40	–
20&21	7/27/2015	3-MTN022.01	2.38	3.30
20&21	8/3/2015	3-MTN022.01	2.57	2.90
20&21	9/30/2015	3-MTN022.01	42.60	6.75
20	9/30/2015	3-HID000.22	5.48	4.66
20	4/16/2018	3-HID000.22	18.20	8.92
20	7/11/2018	3-HID000.22	0.91	1.38
21	4/16/2018	3-MTN022.20	61.90	5.37
21	7/11/2018	3-MTN022.20	1.32	5.37
22	9/30/2015	3-BLS000.08	94.00	11.10
22	4/16/2018	3-BLS000.08	94.50	7.19
22	7/11/2018	3-BLS000.08	18.40	6.58
24	7/2/2014	3-MTN022.49	2.40	–
24	8/12/2014	3-MTN022.49	30.30	–
25	9/30/2015	3-XIH000.06	14.80	4.16
25	4/16/2018	3-XIH000.06	20.20	5.66
25	7/11/2018	3-XIH000.06	1.19	1.37
27	5/7/2013	3-MTN023.88	5.11	–
27	7/18/2013	3-MTN023.88	4.83	–
27	4/16/2018	3-MTN023.88	12.60	5.03
27	7/11/2018	3-MTN023.88	5.48	9.54

B.3 Fish Tissue PCB Concentration Data

Table B-3. Fish Tissue PCB concentration (ng/g or ppb) data for the Mountain Run TMDL Watershed.

Subwatershed	Sample Date	Station	Species Common Name	No. of Fish Analyzed	Lipid Content (%)	Total Fish Tissue tPCB (ng/g)
1	6/27/2013	3-MTN000.59	American Eel	25	44.22	221.38
1	6/27/2013	3-MTN000.59	American Eel	25	0.93	202.54
1	6/27/2013	3-MTN000.59	American Eel	3	28.25	131.22
1	6/27/2013	3-MTN000.59	Yellow Bullhead Catfish	9	4.06	19.06
1	6/27/2013	3-MTN000.59	Redbreast Sunfish	10	4.66	6.51
1	6/27/2013	3-MTN000.59	Green Sunfish	10	4.08	4.25
4	5/31/2001	3-MTN005.79	Rock Bass	10	2.69	12.86
4	5/31/2001	3-MTN005.79	Redbreast Sunfish	10	3.30	12.76
4	5/31/2001	3-MTN005.79	Fallfish	5	2.57	16.39
4	5/31/2001	3-MTN005.79	Smallmouth Bass	4	2.77	20.92
4	5/31/2001	3-MTN005.79	American Eel	4	31.42	202.25
4	5/18/2006	3-MTN005.79	Redbreast Sunfish	10	6.70	8.37
4	5/18/2006	3-MTN005.79	Redbreast Sunfish	11	–	–
4	5/18/2006	3-MTN005.79	American Eel	1	48.67	227.83
4	5/18/2006	3-MTN005.79	American Eel	1	51.76	220.76
4	5/18/2006	3-MTN005.79	American Eel	3	20.14	103.44
4	5/18/2006	3-MTN005.79	Yellow Bullhead Catfish	4	6.42	33.20
4	5/18/2006	3-MTN005.79	Northern Hogsucker	2	–	–
4	6/25/2013	3-MTN005.79	American Eel	9	39.59	191.55
4	6/25/2013	3-MTN005.79	Yellow Bullhead Catfish	2	7.95	22.75
4	6/25/2013	3-MTN005.79	Redbreast Sunfish	10	4.98	7.64
4	6/25/2013	3-MTN005.79	Sunfish species	10	6.34	5.15
6	6/27/2013	3-FLA001.93	Yellow Bullhead Catfish	2	2.45	29.07
10	6/25/2013	3-JOA000.80	American Eel	4	31.00	70.78
10	6/25/2013	3-JOA000.80	Green Sunfish	10	5.36	0.00
14	5/31/2001	3-MTN014.33	Fallfish	7	3.67	25.51
14	5/31/2001	3-MTN014.33	Redbreast Sunfish	10	2.78	20.59
14	5/31/2001	3-MTN014.33	White Sucker	7	6.55	29.32
14	6/18/2013	3-MTN014.33	American Eel	10	45.37	345.41
14	6/18/2013	3-MTN014.33	American Eel	1	16.36	164.06
14	6/18/2013	3-MTN014.33	Yellow Bullhead Catfish	5	5.84	39.93
14	6/18/2013	3-MTN014.33	Sunfish species	5	4.94	22.27

Subwatershed	Sample Date	Station	Species Common Name	No. of Fish Analyzed	Lipid Content (%)	Total Fish Tissue tPCB (ng/g)
15	06/25/99	3-MTN014.88	Redbreast Sunfish	25	0.72	4.47
15	06/25/99	3-MTN014.88	American Eel	4	6.84	269.38
15	06/25/99	3-MTN014.88	Bullhead Catfish	14	1.09	17.32
15	06/25/99	3-MTN014.88	Fallfish	7	1.40	15.76
15	06/25/99	3-MTN014.88	Redhorse Sucker	4	1.30	2.98
18	5/18/2006	3-MTN022.21	Green Sunfish	4	–	–
18	5/18/2006	3-MTN022.21	Redbreast Sunfish	4	7.16	5.10
18	5/18/2006	3-MTN022.21	Fallfish	4	–	–
18	5/18/2006	3-MTN022.21	White Sucker	7	9.55	0.00
18	9/27/2012	3-MTN022.21	White Sucker	10	5.20	21.65
18	9/27/2012	3-MTN022.21	American Eel	15	39.76	149.68
18	9/27/2012	3-MTN022.21	Yellow Bullhead Catfish	10	6.86	21.40
18	6/17/2013	3-MTN022.21	Yellow Bullhead Catfish	6	5.35	18.86

B.4 Sediment-Associated PCB Concentration Data

Table B-4. Observed sediment-associated PCB concentration (ng/g) data for Mountain Run used for PCB model calibration.

Subwatershed	Sample Date	Station	Observed Sediment-Associated tPCB (ng/g)
1	7/9/2015	3-MTN000.59	23.3
8	4/22/2021	3-XMS000.05	113.6
8	4/22/2021	3-MTN012.04	4.4
15	7/9/2015	3-MTN014.88	27.7
17	7/9/2015	3-XEH000.10	0.7
17	7/9/2015	3-XEH000.10	0.8
18	7/9/2015	3-MTN022.01	11.5
20	7/9/2015	3-HID000.22	7.9
22	7/9/2015	3-BLS000.08	0.5
25	7/9/2015	3-XIH000.06	63.1
27	7/7/2014	3-MTN024.05	1.8

B.5 Water Column PCB Concentration Data

Table B-5. Observed water column tPCB (pg/L) data for Mountain Run.

Subwatershed	Sample Date	Station	Observed Water Column tPCB (pg/L)
1	5/7/2013	3-MTN000.59	376.69
1	7/18/2013	3-MTN000.59	426.02
1	7/27/2015	3-MTN000.59	371.63
1	8/21/2015	3-MTN000.59	609.60
1	4/16/2018	3-MTN000.59	4,815.42
1	7/11/2018	3-MTN000.59	408.69
4	5/7/2013	3-MTN005.79	264.98
4	7/18/2013	3-MTN005.79	368.82
4	7/18/2013	3-MTN005.79	451.52
4	7/27/2015	3-MTN005.79	416.87
4	8/21/2015	3-MTN005.79	1,311.39
4	4/16/2018	3-MTN005.79	3,497.36
4	7/11/2018	3-MTN005.79	288.19
6	5/7/2013	3-FLA001.93	71.59
6	7/18/2013	3-FLA001.93	104.16
8	4/16/2018	3-MTN010.98	2,680.68
8	7/11/2018	3-MTN010.98	1,962.12
8	3/11/2021	3-MTN010.98	272.39
8	4/22/2021	3-MTN012.04	360.17
8	4/22/2021	3-MTN012.04	259.04
10	5/7/2013	3-JOA000.80	102.04
10	7/18/2013	3-JOA000.80	122.19
10	4/16/2018	3-JOA000.80	203.66
10	7/11/2018	3-JOA000.80	39.77
15	5/7/2013	3-MTN014.88	1,921.21
15	7/18/2013	3-MTN014.88	617.71
15	7/2/2014	3-MTN014.88	639.61
15	8/12/2014	3-MTN014.88	469.20
15	7/27/2015	3-MTN014.88	571.45
15	8/21/2015	3-MTN014.88	938.31
15	4/16/2018	3-MTN014.88	2,816.85
15	7/11/2018	3-MTN014.88	620.54
16	7/2/2014	3-MTN019.75	350.67
16	8/12/2014	3-MTN019.75	1,618.31
17	9/30/2015	3-XEH000.10	137.11
18	7/2/2014	3-MTN021.11	624.93

Subwatershed	Sample Date	Station	Observed Water Column tPCB (pg/L)
18	8/12/2014	3-MTN021.11	8,355.79
18	7/27/2015	3-MTN021.11	368.31
18	9/30/2015	3-MTN021.11	817.92
19	9/30/2015	3-XBE000.19	1,051.91
19	4/16/2018	3-XBE000.19	1,327.48
19	7/11/2018	3-XBE000.19	721.83
20&21	7/11/2018	3-MTN021.75	452.08
20&21	7/2/2014	3-MTN022.01	385.41
20&21	8/12/2014	3-MTN022.01	2854.23
20&21	8/12/2014	3-MTN022.01	3433.76
20&21	7/27/2015	3-MTN022.01	409.76
20&21	9/30/2015	3-MTN022.01	496.18
20	9/30/2015	3-HID000.22	204.30
20	4/16/2018	3-HID000.22	207.31
20	7/11/2018	3-HID000.22	494.75
21	4/16/2018	3-MTN022.20	355.92
21	7/11/2018	3-MTN022.20	437.02
22	9/30/2015	3-BLS000.08	226.56
22	9/30/2015	3-BLS000.08	206.78
22	4/16/2018	3-BLS000.08	159.02
22	7/11/2018	3-BLS000.08	166.20
24	7/2/2014	3-MTN022.49	325.83
24	8/12/2014	3-MTN022.49	1,718.32
25	9/30/2015	3-XIH000.06	829.87
25	4/16/2018	3-XIH000.06	333.72
25	7/11/2018	3-XIH000.06	3,087.64
25	3/23/2021	3-XIH000.03	420.55
25	3/23/2021	3-UTMTNWhPipe	109.53
27	5/7/2013	3-MTN023.88	76.33
27	7/18/2013	3-MTN023.88	100.59
27	4/16/2018	3-MTN023.88	102.45
27	7/11/2018	3-MTN023.88	122.46

B.6 References

BSE. 2001. Fecal Coliform TMDL, Mountain Run Watershed, Culpeper County, VA. Prepared by Virginia Tech Department of Biological Systems Engineering for Virginia Department of Environmental Quality. April 2001.

Appendix C: Mountain Run Source Assessment

The purpose of Appendix C is to provide additional details focused on potential sources of concern for Polychlorinated Biphenyls (PCBs) within the Mountain Run watershed. The study area (Figure C-1) includes a 24.5-mile stretch of Mountain Run and two unnamed tributaries that are impaired for PCBs. The impaired segment begins immediately below the Lake Pelham dam spillway and extends downstream to where Mountain Run joins the Rappahannock River.

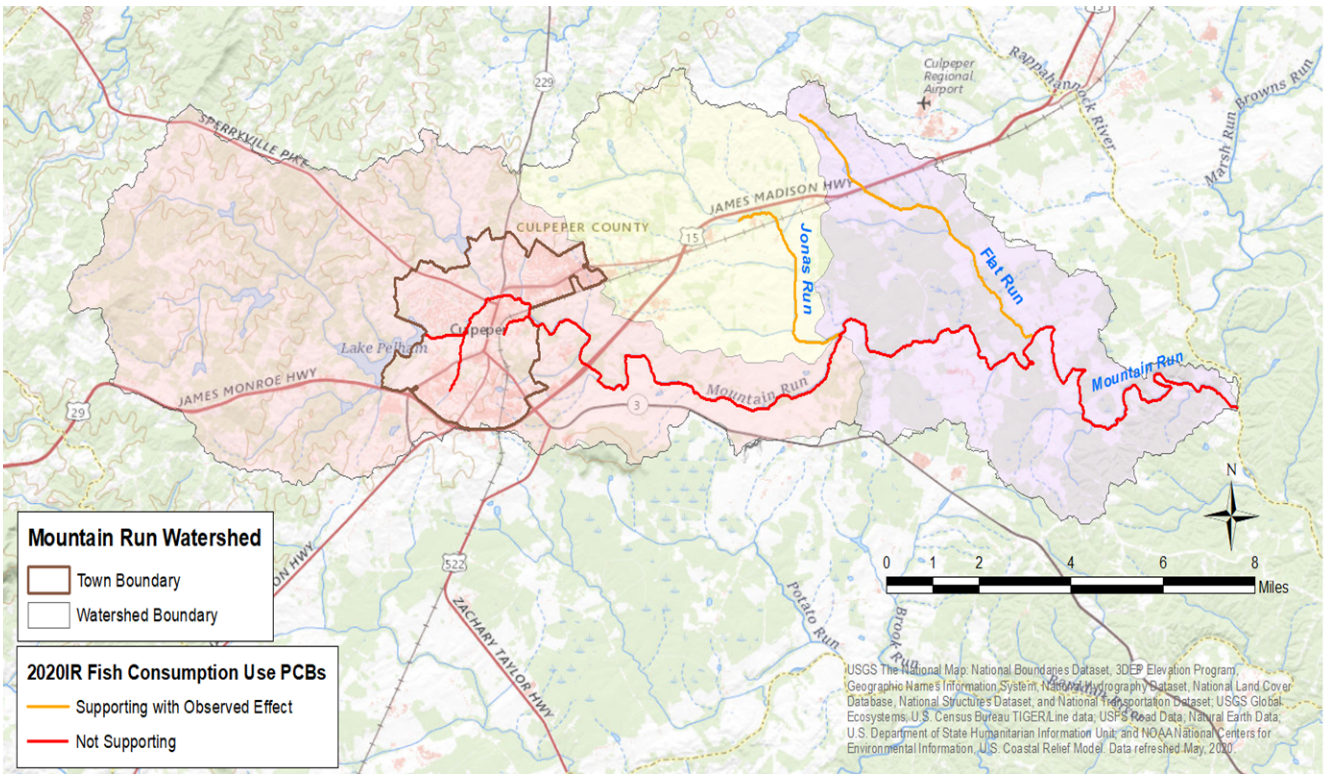

Figure C-1. Map of the Mountain Run PCB TMDL study area.

The EPA PCB TMDL Handbook (EPA, 2011) describes source assessment as a description and cataloging of known and suspected PCB sources. Permitted sources (e.g., Virginia Pollutant Discharge Elimination System, VPDES), known and suspected nonpoint sources (e.g., runoff from contaminated sites, railyards and railway spurs), direct drainage from uncharacterized sources from within the Mountain Run watershed, pollutant spills, atmospheric deposition, and sediment within stream channels, all contribute to the PCB loadings found in this impaired waterbody. Each of these sources are incorporated into the Mountain Run PCB TMDL model.

C.1 Sources of PCBs

PCB sources are divided into several major categories: regulated (permitted) point sources, non-point sources that include contaminated sites, atmospheric deposition, and streambed sediments. Regulated point sources and contaminated sites are further subdivided.

C.1.1 Regulated / Permitted Point Sources

DEQ administers the Virginia Pollutant Discharge Elimination System (VPDES) Program that includes all point sources. Specific categories of point sources typically included in PCB TMDL Source Assessment studies involve municipal wastewater treatment plants (WWTP), individual industrial permitted facilities (IP), industrial storm water general permitted facilities (ISWGP), and Municipal separate storm sewer systems (MS4s) permits (DEQ, 2016).

Municipal Wastewater Treatment Facilities

The Town of Culpeper operates a permitted WWTP on the southeastern side of the Town's boundary area. The existing or baseline PCB loading from this continuous and clearly defined outfall was derived using the mean PCB final effluent concentration provided by the Town. The concentration was calculated by multiplying the average monthly flow rate using flow data obtained from monthly Discharge Monitoring Reports (DMR) that are submitted to DEQ as a permit requirement. The TMDL endpoint concentration was used to calculate the waste load allocations (WLA). Table C-1 includes applicable information for the local WWTP for the Mountain Run study area.

Industrial Stormwater General Permitted Facilities (ISWGP)

Industrial Stormwater General Permitted Facilities that are receiving PCB WLAs were selected by DEQ for this TMDL. The facilities regulated as an ISWGP generally have a smaller industrial footprint whereby the PCB loads are a direct function of stormwater runoff. The PCB loads from these facilities are derived by calculating the annual runoff from the facility (gal/yr), which is an attribute of the drainage areas associated with the industrial activity and impervious acreages, and multiplying it by the PCB concentration at the outfall. The calculated ISWGP loads serve as a constant point source load to the model since the runoff/flow rate is an annual average, whereas the

PCB load from the WWTP varies by month (DEQ, 2016). Table C-1 lists the selected ISWGPs in the Mountain Run study area with the mean PCB concentration and TMDL endpoint used to calculate the existing PCB load and waste load allocation, respectively.

Table C-1. Permitted PCB point source discharges located in the Mountain Run watershed assigned a WLA.

Facility Type	PCB Impaired Waterbody	Facility Name	Permit ID	Mean tPCB Concentration (pg/L)
Municipal WWTP	Mountain Run	Town of Culpeper WWTP	VA0061590	285.5
Industrial Stormwater	Mountain Run, UT*	TE Connectivity - Culpeper Plant	VAR050855	458.6
	Mountain Run, UT	Bingham and Taylor Corp	VAR050900	1,100.0
	Mountain Run, UT	Culpeper Municipal Power Plant	VAR051573	619.4
	Mountain Run	Wise Services and Recycling LLC	VAR051878	2,223.8
	Jonas Run, UT	Culpeper Recycling	VAR051928	314.3
	Mountain Run	Culpeper Towing and Salvage Incorporated	VAR051952	1,169.7
	Jonas Run, UT	AMRF Incorporated	VAR052293	2,218.6

* UT, unnamed tributary

Individual Industrial Permitted Facilities (IP)

Large industrial facilities that fall into this category feature multiple outfalls that may be comprised of one of three types of outfalls: processed, comingled (a combination of processed wastewater and stormwater) that can flow continuously, or intermittent stormwater (SW). Typically, PCB loads are calculated from each outfall, summed and then presented as a single existing load as well as a WLA. It was determined there are no IPs that contribute PCBs in the Mountain Run watershed.

Municipal Separate Stormwater System (MS4) Stormwater Permits

Municipal separate storm sewer systems (MS4s) consist of defined municipal regions that convey stormwater runoff from within their boundary through permitted discharge points. When calculating TMDLs, MS4s are treated as point sources and the PCB loadings from MS4s and contaminated sites they encompass are addressed during the TMDL development process. The Town of Culpeper does not qualify as an urbanized census area that falls under the purview of a Phase II MS4 permit. As such, a WLA is not applicable as a prospective load to Mountain Run.

C.1.2 Nonpoint Sources of PCBs

The nonpoint PCB sources considered when developing a PCB TMDL include several subcategories of contaminated sites, atmospheric deposition and streambed sediment. Properties that are often associated with PCB contamination can include Comprehensive Environmental Restoration, Compensation, and Liability Act (CERCLA) known as Superfund sites, Resource Conservation Recovery Act (RCRA) Corrective Action (CA) facilities, and sites enrolled in DEQ's Voluntary Remediation Program (VRP). Additional subcategories include sites remediated for PCBs with EPA oversight under the Toxics Substances Control Act (TSCA), railyards/railway spurs, electrical substations, and sites with possible PCB spills.

Contaminated sites and railyards were assigned a specific "contaminated" land use type that is similar hydrologically, pedologically (soil classification) and geophysically to the existing land use types (e.g., Commercial, Industrial). The sediment runoff from the "contaminated" land uses included an associated PCB load because PCBs adsorb to sediment. Unknown sources from direct drainage were not assigned specific land use types, but their sediment runoff still included a PCB load. PCB spills were modeled as direct inputs into the stream or as deposition onto the land surface.

Contaminated Sites

For purposes of this study, only those properties and sites where PCBs have been identified as a contaminant of concern or potential concern were included. Contaminated sites are described in the following sections.

CERCLA Facilities

Culpeper Wood Preservers was listed by EPA as a CERCLA site (VAD0591652820) in 1989. PCBs were not identified as a contaminant of concern at this site.

RCRA Corrective Action Facilities

Corrective action is a requirement under RCRA whereby facilities that treat, store or dispose of hazardous wastes investigate and clean up hazardous releases into soil, ground water, surface water and air. Table C-2 includes details for the three facilities located in the Mountain Run watershed that were involved in this regulatory program. However, PCBs were not identified as a contaminant of concern at these facilities under the RCRA corrective action (CA) requirement.

Table C-2. RCRA CA facilities located in the Mountain Run study area.

EPA ID	Facility Name	Address	PCBs a Contaminant of Concern?
VAD059174367	TE Connectivity (The Rochester Corp)	751 Old Brandy Rd	Not identified under RCRA CA; a WLA assigned under VPDES Permit
VAD003064490	Bingham & Taylor	601 Nalie Place	Not identified under RCRA CA; a WLA assigned under VPDES Permit
VAD980715064	VDOT Culpeper Dist. Complex	1601 Orange Rd	Not identified under RCRA CA

Toxics Substances Control Act (TSCA)

Sites that have PCB contamination in excess of 50 ppm are considered under this category of TSCA contaminated sites. EPA has the authority to determine which agency (EPA or DEQ) will have remedial oversight where these contaminated sites exist. There are no sites in the Mountain Run watershed that have been cleaned up or are currently undergoing remediation under the TSCA regulation.

Voluntary Remediation Program (VRP)

DEQ provides a mechanism through the VRP for site owners to provide hazardous waste site cleanups with the end goal of environmental site enhancements and/or site redevelopment. Three sites located in the PCB study area were identified as having participated in this program (see Table C-3). Upon reviewing the available information from the former Keller Manufacturing site, there was no evidence to suggest there is a source of PCBs from this site.

Table C-3. VRP sites located in the Mountain Run study area.

DEQ ID	Facility Name	Address	PCBs a Contaminant of Concern?
VRP00647	Cintas Culpeper	555 James Madison Highway	No Evidence
VRP00379	Keller Manufacturing Facility	601 Germanna Hwy	No Evidence
VRP00024	Jim's Liquid Waste	Carrico Mills Road	Possible

In 2014 Cintas Culpeper was enrolled in the VRP to address on-site contamination from chlorinated solvents. However, a study performed by the Virginia State Water Control Board (1972) concluded that the former site operator, Rental Uniform Service (RUS), was a major source of PCB contamination to the Culpeper Sewage Treatment Plant (STP), which then released PCB contaminated effluent to Mountain Run. DEQ worked with Cintas Culpeper in an effort to determine if this site is a present-day source of PCBs to Mountain Run. The 12.8-acre site is located just east of Hidens Branch in Culpeper. Upon reviewing the available information from the Cintas Culpeper site, and including recent (Eurofins, 2021) PCB results generated from three on-site locations, there was no evidence to suggest there is an on-going source of PCBs from this site to Mountain Run.

A site identified as Jim's Liquid Wastes (VRP00024) is located just west of Carrico Mills Road, about 2 miles south of Brandy Station and between Mountain Run river mile 10.98 and its confluence with Jonas Run in Culpeper County, Virginia (Figure C-2). The 67-acre site was discovered in the late 1970's where the landowner operated a septic refuse and industrial waste disposal business from 1974 to 1981 (GSX Services, Inc., 1988). The records indicate there were several industrial sources of waste that were disposed at this site. For example, liquid wastes from the Virginia Power North Anna Power station consisting of solvents, paints, and oil (Virginia Dept. of Waste Management, 1989) were disposed of on-site as well as sludge from the Rental Uniform Service in Culpeper. PCBs are historically related to the electrical generating industry and based on the 1972 report from the SWCB, were also associated with RUS. Remediation activities occurred during the mid to late 1980's. At least 358 drums were removed in addition to 360 cubic yards of contaminated soil. PCBs were included on the long list of potential contaminants that were monitored at this location. However, the results indicate this contaminant was largely not detected using analytical methods appropriate during that time period (i.e., PCB detection occurred at levels > 1,000 – 3,300 ppb). EPA did consider the site for CERCLA listing (EPA ID VAD080559065) during the late 1980's but had determined the site did not qualify based on existing information. Therefore, in the early 1990's this site was identified as No Further Remedial Action Planned (NFRAP).

Figure C-2. Location of VRP site Jim's Liquid Wastes (VRP00024) in Culpeper County, VA.

Sites of Possible Interest

The following sites are of possible interest based on the former land use of the property. Of note, these properties have not been identified by a regulation based remedial program that is overseen by DEQ or the EPA.

Former Culpeper Municipal Electric Plant & Waterworks

The electrical generation portion of the Culpeper Municipal Electric Plant & Waterworks facility was built in 1934. The old electric generation plant remained operational until 2006. The former facility is located on less than an acre of land on West

Spring Street that backs up to Mountain Run and Yowell Meadow Park (Figure C-3 and Figure C-4). The former electric plant's proximity to Mountain Run was key in providing water for the electric generating system, and for cooling engine equipment (DHR, 2019).

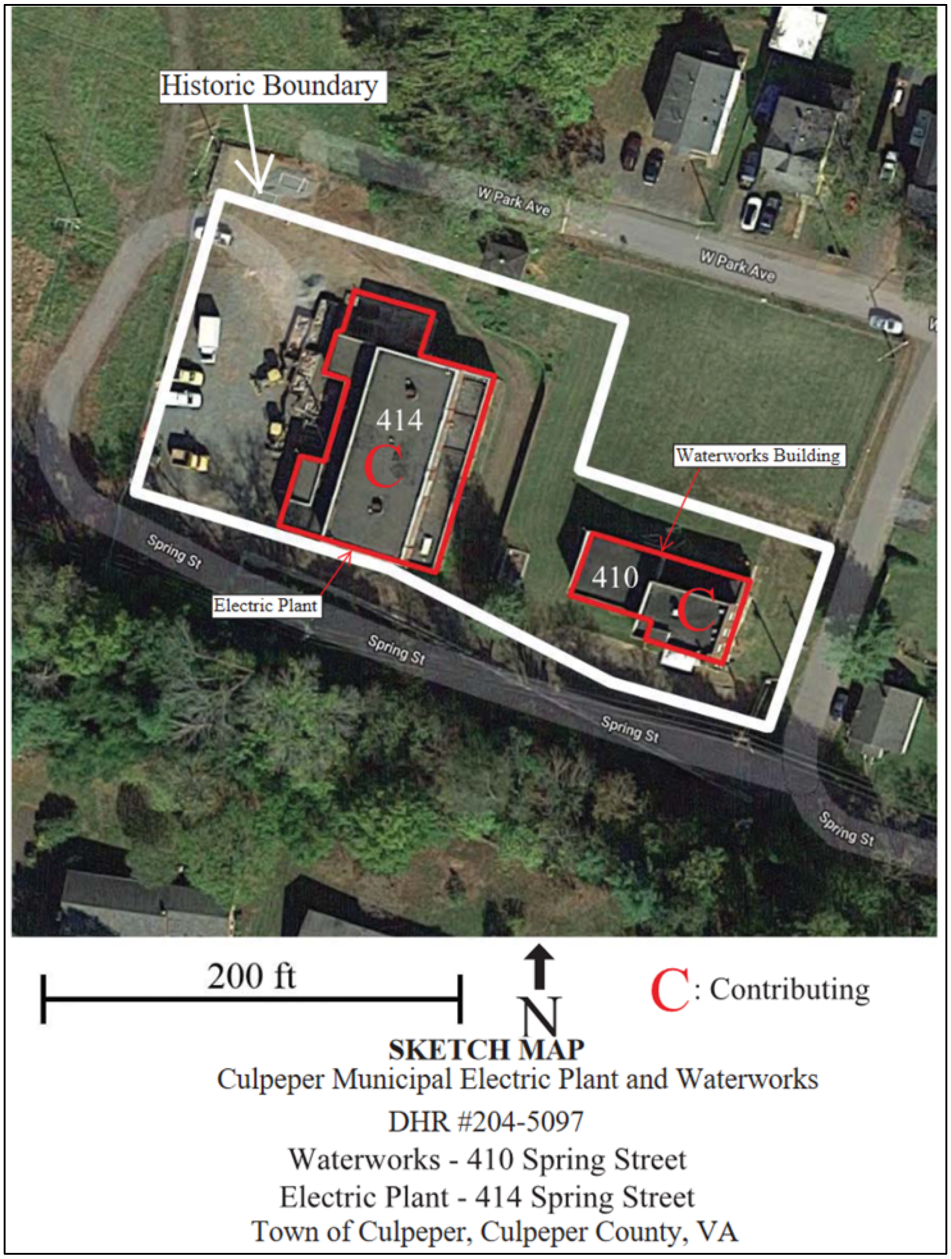

Figure C-3. Satellite image of the old Culpeper Municipal Electric Plant & Waterworks facility, Virginia Department of Historic Resources (DHR, 2019).

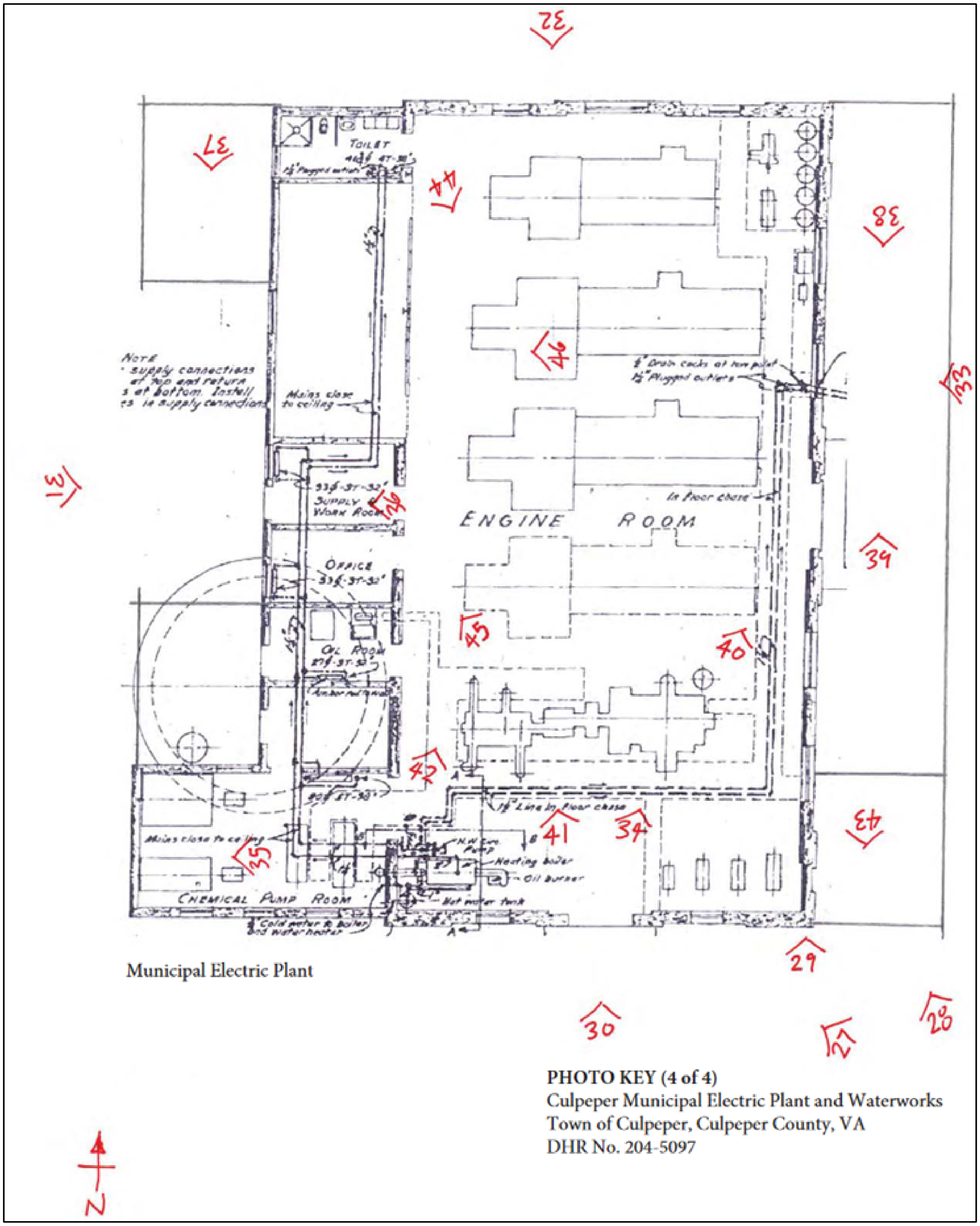

Figure C-4. Former Culpeper Municipal Electric Plant building plan (DHR, 2019).

Former Town of Culpeper WWTP

The location of the former Town of Culpeper WWTP was identified as a possible historical source of PCBs. Located at 610 Old Brandy Road, the former sewage treatment plant was decommissioned on February 8, 1983 (Figure C-5).

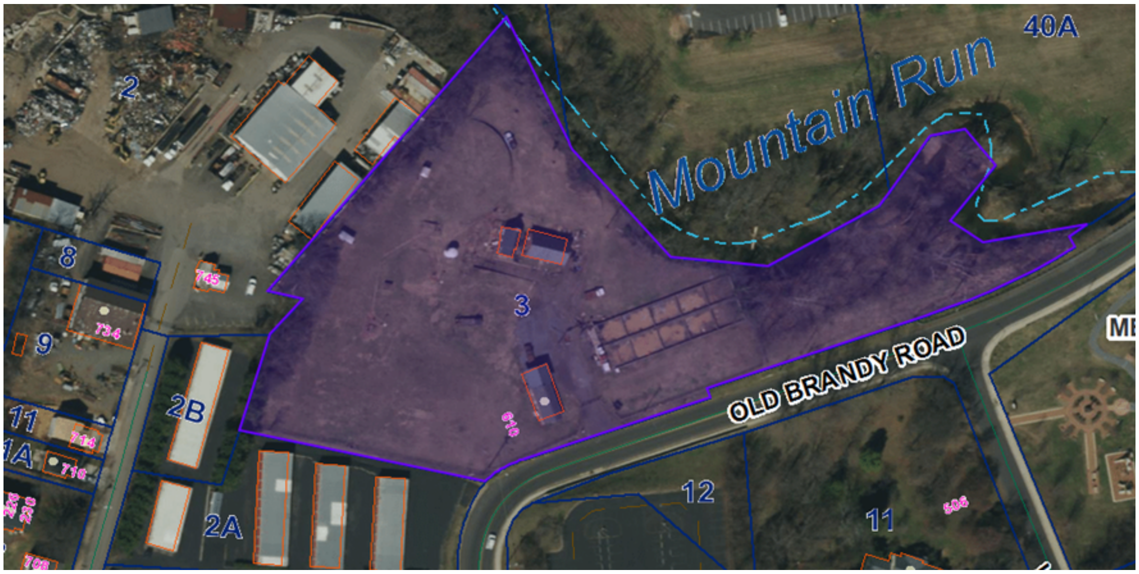

Figure C-5. Location and image of the decommissioned Culpeper Wastewater Treatment Plant.

Railyards and Railway Spurs

Railyards and railway spurs are included as PCB sources because the EPA allows continued operation of older, PCB-containing train engine transformers. Railyards were previously included as potential sources in other PCB TMDLs including that developed for the Roanoke River (DEQ, 2009) and the New River watershed (DEQ, 2018). The Mountain Run watershed does not contain rail yards regulated under the VPDES Program, but analysis of satellite imagery shows they are present. Locations of rail yards and railway spurs in the Mountain Run study area are shown in Figure C-6. Rail yards and railway spurs in the Mountain Run PCB TMDL study area were identified using a combination of GIS using Google Earth historical satellite imagery and tax parcel data for Culpeper County. Examples of identified railway spurs using the DEQ Environmental Data Mapper (DEQ, 2021b) can be seen in Figure C-7 and Figure C-8. Estimated railway spur acreages and site descriptions are shown in Table C-4. Railroad lines were visually traced until a rail yard, or in the case of the Mountain Run watershed a railway spur was identified. Key indicators of a railway spur were rail lines that diverted off the main track before ending abruptly and/or the presence of secondary and tertiary tracks. These extra rail lines were potentially used for maintenance purposes or for possible locomotive storage. PCBs may have leached into the soil over the course of time.

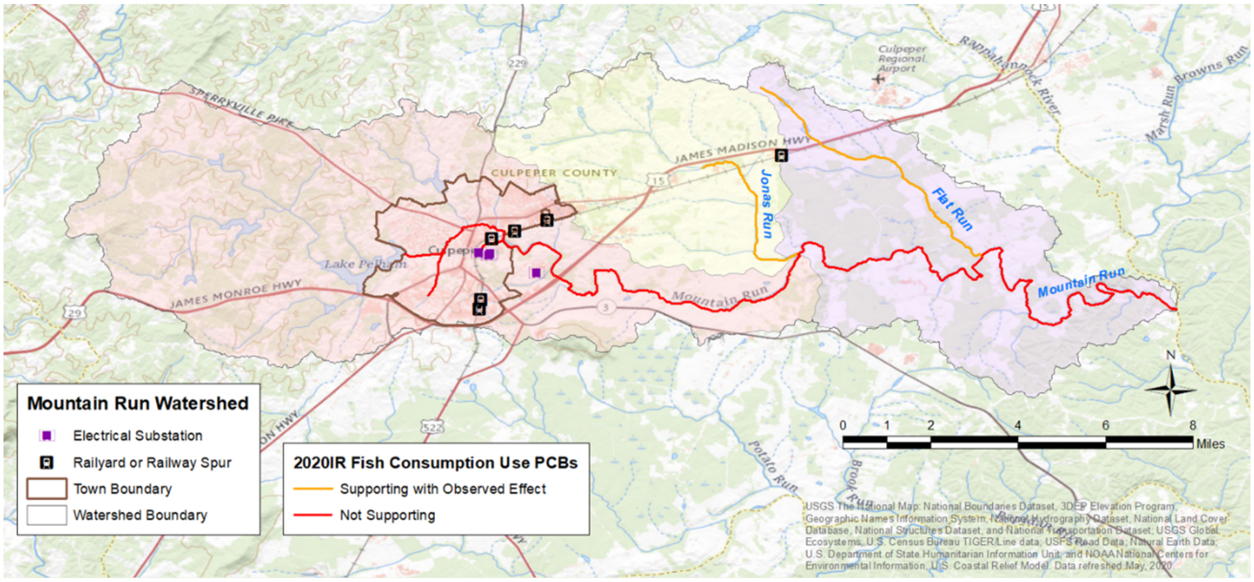

Figure C-6. Map includes the location of railway spurs and electrical substations in Culpeper, Virginia.

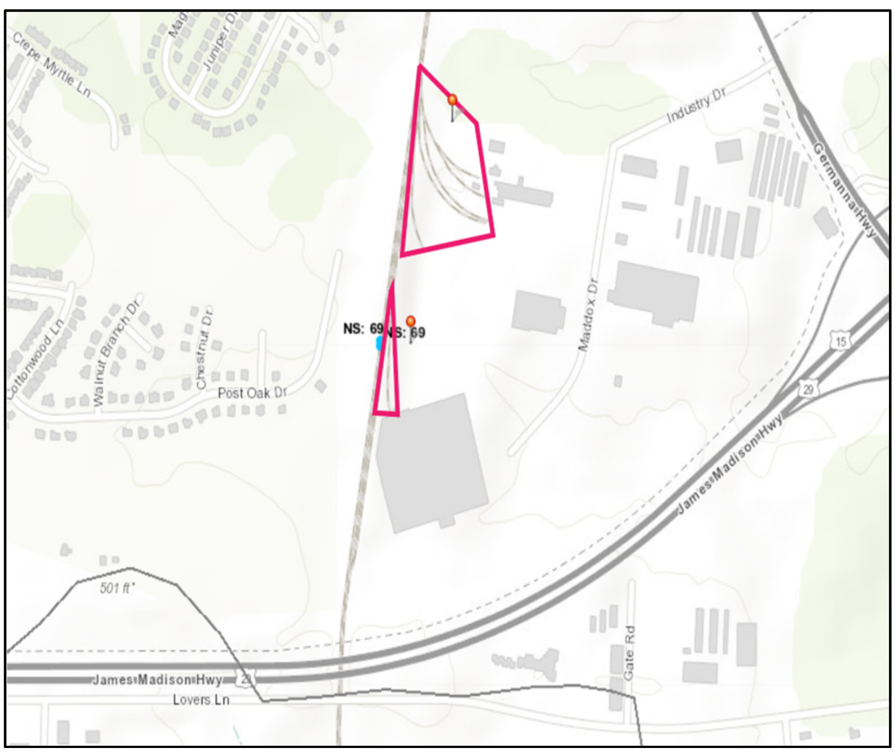

Figure C-7. Example map #1 showing the approximate locations of the railway spurs identified in Culpeper, Virginia.

Figure C-8. Example map #2 showing the approximate locations of the railway spurs identified in Culpeper, Virginia.

Table C-4. Contaminated sites identified as Railyards, Railway Spurs, and Electrical Substation in the Mountain Run watershed.

Source	Site Description and Adjacent Parcel ID	Estimated Area (ac)
Railyard/Railway Spur	Railway Spur #1 (51-5, 51-6A, 51-6C)	4.4
	Railway Spur #2 (51-6A)	1.1
	Railway Spur #3 (41A2-1C2-9A,10)	0.9
	Railway Spur #4 (41-90, 41-92)	1.6
	Railway Spur #5 (41-76A, 41-77, 41-78B)	1.1
	Railway Spur #6 (33-24, 33-41, 33-42A)	0.8
Electrical Transformers	Electrical Substation #1 (41-106C)	2.1
	Electrical Substation #2 (41A2-1H2-6)	0.4
	Electrical Substation #3 (41-102)	1.0

Electrical Substations

Electrical substations are part of an electrical generation, transmission, and distribution system that are used to convert voltage from high to low (or the reverse) through the use of electrical transformers. The equipment associated with this function historically contained dielectric fluids that contained high levels of PCBs. Acreage associated with Electrical substations in the Mountain Run watershed can be found in Table C-4. The applied loading rate was based on data provided by Dominion Energy and Appalachian Power for previous PCB TMDL studies (ICPRB, 2007; DEQ, 2018) and was estimated at 1.29×10^{12} (pg/ton).

Pollution Response Program (PREP) PCB Spills

The Pollution Response Program (PREP) database is managed by DEQ and tracks pollution incidents that result in potential human health or environmental impact. Agencies, businesses, or individuals report the incidents to DEQ who dispatch personnel to investigate the report. Entries in the database may include improper liquid or solid waste disposal, leakages, sewer overflows, legal or illegal burnings, or unidentified contaminants visible in a stream. DEQ reviewed the database entries for incidents in the Mountain Run study area that occurred during the modeling period. The database was pared down to oil spills since PCBs are commonly found in oils. Database entries that noted the oil was non-PCB was ignored in the report.

In the model, PREP incidents were simulated as one-time localized events. If a duration was not provided in the PREP database, it was estimated using best professional judgement. The PREP spills were often listed as a volume. Given the fact that many of the spills were in the form of oil, it was assumed that the density of the liquid spills was 0.9 kg/L (less than the density of water). The assumed concentration of PCBs in the oil was 0.05%, which is conservative for spills from an unknown origin (DEQ, 2018). Locations of the spill incidents are provided in Table C-5 in addition to the details for the estimated quantities of PCBs (mg) released from each spill incident. For incidents with spills of unknown quantity, the modeled PCB load was based on an estimated spill volume of one gallon.

Table C-5. Spills that have occurred in the Mountain Run watershed during the TMDL study period.

Incident Date	Site Name/Description	Site Address	Fluid Spilled	Estimated Spill Volume (gal)	Estimated PCB (mg)
05/05/17	Updike Industries Hydraulic Oil Discharge	12340 Robin Road	Hydraulic fluid	10	18,928
11/18/09	Builders First Source - Hydraulic Oil	13234 Air Park Rd	Hydraulic oil	Unknown	–
04/16/16	Tyco Electronics	751 Old Brandy Rd	Hydraulic oil	37.5	70,980
03/28/17	Oil Leak From TT (tractor trailer)	890 Willis Lane	Hydraulic oil	Unknown	–
03/01/17	Loudoun Composting Hydraulic Oil (12-20 gals)	16332 Cyclone Way	Hydraulic oil	16	30,285
05/25/11	Hydraulic Oil Spill	16033 Laurel Springs Rd	Hydraulic oil	Unknown	–
07/10/14	Lub Oil Release (Norfolk & Southern)	Milepost 66	Lube oil	0.1875	355
–	AMRF Solid Waste & Oil	Between Route 29 & Brandy Rd (down from Exxon)	Oil	Unknown	–
01/27/12	Oil Dumping	16232 Brandy Rd	Oil	Unknown	–
05/20/10	Norfolk Southern Railway	Milepost 67	Oil (Lubricating)	0.25	473
02/29/16	Illegal Dumping of Oil & Tires-Muriel Way	Creek in area of 801 Muriel Way	Oil (Unknown)	Unknown	–
09/23/18	CubeSmart Motor Oil Spill*	510 Germanna Hwy	*Oily Water	50	47,320
–	–	16085 Brandy Rd	Waste oil	Unknown	–
09/12/11	TTA (tractor trailer accident)	Rt 29 1/2 Mile Pass Rt 3	Motor oil	5	9,464
03/23/15	Diesel & Motor Oil Spill	22508 Cedar Mountain Rd	Motor oil	Unknown	–
08/27/18	Kiewit Motor Oil Spill	1 JB Carpenter Dr	Motor oil	0.0625	118
10/31/16	Motor Oil on Kenney Store Lane	182 Kenney Store Lane	Motor oil	Unknown	–
05/05/17	Updike Industries Hydraulic Oil Discharge	12340 Robin Road	Hydraulic fluid	10	18,928

*Concentration reduced by ½ since spill classified as oily water

Unregulated Surface Runoff

Unregulated surface runoff is a term that collectively accounts for PCB loadings from an uncertain origin found within regulated and non-regulated areas that drain to Mountain Run. Unregulated surface drainage includes areas adjacent to Mountain Run and associated tributaries within the watershed that are recognized as contributing PCB loads. These areas contribute background PCBs associated with atmospheric deposition to the land surfaces as well as unknown or uncharacterized PCB contaminated sites (including past spill sites), unregulated stormwater runoff from commercial land use areas, loads from small tributaries that are not explicitly specified in the model, and unspecified point source discharges. Sources represented by this category include PCB loads supported by the observed instream data whose specific location have yet to be identified.

C.1.3 Atmospheric Deposition

Due to their molecular stability, PCBs persist in the atmosphere after volatilization and may contaminate waterbodies through direct deposition onto the water surface or by runoff after deposition onto the land surface.

Atmospheric deposition was applied on all water surfaces in the Mountain Run watershed at a constant rate. Atmospheric deposition on the water surface immediately enters the water column as a freely available pollutant constituent. Since there are no available data to characterize the atmospheric deposition of tPCBs to the surface waters, Virginia Tech Biological Systems Engineering (BSE) elected to use a PCB atmospheric deposition rate of 3.0×10^6 pg/ac/month applied across the Mountain Run study area. This rate corresponds with results in the Roanoke River and New River PCB TMDLs.

PCB deposited onto the land surface adsorb to soil particles. These PCBs do not enter into the stream network until a precipitation event induces a runoff event that carries soils with the adsorbed PCB contamination into a stream. Atmospheric deposition to the land surface was modeled as part of the non-regulated watershed runoff.

C.1.4 Streambed Sediment (bottom sediment)

The historical discharges of PCBs into the water combined with the ability of PCBs to persist in the environment and their tendency to adsorb to sediment particles make sediment within stream channels a major source of PCBs. Due to their hydrophobic properties, PCBs adsorb to sediment particles. PCBs have a higher tendency to associate at elevated concentrations with finer sediment particles, which have more surface area and higher carbon content, such as clay and silt rather than coarser particles like sand. PCB contaminated sediment may settle to the streambed, but when disturbed the sediment may re-suspend into the water column and the soil-attached PCBs may desorb into the water. Streambed sediment sampling by DEQ has shown measurable concentrations of PCBs in Mountain Run. The sediment PCB concentrations in these observed samples were used in the Mountain Run PCB model to provide initial concentrations of PCBs associated with sediment.

C.2 References

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Appendix D: Sediment Calibration for Mountain Run

Sediment acts as a transport mechanism for PCBs. As part of the Mountain Run PCB TMDL development process, a model calibration was performed for the coupled hydrology/water quality simulation model Hydrological Simulation Program-FORTRAN (HSPF) to predict sediment loads through Mountain Run.

The sediment calibration process was divided into two phases. Phase I addressed sediment detachment from land surfaces and loading into the subwatershed stream/river reaches (water course) by comparing model-calculated loadings with published calibration targets. Phase II addressed instream total suspended sediment (SSC) concentrations within each stream/river reach. Phase II accounted for land surface loadings from Phase I and sediment deposition/scouring along stream/river beds. The outline of the Phase I and Phase II calibration process is described below. Since there were no hourly observed SSC monitoring data for Mountain Run, HSPF was executed using daily time-step.

D.1 Calibration Methodology

D.1.1 Phase I Calibration Methodology

Phase I sediment modeling used the sediment detachment and transport functionality in HSPF. The final model output for previous land uses with pervious (e.g., cropland) was split into two sets of data: the rate of sediment and sediment removal from the land surface (SOSED, tons/ac-yr) and the storage of detached sediment on the land surface (DETS, tons/acre). Impervious land uses (e.g., residential) included two additional model outputs: wash off of solids from impervious land surface (SOSLD, tons/ac-yr) and storage of solids on impervious land surface (SLDS, tons/acre).

Unlike typical water quality calibrations, there were no sediment storage and sediment removal observed data for model calibration. Measuring the quantity and removal rate of sediment on a land surface would be a laborious and expensive task, and include a high degree of uncertainty. Therefore, instead of comparing model performance against monitoring data, a “weight-of-evidence” approach was used to assess calibration sufficiency. That approach entailed calibrating the model output SOSED and SOSLD values using target ranges listed in EPA BASINS Technical Note 8

(USEPA, 2006), Table D-1. As part of the “weight-of-evidence” approach, model outputs were graphed to visualize the fluctuations in sediment storage on the land surface. The goal was to calibrate the wash off and removal rates such that sediment storage (DETS and SLDS) increased and decreased in conjunction with precipitation patterns, i.e. sediment storage totals should increase steadily before decreasing as a result of storm events. Further, DETS and SLDS totals should not continually increase or decrease over time, and significant storage reductions should be more frequent on impervious surfaces. These are sediment removal characteristics that could be reasonably expected in a watershed.

Table D-1. Target SOSED and SOSLD ranges for pervious and impervious land uses (USEPA, 2006).

Pervious Land Use	Target SOSED Range (tons/ac-yr)
Forest	0.05-0.4
Pasture/Hay	0.3-1.8
Cropland	0.5-5.0
Residential	0.2-1.0
Commercial	0.2-1.0
Water	0.001-0.010
Impervious Land use	**Target SOSLD Range (tons/ac-yr)**
Residential	0.2-1.0
Commercial	0.2-1.0

Analysis of the SOSED, SOSLD, DETS, and SLDS for each land use was performed qualitatively using time series plots to determine if the simulated sediment storage and removal values trended as expected. In the interest of consistency, and because no observed data were used, the same calibration period (January 1, 2011 to November 18, 2019) was used for the Phase I sediment calibration for Mountain Run. In a typical water quality calibration with a defined pollutant, calibration periods would be tailored by subwatershed and station according to when observed samples were acquired. Since no observed data were available, a uniform, multi-year calibration period that included a range of annual precipitation magnitudes was used for Mountain Run watershed calibration.

D.1.2 Phase II Calibration Methodology

Phase II sediment modeling built off the sediment model parameter values established during Phase I calibration. In Phase II, HSPF was configured to output sediment bed depth (ft), sediment inflow (tons), sediment outflow (tons), deposition/scouring along the sediment bed (tons), sediment storage (tons), flow rate (cfs), shear stress (lb/ft^2), and total suspended sediment concentrations (SSC, mg/L) for each reach. Once the model was run, annual averages of these outputs were examined to ensure the model did not produce unusually large or small values for sediment inflows, outflows and deposition/scouring, that bed depth remained relatively stable for the duration of the simulation, and to confirm that model output was consistent with the simulated hydrology. The Phase II calibration process entailed comparing simulated instream SSC values against observed SSC[3] data (mg/L) provided by the Virginia Department of Environmental Quality (DEQ). Observed total SSC is the summation of both observed fine SSC and observed coarse SSC. Table D-2. lists the number of DEQ water quality stations with observed SSC data in each calibration segment and the number of observed samples available.

Table D-2. Mountain Run calibration segments and number of water quality stations with observed SSC data

Calibration Segment	No. Water Quality Stations w/ Observed SSC Data	Total No. Observed SSC Data Samples
Mountain Run	17	64

Model performance was assessed using a "weight-of-evidence" approach, as discussed in EPA BASINS Technical Note 8 (USEPA, 2006). In this approach, the Phase II calibration process focused on subwatershed reaches within each calibration segment where observed data were available, and the model was evaluated based on knowledge of the study area and expected behavior. The BASINS Technical Note recommends a graphical analysis to compare the simulated and observed. Additionally, in other TMDL studies where observed data were sparse, as is the case here, 3- and 5-day calibration windows have been used both qualitatively (graphical/visual) and

[3] In order to distinguish between simulated suspended sediment concentration (SSC) and observed suspended sediment concentration (SSC), the acronym will be preceded by "simulated" or "observed."

quantitatively to evaluate model calibration sufficiency. Calibration windows are centered (in time) on observed data (Kim *et al.*, 2007; Russo *et al.*, 2011; Liao *et al.*, 2015). Calibration windows were used in the Mountain Run sediment calibration as part a "weight-of-evidence" approach to assess model calibration sufficiency.

The first Phase II model run for every calibration segment was used to generate estimates of the critical bed shear stress parameters (TAUCD and TAUCS) for each subwatershed reach. These critical shear stress values determined the shear stress threshold at which clay or silt was deposited (TAUCD) or scoured (TAUCS) from the reach bed. Since these thresholds were dependent on flow, specifically the 5%, 10%, 85% and 90% flows in a reach, it was difficult to determine their values *a priori*. Instead, the first model run was used to provide initial parameter estimates. At the end of this run, simulated shear stress and simulated flow were output as daily averages. Then, they were ranked in order of lowest flow/shear stress to highest flow/shear stress. The shear stress value corresponding to the 5% lowest flow in each reach was the critical bed shear stress deposition (TAUCD) for clay. The shear stress value corresponding to the 10% lowest flows in each reach was the deposition critical bed shear stress (TAUCD) for silt. Flows below these levels caused sediment to settle out and be deposited on the reach bed. The shear stress values corresponding to the 85% and 90% highest flows in each reach were the scour critical bed shear stress (TAUCS) for clay and silt, respectively. Flows above these levels caused sediment to scour from the reach bed. When the flow rate was between the upper and lower thresholds, no deposition or scouring occurred (i.e., sediment was transported downstream through the reach). Figure D-1 illustrates the parallel relationship between flow and shear stress with critical shear stress values denoted as horizontal lines for an example subwatershed (Mountain Run, subwatershed reach 1).

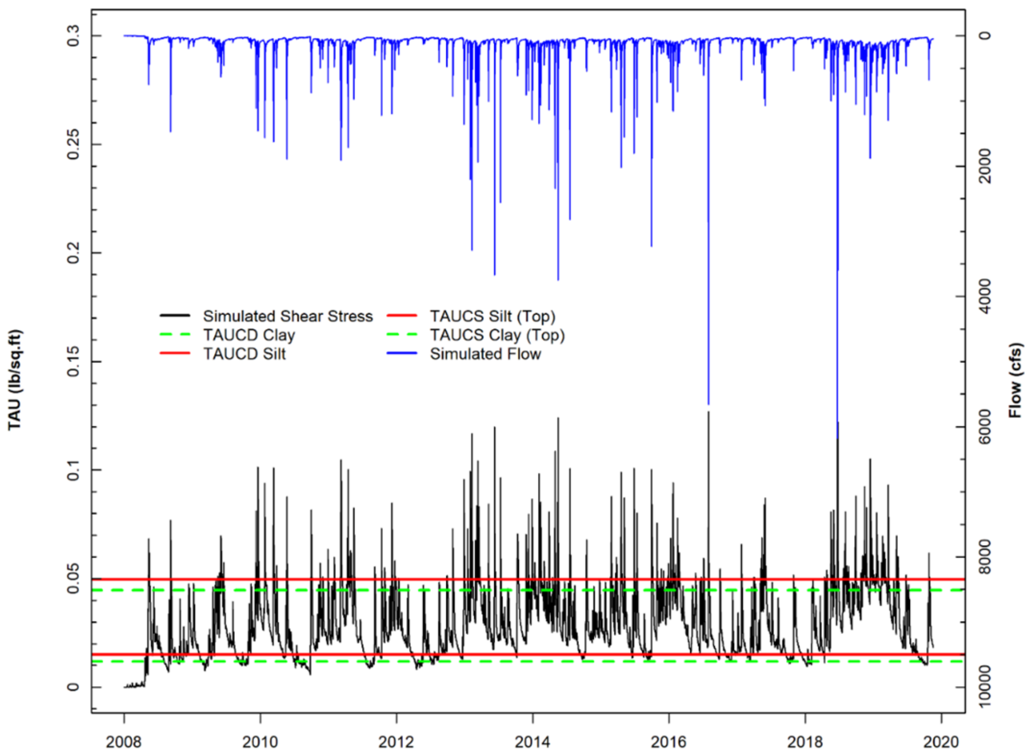

Figure D-1. Example shear stress and flow relationship with critical deposition and scour thresholds (Mountain Run, subwatershed reach 1).

Although TAUCD and TAUCS are calibration parameters that were subject to change during the calibration, it was necessary to calculate initial estimates in the first model run to expedite the calibration process. In the second run, the "placeholder" TAUCD and TAUCS values were replaced with the estimates. Then the calibration continued with all calibration parameters subject to change to achieve a sufficiently calibrated model. A table of Phase II calibration parameters and final values is included at the end of each calibration segment's section.

Graphical Analysis

After each successful HSPF model run, the sediment outputs were analyzed for calibration. The graphical analysis component of the sediment calibration was multifaceted and included two types of plots. With the available observed SSC data, DEQ and BSE believe the graphs produced show adequate model calibration. Other calibration plots and the 3- and 5-day windows supplemented the sediment calibration assessment for these ungaged calibration segments. A similar graphical calibration approach was used in the Roanoke River PCB TMDL (DEQ, 2009) and New River PCB TMDL (DEQ, 2018).

The first plot was used to assess how the model performed on a given sampling date when compared to observed data. A two-part calibration graph was produced to address this need. First, observed sediment concentration data were plotted by date on the x-axis. The average daily simulated SSC for a 3-day window centered on the observed sampling date was also plotted. The maximum and minimum simulated daily SSC concentrations during the 3-day window was plotted as well. In a well-calibrated model, a majority of the observed data points should fall within the 3-day window maximum-minimum range. When the observed data is not captured within a surrounding 3-day window range well calibrated model should under- and over-estimate roughly equally. Using the 3-day window to assess model performance accounts for temporal fluctuations in the model that may cause the sediment concentrations to have a delayed or early response.

The second plot that was used to assess model calibration was a time series plot of daily average simulated SSC and observed SSC with daily average simulated flow plotted on a secondary axis. These plots were generated for all subwatershed reaches where observed SSC data was available. The objective of this analysis was to show that simulated SSC responded to fluctuations in simulated flow, and that simulated SSC could adequately predict observed SSC.

Three- and Five-day Windows Quantitative Model Performance Assessment

In addition to the 3-day window graphical assessment discussed previously, 3- and 5-day calibration windows metrics were used to quantitatively assess model performance. Again, the 3-day and 5-day calibration windows are centered (in time) on observed data. Each window included an equal number of simulated data points before and after the sample date. The minimum and maximum daily simulated SSC values within the windows were determined. If the observed SSC value was between the minimum and maximum values, then that data point was considered to be “within” the window. If the observed SSC value was less than the minimum value, then it was considered to be “below” the calibration window. If the observed SSC value was greater than the maximum, then it was considered to be “above” the calibration window. It should be emphasized that 3- and 5-day windows were only generated around observed SSC sample data.

Kim *et al.* (2007) justified the use of 5-day windows for developing bacterial TMDLs in watersheds with limited observed data. Kim *et al.* (2007) stated that the goal of the calibration was to achieve at least 70% observed data points within the 5-day window. Additionally, in order to avoid model bias, the percentage of data points above and below the window (if any) should be roughly equal. BSE believed the use of a 5-day calibration window could also be applied to assessing sediment model performance.

The 3-day calibration window is 'stricter' in terms of analyzing model performance since it shrinks the calibration window. Both Russo *et al.* (2011) and Liao *et al.* (2015) used 3-day calibration windows to assess bacteria model performance. Unlike the 5-day calibration window, calibration criteria for a 3-day window are not clearly defined in the literature. However, since a 3-day window is narrower, BSE believes achieving a majority of data points (i.e. >50%) within the 3-day calibration window demonstrates an adequate measure of model fit. Again, in order to avoid model bias, the percentage of data points above and below the 3-day calibration window maximum and minimum values should be roughly equal.

The 3- and 5-day calibration window "within", "below", and "above" statistics were calculated once per model run and included all observed SSC data available from DEQ. During calibration, the 3-day and 5-day windows metrics were examined after each run as a primary indicator to determine if additional calibration was necessary.

D.2 Mountain Run Calibration Results

This section presents the HSPF sediment calibration results for the Mountain Run watersheds and the calibration results are summarized by Phase I and Phase II.

D.2.1 Phase I Calibration

Average annual SOSED and SOSLD (sediment and solids wash off rate) values for Mountain Run were calibrated to within the load target ranges (Table D-1) for each Mountain Run subwatershed and land use. Due to the large size of the resulting SOSED and SOSLD calibration tables, they are not included in this Appendix; including tables would have increased report length significantly. These tables can be made available upon request.

Pervious Land Use Calibration

Figure D-2, Figure D-3, and Figure D-4, show observed precipitation (upper axis) and simulated SOSED, DETS values for Forest, cropland and pervious Residential land uses for the calibration period (2011-2019), respectively for subwatershed 1 in Mountain Run. Other pervious land uses and subwatersheds produced similar SOSED and DETS plots. The DETS in each subwatershed for each pervious land use increased over time before decreasing during instances of sediment removal caused by storm events. The magnitude of DETS was smallest for the Forest land use and largest in Cropland land use, which was expected since forested lands have a greater percentage of vegetative cover and cropland is periodically fallow.

Impervious Land Use Calibration

Figure D-5 shows the observed precipitation (upper axis) and SOSLD and SLDS values for the impervious fraction of the Residential land use for subwatershed 1 from January 1, 2011 to November 18, 2019. Impervious land cover was subject to greater sediment loss during smaller magnitude precipitation events than pervious land cover.

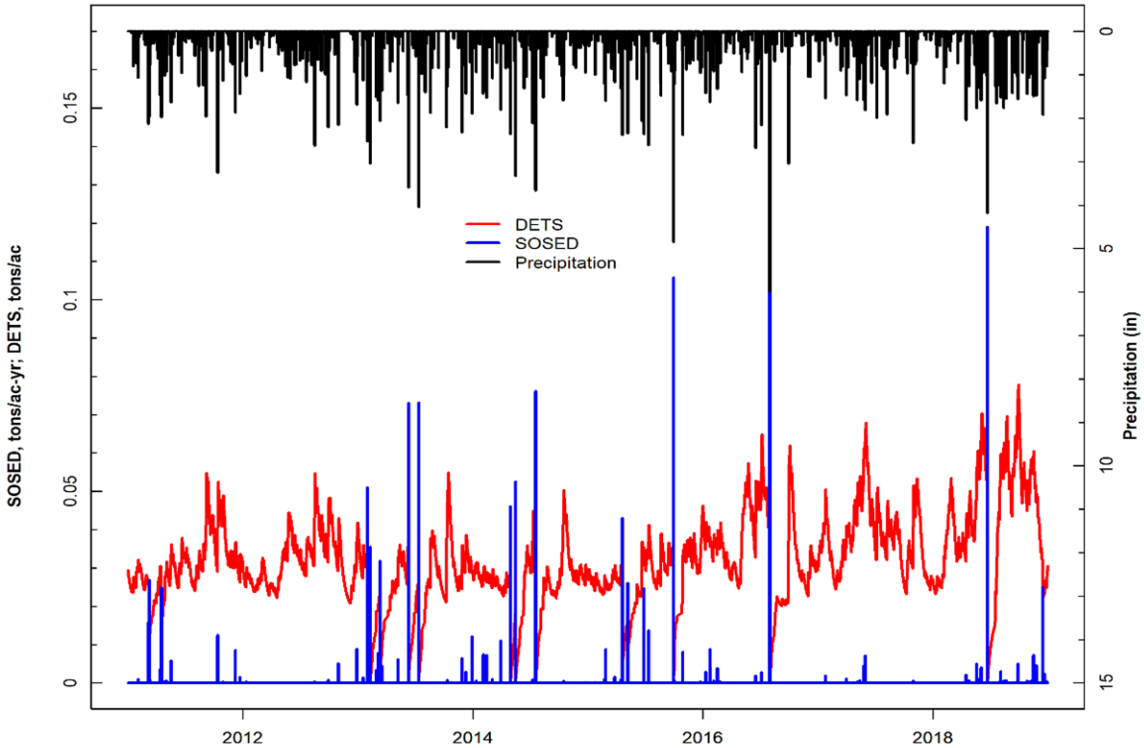

Figure D-2. Forest SOSED, DETS, and observed precipitation for subwatershed 1 in Mountain Run.

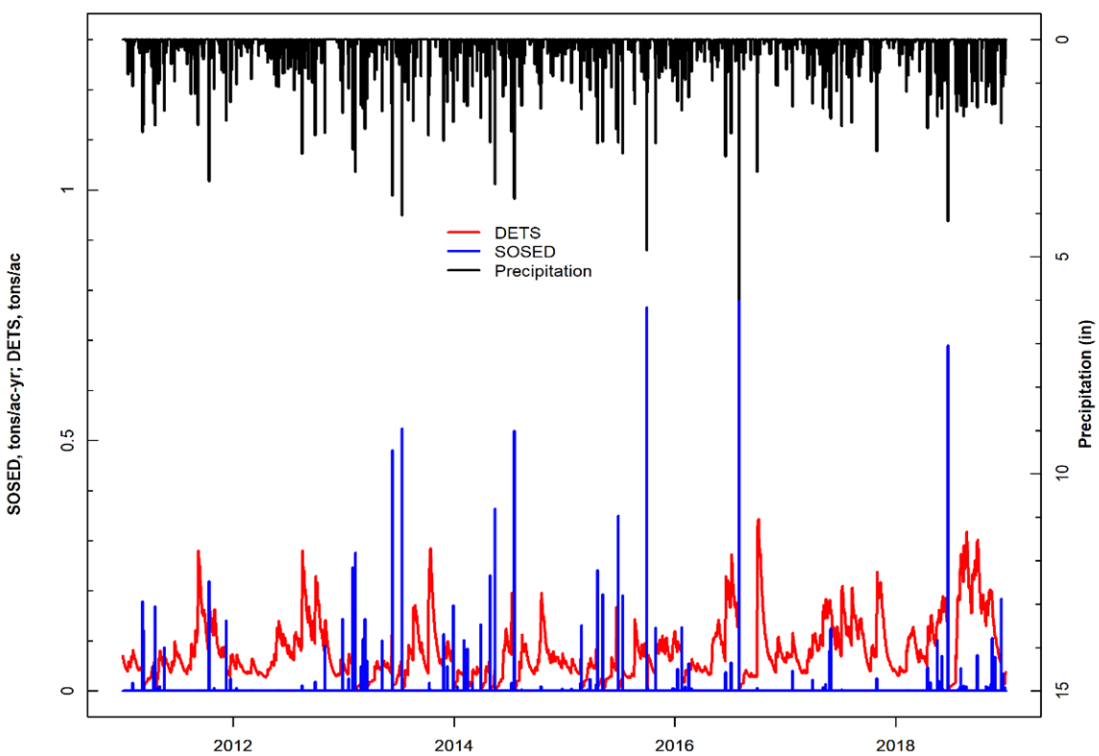

Figure D-3. Cropland SOSED, DETS, and observed precipitation for subwatershed 1 in Mountain Run.

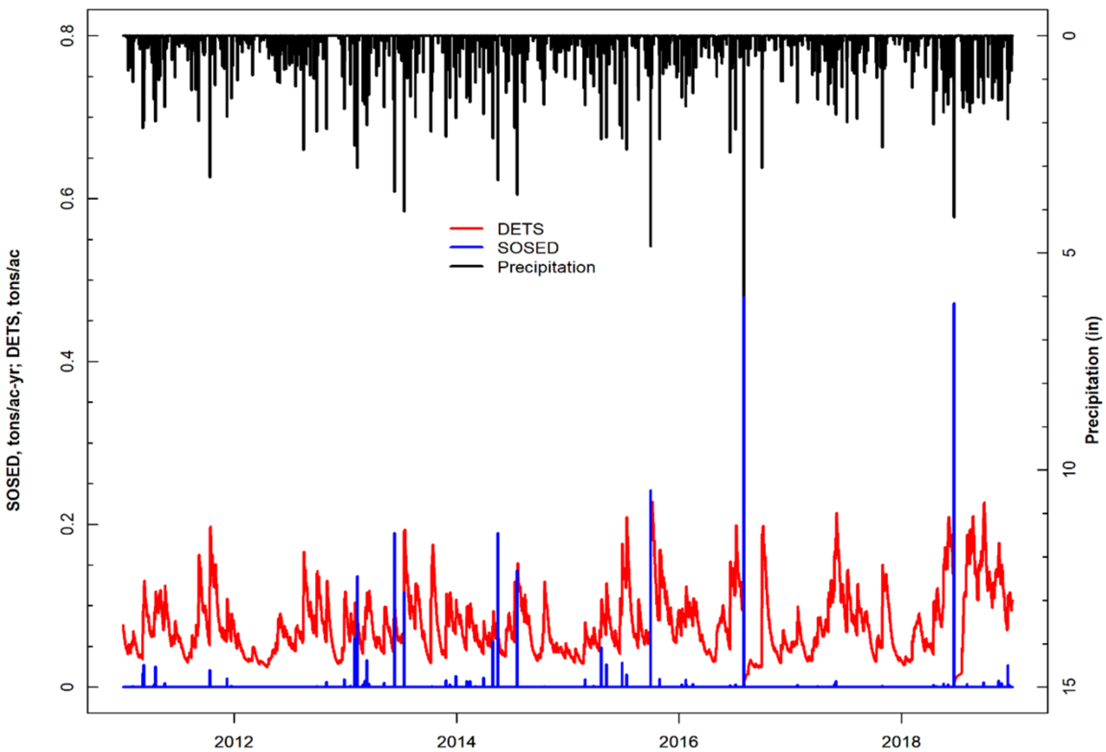

Figure D-4. Pervious Residential SOSED, DETS, and observed precipitation for subwatershed 1 in Mountain Run.

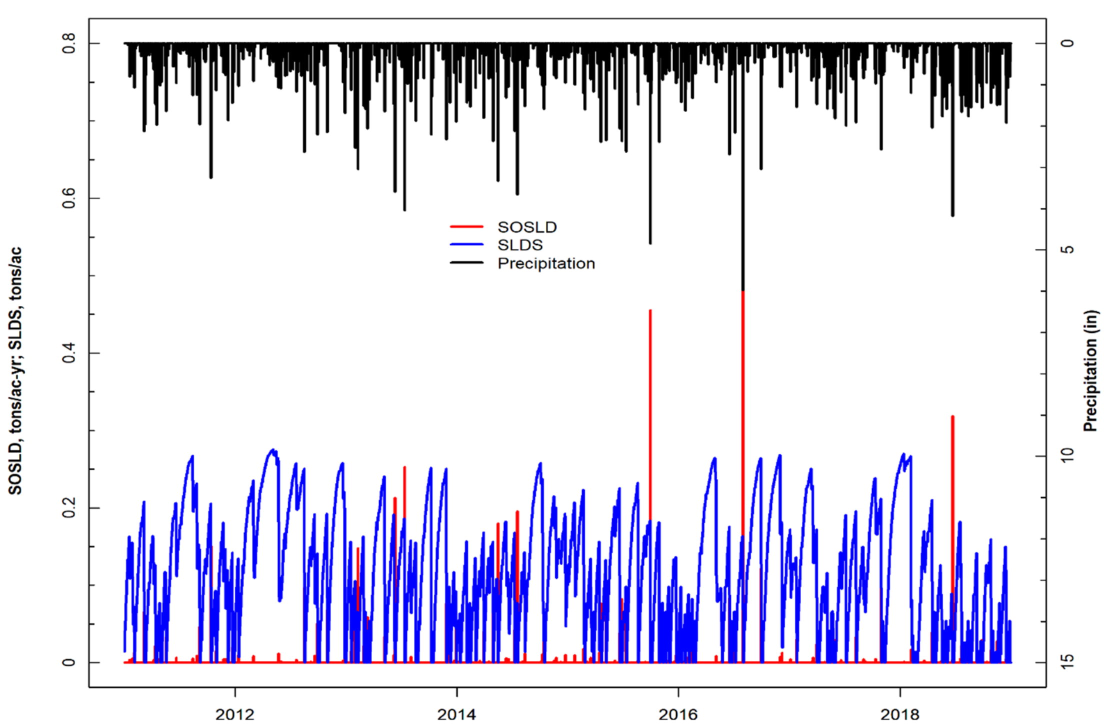

Figure D-5. Impervious Residential SOSLD, SLDS, and observed precipitation for subwatershed 1 in Mountain Run.

SOSED, SOSLD, DETS, and SLDS Summary

The simulated SOSED, SOSLD, DETS, and SLDS values on the pervious and impervious land uses followed expected patterns. On pervious land uses, the DETS (sediment storage) increased steadily before decreasing sharply due to spikes in SOSED (sediment removal) which were a result of major storm events. This periodic rise and fall of sediment storage are characteristic of a well calibrated model. On impervious land use, the SLDS (solids storage) fluctuations (increases and decreases) were more frequent when compared to the DETS for the pervious land uses. Impervious land uses were more sensitive to smaller storms and subject to more frequent wash off. Pervious Residential and impervious Residential land use were included in the analysis to provide a comparison of the difference between pervious and impervious land cover. The calibrated Phase I model provided a reasonable approximation of the behavior of sediment detachment and removal in the Mountain Run calibration. Due to the large number of subwatersheds and land uses in Mountain Run, Phase I graphs for the other subwatersheds are not included in this report; attaching all of the Phase I graphs would increase report significantly. They can be made available upon request. The final calibrated sediment parameters for the Phase I calibration are presented in Table D-2.

Table D-2. Final calibrated parameters for the Mountain Run Phase I Calibration.

Parameter	Definition	FUNCTION OF…	Units	FINAL CALIBRATION	POSSIBLE RANGE OF VALUES‡	CALCULATION METHOD‡
PERLND[a]						
SED-PARM2 (Sediment Parameter Group 2)						
SMPF	Management Practice (P) factor from USLE	Land use, agricultural practices	none	0.0-1.0	0.0 - 1.0	Constant at 1.0, Assumed no Management Practices
KRER	Coefficient in the soil detachment equation	Soils	complex	0.050 - 0.392[b]	0.05 - 0.75	Estimated in GIS, **Calibrated in HSPF**
JRER	Exponent in the soil detachment equation	Soils, climate	none	3.0 for water and 2 for others	1.0 - 3.0	Based on Technical Note Recommended Values
AFFIX	Daily reduction in detached sediment	Soils, compaction, agricultural operations	per day	0.065 - 0.5[b]	0.01 - 0.50	Estimated from Recommended Values, **Calibrated in HSPF**
COVER	Fraction land surface protected from rainfall	Vegetal cover, land use	none	0.225-0.980[b]	0.0 - 0.98	Estimated from Recommended Values, **Calibrated in HSPF**
NVSI	Atmospheric additions to sediment storage	Deposition, activities, etc.	lb/ac-day	0.0 - 2.5[b]	0.0 - 20.0	Based on Tech. Note Recommended Values
SED-PARM3 (Sediment Parameter Group 3)						
KSER	Coefficient in the sediment washoff equation	Soils, surface conditions	complex	0.10 - 7.50[b]	0.001 - 10.0	Estimated from Recommended Values, **Calibrated in HSPF**
JSER	Exponent in the sediment washoff equation	Soils, surface conditions	none	1.0 for water and 2 for others	1.0 - 3.0	“ ”
KGER	Coefficient in the soil matrix scour equation	Soils, evidence of gullies	complex	0.0	0.0 - 10.0	“ ”
JGER	Exponent in the soil matrix scour equation	Soils, evidence of gullies	none	2.5	1.0 - 5.0	“ ”
IMPLND[c]						
SLD-PARM2 (Solids Parameter Group 2)						
KEIM	Coefficient in the solids washoff equation	Surface conditions, solids characteristics	complex	1.0	0.1 - 10.0	Based on Tech. Note Recommended Values
JEIM	Exponent in the solids washoff equation	Surface conditions, solids characteristics	none	1.8	1.0 - 3.0	“ ”
ACCSDP	Solids accumulation rate on the land surface	Land use, traffic, human activities	lb/ac-day	0.0045	0.0 - 30.0	“ ”
REMSDP	Fraction of the solids removed per day	Street sweeping, wind, traffic	per day	0.05	0.01 - 1.0	“ ”

‡ Acquired from EPA BASINS Technical Note 8 (2006)
[a] Pervious land segment
[b] Varies with land use (data available upon request)
[c] Impervious land segment

D.2.2 Phase II Calibration

As mentioned in the introductory calibration methodology section, the first run of the Phase II calibration was used to generate initial estimates of critical shear stress values (TAUCD and TAUCS). Once the initial run was complete, the calibration continued by substituting the placeholder TAUCD and TAUCS values with updated estimates. In subsequent calibration runs, all sediment calibration parameters including TAUCD and TAUCS were subject to adjustment. Phase II calibration sufficiency metrics were analyzed after each run to determine if model calibration would continue. Although not explicitly part of the calibration evaluation process, the change in sediment bed depth was reviewed after each calibration run. Bed depth was output as an annual average for each subwatershed reach. Large swings in bed depth trends were indications that the model could be encountering calculation errors and misrepresenting the subwatershed.

Graphical Analysis

The Phase II graphical calibration focused on model fit at the stations and subwatersheds where observed SSC data were available. Figure D-6 illustrates the model performance, this figure shows observed sediment concentrations plotted on each day that observed SSC data were collected at DEQ station 3-JOA000.80. The average daily simulated SSC for a 3-day window surrounding the date of the observed sampling was also included in the plot. In addition, the maximum and minimum simulated daily SSC concentrations during that 3-day window are shown. Figure D-6 shows all the observed SSC data points were captured within the 3-day sediment windows by the model for reach 10.

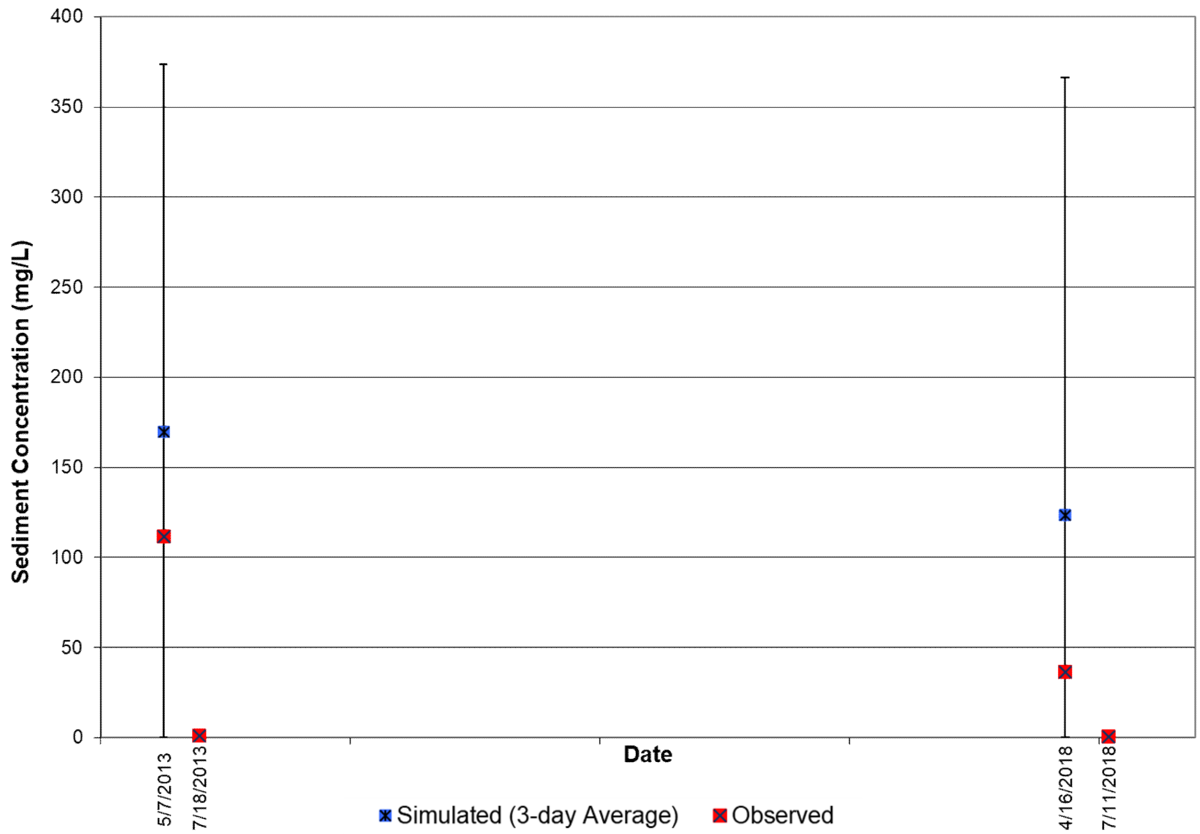

Figure D-6. Three-day window plot for sediment concentration showing the 3 and 5-day average, maximum minimum, and observed values at station 3-JOA000.80 (Mountain Run sub watershed reach 10).

Figure D-7 illustrates another comparison of daily average simulated and observed SSC. Both were plotted on the same graph with the daily average simulated flow for subwatershed reach 1 on a secondary axis. The flow and SSC time series have been scaled along the y-axis to emphasize the magnitude of simulated SSC fluctuations and to better illustrate observed SSC and simulated SSC. This time series plot is representative of the results from the other Mountain Run subwatershed reaches and water quality stations. This graph shows that increases in simulated flow resulted in increases in simulated sediment concentration. It also shows that high and low observed SSC values were predicted by the simulated SSC.

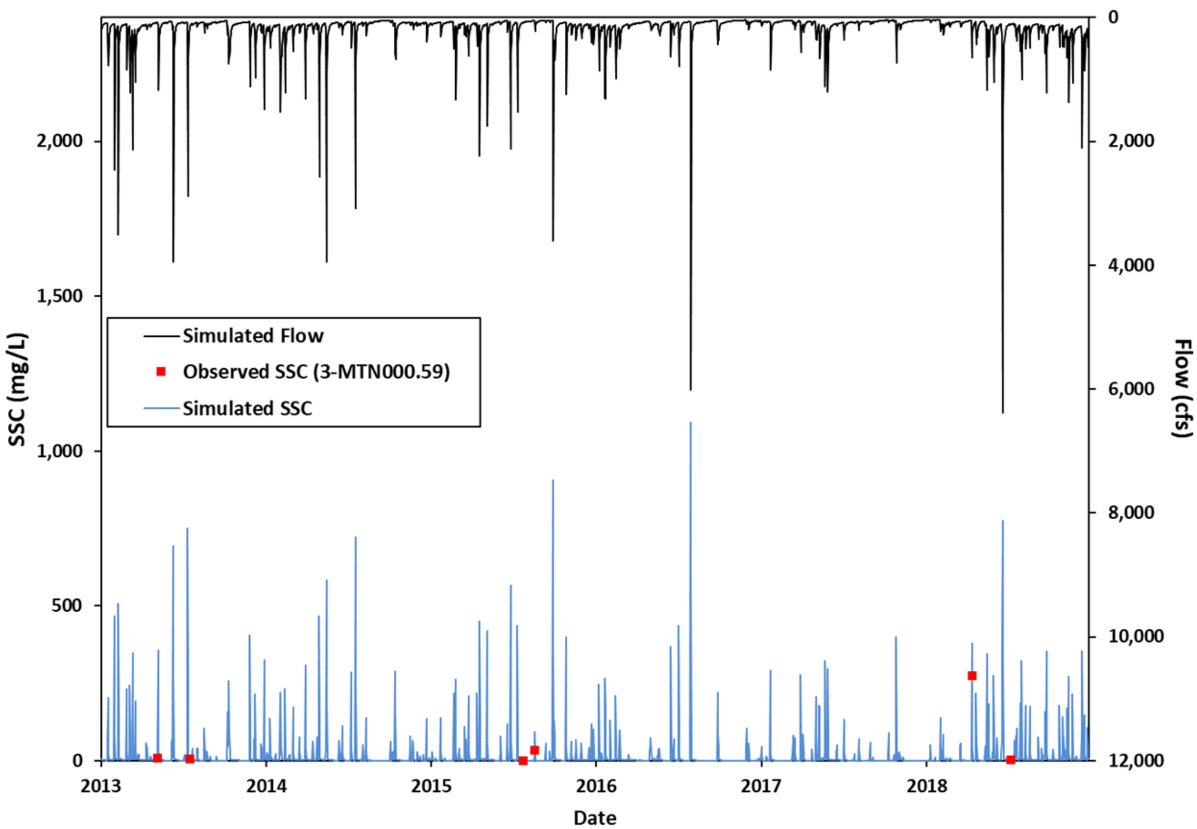

Figure D-7. Comparison of observed SSC, simulated SSC, and simulated flow for subwatershed reach 1 in Mountain Run.

Three- and Five-day Windows Quantitative Model Performance Assessment

Table D-3 includes the results of the 3- and 5-day windows calibration sufficiency analysis which was calculated for all observed SSC data in the Mountain Run calibration segment. Three- and 5-day windows were only calculated around the days on which observed data are available. The 70% of observed data within the 5-day window meets the published 70% criteria that has been used for sparse data bacteria model calibration applications (Kim *et al.*, 2007), and the 70% of the observed data within the 3-day window is greater than the desired 50% discussed earlier the model. Also, the model fairly predicted both lower and higher values without bias. Despite the sparsity of the observed data, the results of the calibration window analysis indicate that the model is sufficiently well calibrated. The final calibrated sediment parameters for the Phase II calibration can be found in Table D-4.

Table D-3. Three- and five-day window calibration statistics for the Mountain Run Phase II Calibration.

Statistics	Value
Number of Observed Data Points	64
Percentage within 3-day window	70%
Percentage above 3-day maximum	16%
Percentage below 3-day minimum	14%
Percentage within 5-day window	70%
Percentage above 5-day maximum	16%
Percentage below 5-day minimum	14%

Table D-4. Final calibrated parameters for the Mountain Run Phase II Calibration.

Parameter	Definition	FUNCTION OF…	Units	FINAL CALIBRATION	POSSIBLE RANGE OF VALUES‡	CALCULATION METHOD‡
RCHRES[a]						
SANDFG (Sand Parameter Flags)						
SDFG	Indicates method used for Sandload Simulation	Type of stream; user experience	none	3	1 - 3	Constant, Power Function Method
SED-GENPARM (General Parameters)						
BEDWID	Width of cross-section over which HSPF will assume bed sediment is deposited	Reach \ Waterbody morphology	ft	60	5 - 1000	Estimated from terrain GIS analysis
BEDWRN	Bed depth which, if exceeded (i.e., through deposition) will cause a warning message to be printed	Reach \ Waterbody morphology, User needs	ft	20.5	0.5 - 20	Estimated from terrain GIS analysis and Knowledge of Stream
POR	Porosity of the bed (volume voids/total volume)	Reach \ Sediment Bed Characteristics	none	0.5	0.25 - 0.9	Based on Technical Note Recommended Values
SAND-PM (Sand Parameters)						
D	Effective diameter of the transported sand particles	Sediment properties	in	0.01	0.0005 - 0.2	Based on Tech. Note Recommended Values
W	Fall velocity of transported sand particles in still water	Particle diameter and density	in/sec	0.2	0.1 - 10	" "
RHO	Density of sand particles	Sediment properties	g/cm^3	2.5	1.5 - 3.0	" "
KSAND	Coefficient in sandload power function formula	Sand properties and hydraulics	complex	0.01	0.001 - 10	Estimated from Recommended Values, **Calibrated in HSPF**
EXPSND	Exponent in sandload power function formula	Sand properties and hydraulics	complex	1.0	1.0 - 6.0	Estimated from Recommended Values, **Calibrated in HSPF**
SILT-CLAY-PM (Silt Parameters)						
D	Effective diameter of silt particles	Sediment properties	in	0.0006	0.0001 - 0.004	Based on Tech. Note Recommended Values
W	Fall velocity of transported silt particles in still water	Particle diameter and density	in/sec	0.0005 - 0.0500[b]	0.0 - 0.1	" "
RHO	Density of silt particles	Sediment properties	g/cm^3	2.3	1.5 - 3.0	" "
TAUCD	Critical bed shear stress for deposition	Silt properties and hydraulics	lb/ft^2	0.009 - 0.152[b]	0.001 - 1.0	Estimated from Initial Run, **Calibrated in HSPF**
TAUCS	Critical bed shear stress for scour	Silt properties and hydraulics	lb/ft^2	0.023 - 0.299[b]	0.01 - 3.0	Estimated from Initial Run,

Parameter	Definition	FUNCTION OF…	Units	FINAL CALIBRATION	POSSIBLE RANGE OF VALUES‡	CALCULATION METHOD‡
						Calibrated in HSPF
M	Erodibility coefficient	Silt properties and hydraulics	lb/ft^2-d	0.001 - 0.300	0.001 - 5.0	Estimated from Recommended Values, **Calibrated in HSPF**
SILT-CLAY-PM (Clay Parameters)						
D	Effective diameter of clay particles	Sediment properties	in	0.0001	0.000005 - 0.00025	Based on Tech. Note Recommended Values
W	Fall velocity of transported clay particles in still water	Particle diameter and density	in/sec	0.00005-0.00050	0.0 - 0.1	" "
RHO	Density of clay particles	Sediment properties	g/cm^3	2.0	1.5 - 3.0	" "
TAUCD	Critical bed shear stress for deposition	Clay properties and hydraulics	lb/ft^2	0.006 - 0.125[b]	0.001 - 1.0	Estimated from Initial Run, **Calibrated in HSPF**
TAUCS	Critical bed shear stress for scour	Clay properties and hydraulics	lb/ft^2	0.021 - 0.260[b]	0.01 - 3.0	Estimated from Initial Run, **Calibrated in HSPF**
M	Erodibility coefficient	Clay properties and hydraulics	lb/ft^2-d	0.001-0.300	0.001 - 5.0	Estimated from Recommended Values, **Calibrated in HSPF**
SSED-INIT	Initial concentrations of suspended sediment	Reach	mg/L	2 sand; 2 silt; 2 clay	n/a	Estimated
BED-INIT	Initial content of bed sediment	Sediment Bed Characteristics	pct.	15% sand; 65% silt; 20% clay	n/a	Estimated

‡ Acquired from EPA BASINS Technical Note 8 (2006)
[a] Main stem of stream in each subwatershed
[b] Varies with subwatershed reach (data available upon request)

Calibration Summary

Using a "weight-of-evidence" approach presented here, the conclusion is that the Mountain Run HSPF sediment model is sufficiently well calibrated to adequately simulate sediment loads in this model calibration. SSC-flow time series plots for all Mountain Run SSC stations can be provided upon request.

D.3 References

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Appendix E: PCB Calibration for Mountain Run

The final phase of the Mountain Run PCB TMDL model calibration focused on modeling the fate and transport of polychlorinated biphenyls (PCB) throughout the study area. The PCB model includes the previously developed hydrology and sediment transport models of Mountain Run. PCBs in the Mountain Run study area were simulated as water quality constituents that existed in "dissolved"[4] and sediment-associated states.

E.1 Calibration Methodology

The Mountain Run watershed was calibrated for reaches with observed PCB concentration data. The simulated, dissolved PCB concentrations were calibrated against observed water column PCB samples. PCB sources in the Mountain Run watershed included washoff loading from known contaminated sites (e.g., spills, railyards), unregulated surface sources (the sum of net atmospheric deposition to land surfaces, loads from small tributaries that are not explicitly specified in the model, unregulated stormwater runoff, loads from unidentified contaminated sites, and unspecified point source discharges), atmospheric deposition to water surfaces, and legacy instream sediment-associated PCBs (i.e., streambed sediment). The PCB model calibration was an iterative process in which calibration parameters were adjusted, the model was executed, and the outputs were assessed using graphical and quantitative analyses. This series of steps was repeated until an acceptable model calibration was achieved.

E.1.1 Calibration Parameters

The HSPF parameters and inputs that were used in the PCB calibration are described below. Calibration parameters included loading rates from pollutant sources and PCB-sediment association variables. Initial estimates for parameters were calculated from the best available observed data. Calibration decisions for each parameter are specified in the following parameter descriptions.

[4] PCBs are hydrophobic and do not quickly break down in water. It is assumed that "dissolved" PCBs are those PCBs freely available in the water column and not associated with sediment.

Atmospheric Deposition Rate on Water Surface, MONTH-DATA (pg/ac/month)

For the Mountain Run PCB TMDL, atmospheric deposition was applied or “input” into the model differently on water and land surfaces. Due to the limitations of HSPF, atmospheric deposition is modeled as a dissolved pollutant. Thus, an atmospheric deposition pollutant input, as defined by the model, cannot be sediment-associated. Modeling PCB atmospheric deposition applied to water surfaces as a “dissolved” constituent is appropriate. However, BSE believes that it is more reasonable and defensible to treat PCB atmospheric deposition on the land surface as a sediment-associated pollutant, and is discussed further in the next subsection. As a result, PCB atmospheric deposition to water surfaces was quantified using the MONTH-DATA parameter, which applied a PCB atmospheric deposition rate to only the water surface.

The MONTH-DATA parameter was used to apply a constant rate of dissolved PCBs to the surface of all stream/river reaches and reservoirs. The deposition rate uses units of pg/acre/month which was then subdivided by HSPF into the user-selected time step units (hours). This method is similar to that used in previous Virginia PCB TMDLs. In the New River (2018), Roanoke River (2009) and Levisa Fork (2011) PCB TMDLs, monthly atmospheric deposition was applied only to reaches and reservoirs.

During calibration of the Mountain Run PCB model an initial PCB atmospheric deposition rate of 5.4×10^8 pg/ac/month was used. However, this value resulted in simulated instream PCB concentrations at low flows that were greater than the available, observed data. The developers of the Roanoke River and New River PCB TMDLs found similar issues when using the PCB atmospheric deposition rate reported in the 1999 Chesapeake Bay Program (CBP) report (CBP, 1999). The Roanoke River and New River PCB TMDL reports note that high instream PCB concentrations were simulated at low flows which was attributed to PCB atmospheric deposition. Based on the Mountain Run modeling results and the results reported in the Roanoke River and New River PCB TMDLs, BSE elected to use the PCB atmospheric deposition rate of 3.0×10^6 pg/ac/month that was used in the New River PCB TMDLs.

Research has shown that PCB atmospheric deposition can increase by near-field land use such as urban development, manufacturing facilities, or contaminated sites (Totten *et al.*, 2006). However, the data needed to discretely apply varying atmospheric deposition rates within the Mountain Run watershed were not available. The Mountain Run PCB TMDL model applies the PCB atmospheric deposition to the water surface at a constant rate that does not fluctuate during the year.

Washoff Potency Factor, POTFW (pg/ton)

The washoff potency factor (POTFW) parameter determines the PCB loading from the land surface during precipitation events. It is used when the water quality constituent of interest, such as PCBs, is sediment-associated. The POTFW value determines the mass of PCBs (pg) that are washed from the land surface per ton of simulated sediment loss. Higher POTFW values simulate greater PCB loads entering a stream as sediment is detached from the land surface.

For the Mountain Run PCB model, the magnitude of the POTFW varied depending on the land use category. For land use categories other than commercial (forest, agricultural, residential), and not part of a known contaminated site area, a POTFW value of 2.39 x 10^{09} pg/ton was used to account for loads from unregulated surface sources. The POTFW for commercial land use was used as a primary calibration parameter because of the uncertainty in its value. POTFW values for commercial land use ranged from 2.76 x 10^{11} to 2.21 x 10^{13} pg/ton.

Known contaminated sites include active and inactive manufacturing facilities, railyard and railway spurs, and electrical transformer pads, and were modeled as discrete land parcels. Known contaminated sites retained the same hydrologic properties as the subwatershed where they were located, but they were assigned different water quality parameters. For known contaminated sites, soil sample data collected by DEQ were used to calculate POTFW values. For one specific type of known contaminated site, railyards, the POTFW estimate from the New River and Roanoke River PCB TMDLs (7.02 x 10^{10} pg/ton) was used for Mountain Run because of the proximity and similar history of rail activity within the watersheds. For electrical transformer pads, the POTFW value was estimated as 1.29 x 10^{12} (pg/ton) based on data provided by Dominion Energy and Appalachian Power for previous PCB TMDL studies (ICPRB, 2007; DEQ, 2018).The POTFW values used in the Mountain Run model implicitly include atmospheric deposition of PCBs on the land surface.

PCB Adsorption Coefficient, KD (L/mg)

The adsorption coefficient (KD) is a measure of the tendency for PCBs to adsorb to sediment. HSPF splits KD values into six categories for each reach corresponding to the type of sediment-associated PCBs: 1) suspended sand, 2) silt, and 3) clay in the water column; and 4) sand, 5) silt, and 6) clay on the streambed. KD values were calculated in two stages. In the first stage, an initial KD value was calculated based on a formula that accounts for the proportion of each PCB homolog and organic carbon content. In the second stage, the initial KD values were multiplied by a sediment adjustment factor. This factor adjusted the KD value for each sediment size (sand, silt, and clay) according to the corresponding organic carbon content.

All observed water column samples and some observed sediment PCB samples provided PCB homolog composition data. From this information, initial KD values were calculated using Equation **E-1**.

$$KD = 1 \times 10^{-6} \times f_{oc} \times K_{ow} \qquad \text{Eqn. E-1}$$

Where:

KD = the (initial) adsorption coefficient between the dissolved and sediment-associated states (L/mg)
f_{oc} = weight fraction of the total carbon in the solid matter (gC/g)
K_{ow} = octanol-water partition coefficient (L/kg)

In Equation **E-1**, f_{oc} was derived from observed total organic carbon (TOC) data, and K_{ow} is a coefficient that varies by PCB homolog type as listed in Table E-1 (ICPRB, 2007). For a given observed PCB water quality sample with a distinct distribution of homolog concentrations, a weighted K_{ow} value was calculated by multiplying each homolog concentration by its respective K_{ow_H}, summing, and dividing by the total PCB concentration. The initial estimate for KD was calculated using the weighted K_{ow} and the derived f_{oc}.

Table E-1. Homolog-specific partitioning coefficients.

Homolog	log K_{ow_H}	K_{ow_H} (L/kg)
$K_{ow\_mono+di}$	4.675	47,315
K_{ow_tri}	5.425	266,073
K_{ow_tetra}	6.005	1,011,579
K_{ow_penta}	6.525	3,349,654
K_{ow_hexa}	6.73	5,370,318

Homolog	log K_{ow_H}	K_{ow_H} (L/kg)
K_{ow_hepta}	7.235	17,179,084
K_{ow_octa}	7.6	39,810,717
K_{ow_nona}	7.915	82,224,265
K_{ow_deca}	8.18	151,356,125

Source: ICPRB, 2007.

The second stage of the KD calculation multiplied the initial KD by a sediment adjustment factor since organic carbon content varies by sediment size fraction (Li and Ping, 2014). The results of Li and Ping (2014) showed that organic carbon content attached to clay is 70% greater than on silt, and the quantity of organic carbon content attached to sand is 94.1% less than on silt. Silt was established as the baseline. A sediment adjustment factor of 1 was used for silt KD values. The silt KD values were effectively equal to the initial KD values from the first stage. Sand and clay KD values were then calculated by multiplying by their respective sediment adjustment factors, 1.7 and 0.059 (1 - 0.941).

Suspended sediment KD values were calculated with observed water column samples. Bed sediment KD values were calculated using observed sediment PCB data when available. Since every reach in the Mountain Run watershed did not have its own water quality monitoring station with observed PCB data, KD values were assigned for those reaches with observed PCB data. KD values were calculated from observed data and were not adjusted during the calibration.

Adsorption/Desorption Rate, ADRATE (1/day)

The adsorption/desorption rate (ADRATE) quantifies how quickly PCBs attach and detach from sediment and enter the water column. In HSPF, ADRATE is split into six categories corresponding to the size fraction of sediment-associated PCBs: suspended sand, silt, and clay; and bed sand, silt, and clay. In the Roanoke River PCB TMDL (2009) and New River PCB TMDL (2018), the ADRATE was calculated by first identifying the median representative homolog from the observed water column PCB data. This entailed summing the concentrations of each homolog of all observed water column samples, reordering the homologs from mono to deca, and then determining which homolog was at the median point in the list. The adsorption/desorption rate corresponding to that median homolog was calculated from the rates provided in Schneider (2005).

A similar methodology was used for the Mountain Run model in that the median representative homolog was determined for each reach. The adsorption/desorption rate corresponding to that median homolog was calculated from the rates provided in Schneider (2005). A consistent ADRATE value was used in all reaches within the Mountain Run watershed. Also adhering to the modeling methodology used in the Roanoke River and New River PCB TMDLs, an ADRATE value was only applied to the suspended sediment (sand, silt, and clay). The bed sediment ADRATE value was set to the minimum allowable in HSPF. It was assumed that the adsorption/desorption on the bed sediment was negligible. Similar to KD, the ADRATE value was derived from observed data. As such, once the initial value was calculated, it was not adjusted during calibration. The ADRATE value for suspended sediment in Mountain Run was 0.79 because the median representative homologs for the water column PCB samples in the calibration segments were pentachlorobiphenyl homologs.

Initial Concentration of PCBs on Sediment, SEDCONC (pg/mg)

The initial concentration of PCBs on sediment is a measure of the mass of sediment-associated PCBs (pg) per unit mass of sediment (mg). Similar to KD and ADRATE, SEDCONC is also split into six categories for each reach corresponding to sediment size fraction: suspended sand, silt, and clay; and bed sand, silt, and clay. Compared to water column PCB observed data, there were few, recent observed data on sediment-associated PCB concentrations. The available observed data were used as the initial estimates of SEDCONC. During calibration, it was found that low concentrations of SEDCONC (<5 pg/mg) had little impact on the dissolved PCB concentrations. However, when increased into the range of >40 pg/mg, SEDCONC increased the PCB concentrations during low flow conditions.

Adhering to the modeling methodology used in the Roanoke River and New River PCB TMDLs, SEDCONC values were only applied on the bed sediment silt and clay. It was assumed that the initial concentration of sediment-associated PCBs on suspended sediment and bed sand was negligible. The bed sediment SEDCONC values were adjusted during the calibration process and range from 7 – 63 pg/mg depending on the stream segment.

E.1.2 Calibration Analysis

The analysis of each calibration run involved a series of assessments both graphical and quantitative. The simulated dissolved PCB concentrations output at the end of each model run were compared against the observed water column PCB samples. The number of calibration water quality stations and the number of total observed water column PCB samples are shown in Table E-2. A total of 62 observed water column PCB samples were available in the Mountain Run study area. All of these data were reviewed/considered when developing the Mountain Run PCB model. However, one station had repeated PCB observations for the same date, thus, for the purposes of model calibration, an average of samples collected on the same day was used for model calibration.

Model performance was assessed using a “weight-of-evidence” approach. The calibration process focused on subwatershed reaches where observed data were available, and the model was evaluated based on knowledge of the study area. Similar to the sediment model calibration, a graphical analysis was used to compare the simulated and observed data. Additionally, a quantitative analysis was used to assess how well the model output compared with the observed data.

PCB Concentration Time Series Graphs

Two PCB concentration time series graphs were generated for each subwatershed reach with observed PCB water quality data. Both graphs include simulated average daily and observed PCB concentrations on the primary y-axis, and date (from 1/1/2013 to 1/1/2019) on the x-axis, while one graph plots observed daily rainfall and the other plots simulated average flow rate on a secondary, inverted y-axis. The time series graphs are used to show how simulated PCB concentrations respond to fluctuations in observed rainfall and simulated flow, and demonstrate the ability of the model to simulate PCB concentrations comparable to observed PCB concentrations.

Table E-2. Mountain Run calibration and number of water column PCB water quality stations used in the calibration with observed PCB data

DEQ Monitoring Station	Subwatershed Reach	No. of Observed PCB Data Samples
3-MTN000.59	1	6
3-MTN005.79	4	7
3-FLA001.93	6	2
3-MTN010.98	8	3
3-MTN012.04	8	2
3-JOA000.80	10	4
3-MTN014.88	15	8
3-MTN019.75	16	2
3-XEH000.10	17	1
3-MTN021.11	18	4
3-XBE000.19	19	3
3-MTN021.75	20&21	1
3-MTN022.01	20&21	5
3-HID000.22	20	3
3-MTN022.20	21	2
3-BLS000.08	22	4
3-MTN022.49	24	2
3-XIH000.03`	25	1
3-XIH000.06	25	3
3-UTMTNWhPipe	25	1
3-MTN023.88	27	4
Total	**21**	**68**

Five-Day Calibration Window Assessments

Five-day calibration window metrics were used as a quantitative method of analyzing model performance. These metrics were instrumental in analyzing model performance for the calibration segments since Mountain Run does not have any active USGS flow gages. Each 5-day window consists of the date of each observed PCB sample, two days before the sample, and two days after the sample. The simulated daily PCB concentration outputs during those 5 days are used to identify the hourly maximum and minimum PCB concentrations within the 5-day window. If the observed PCB value falls between the minimum and maximum simulated values, then that data point was considered to be “within” the window. If the observed PCB value was less than the minimum value, then it was considered to be “below” the calibration window. If the data point was greater than the maximum, then it was considered to be “above” the calibration window. It should be emphasized that 5-day windows were only generated around the date and time when each observed PCB sample was collected.

Kim *et al.* (2007) justified the use of a 5-day window to assess model performance for developing bacterial TMDLs in watersheds with limited observed data. They stated that the goal of the calibration was to achieve at least 70% observed data points within the 5-day window. Additionally, in order to avoid model bias, the fraction of data points above and below the window (if any) should be roughly equal. BSE believes the use of a 5-day calibration window is effective for assessing PCB model performance. While Kim et al. (2007) recommended a “70% within” threshold 5-day window value for bacteria modeling, because PCB modeling is more complex than bacteria modeling (i.e., PCB modeling is also dependent on modeling sediment while bacteria is not) a threshold of “50% within” the window is considered to be reasonable for assessing PCB model performance.

The 5-day calibration window “within”, “below”, and “above” statistics were calculated once per model run using the observed PCB data from all calibration water quality stations within a given calibration segment. The statistics were examined after each run as an indicator to determine model calibration sufficiency. The Mountain Run PCB model calibration 5-day window analysis summary includes a box-and-whisker graph and table. Together, the flow-PCB concentration comparison, time series graphs, and 5-day window analysis constituted the “weight-of-evidence” approach used to evaluate PCB calibration sufficiency for the HSPF Mountain Run PCB TMDL model.

E.2 Mountain Run Calibration

This section presents the HSPF PCB calibration for the Mountain Run calibration. The calibration results are summarized in tabular format for the entire calibration segment and graphed for a representative subwatershed reach.

E.2.1 PCB Calibration

PCB model calibration was an iterative process in which adjustments were made to the calibration parameters. After executing the model, the results were analyzed, and the parameters were adjusted again. The results of the model were analyzed using the “weight-of-evidence” metrics discussed previously. It should be reiterated that an observed flow-PCB concentration graphical comparison could not be completed for Mountain Run due to the lack of observed flow data.

PCB Concentration Time Series Graphs

Figure E-1 and Figure E-2 illustrate the comparison of daily average simulated PCB concentrations and observed water column PCB concentrations for subwatershed reach 1 (outlet) of Mountain Run. These graphs show that the simulated PCB concentration responded to fluctuations in rainfall and simulated flow. During the extreme rainfall and peak flow events, the model also simulated the corresponding response of the watershed to PCB concentrations very well. The graph illustrates that the simulated PCB concentrations followed a pattern of increasing and decreasing similar to the observed data and captured the base PCB, although the model was unable to simulate one peak observed PCB concentrations on the exact date. Time series graphs for the other Mountain Run water quality calibration stations and their corresponding reaches, as well as the 5-day window plots, can be provided by BSE upon request.

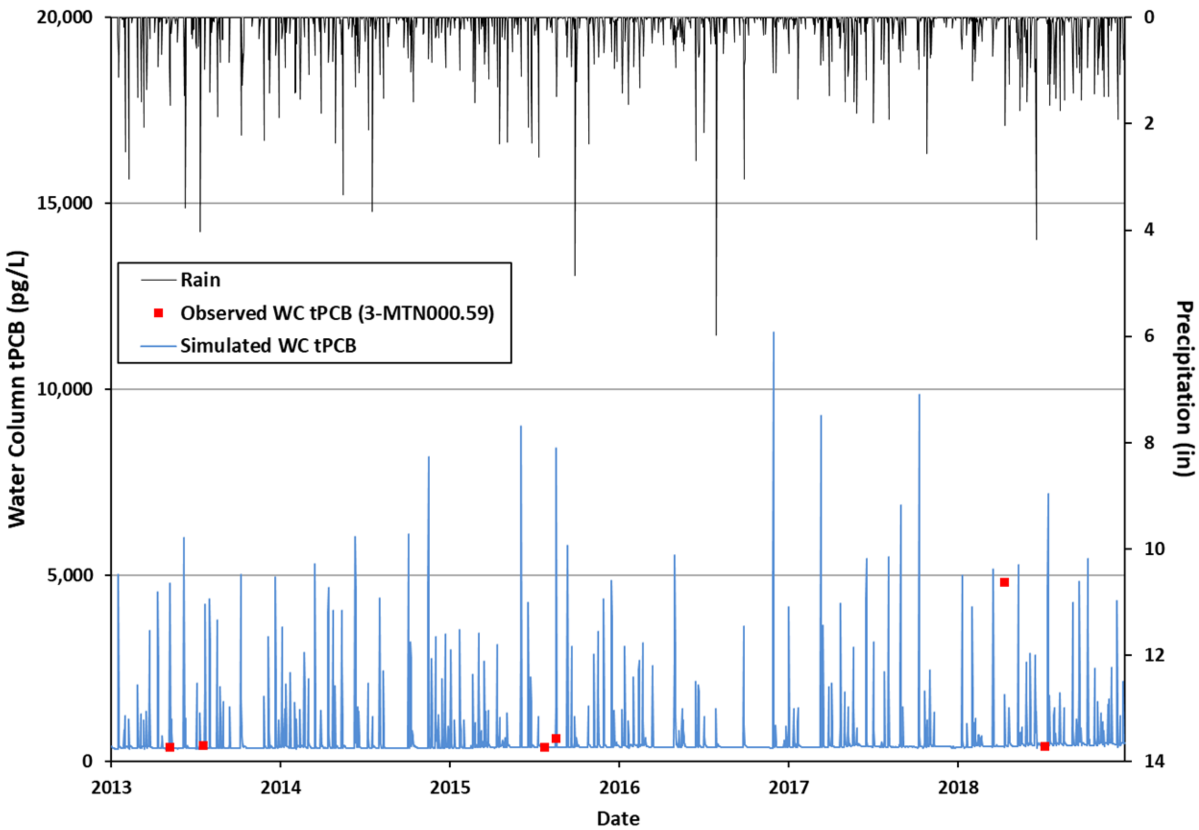

Figure E-1. Comparison of observed water column PCB concentrations, simulated water column PCB concentrations, and observed rainfall for subwatershed reach 1 in Mountain Run.

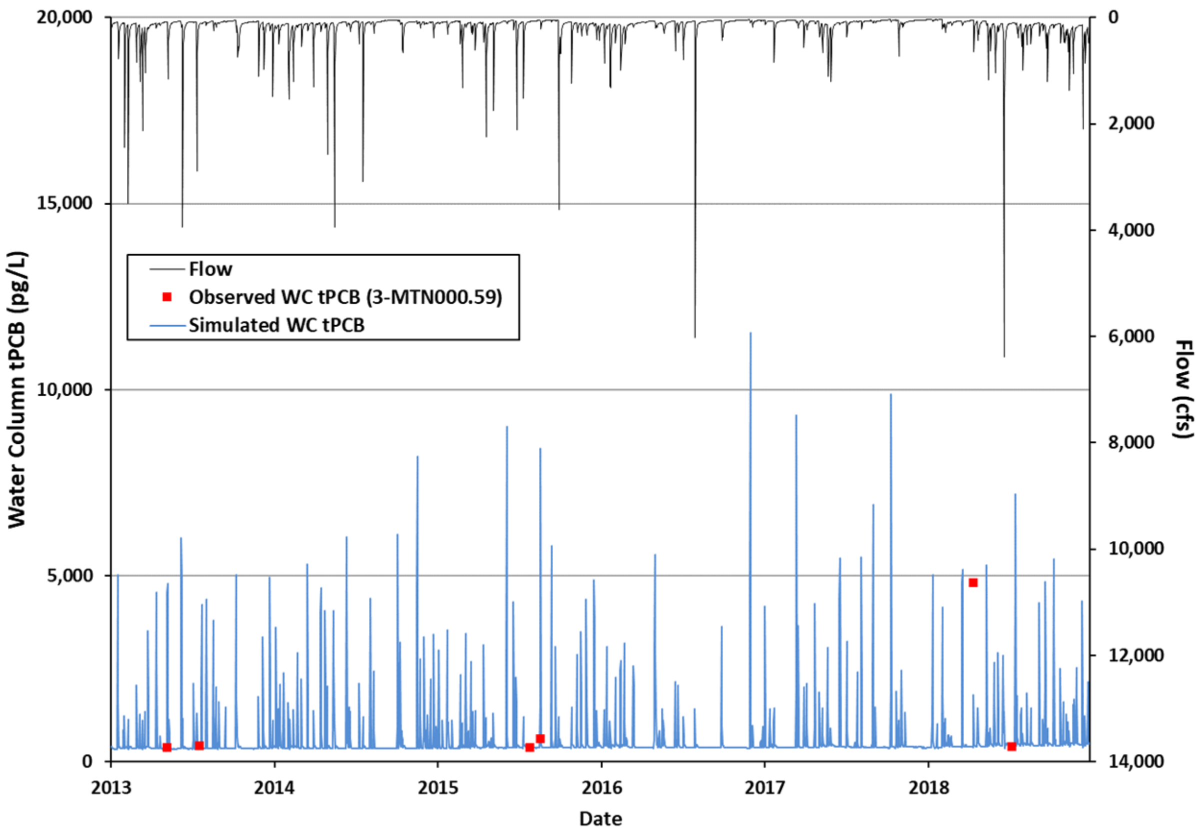

Figure E-2. Comparison of observed water column PCB concentrations, simulated water column PCB concentrations, and simulated flow for subwatershed reach 1 in Mountain Run.

Five-day Window Performance Assessment

Figure E-3 shows the 5-day windows and observed data for Mountain Run subwatershed reach 1, which is located at the outlet of the watershed. Although the Mountain Run simulated 5-day averages missed some PCB peaks of some reaches compared to the observed water column PCB concentrations, the results show a good fit between the simulated and observed data. The 5-day window plots for the other Mountain Run water quality calibration stations can be provided upon request. Table E-3 includes the results of the 5-day window calibration analysis for all Mountain Run calibration reaches. Results show that across all stations, eighty-one percent (81%) of the observed data were within a 5-day window, exceeding the 50% calibration threshold goal. Also, 14% and 5% of the data were above and below the 5-day windows respectively, indicating that the model has a slight bias to higher values. In summary, based on 5-day window metrics and plots of PCB concentration against flow and rainfall, BSE believes that the

Mountain Run PCB model is sufficiently calibrated to simulate water column PCB concentrations in Mountain Run.

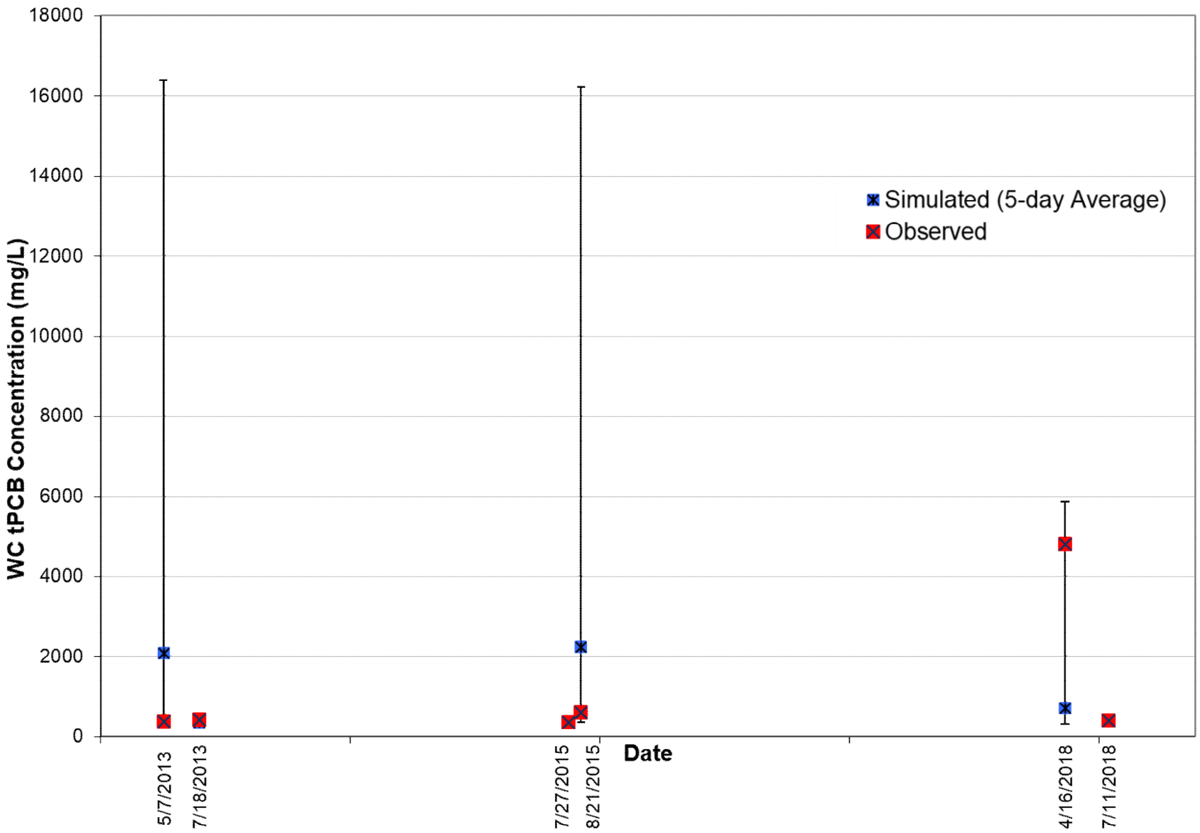

Figure E-3. Five-day window plots for water column PCB concentrations showing the 5-day average, max, and min, and observed values at station 3-MTN000.59 (Mountain Run subwatershed reach 1) where A: 5/7/2013; B: 7/18/2013; C: 7/27/2015; D: 8/21/2015; E: 4/16/2018; F: 7/11/2018 represents dates when PCB samples were taken.

Table E-3. Simulated water column PCB concentrations (pg/L) 5-day calibration windows and observed PCB concentrations (pg/L) for Mountain Run and observed/simulated flow regime comparison.

Sub-watershed	Date	Station	Observed Water Column PCB	Simulated 5-Day Average	Simulated 5-Day Max.	Simulated 5-Day Min.
1	5/7/2013	3-MTN000.59	377	2,079	16,387	308
1	7/18/2013	3-MTN000.59	426	368	416	345
1	7/27/2015	3-MTN000.59	372	371	378	365
1	8/21/2015	3-MTN000.59	610	2,241	16,224	360
1	4/16/2018	3-MTN000.59	4,815	724	5,867	326
1	7/11/2018	3-MTN000.59	409	416	426	407
4	5/7/2013	3-MTN005.79	265	1,301	16,055	204
4	7/18/2013	3-MTN005.79	369	360	394	302
4	7/18/2013	3-MTN005.79	369	372	394	335
4	7/27/2015	3-MTN005.79	417	416	423	407
4	8/21/2015	3-MTN005.79	1,311	1,341	9,054	349
4	4/16/2018	3-MTN005.79	3,497	584	6,517	264
4	7/11/2018	3-MTN005.79	288	491	505	484
6	5/7/2013	3-FLA001.93	72	124	721	3
6	7/18/2013	3-FLA001.93	104	100	123	90
8	4/16/2018	3-MTN010.98	2,681	2,566	29,815	755
8	7/11/2018	3-MTN010.98	1,962	1,959	2,122	1,758
10	5/7/2013	3-JOA000.80	102	346	8,181	5
10	7/18/2013	3-JOA000.80	122	35	37	32
10	4/16/2018	3-JOA000.80	204	83	2,659	15
10	7/11/2018	3-JOA000.80	40	40	40	39
15	5/7/2013	3-MTN014.88	1,921	4,203	123,771	60
15	7/18/2013	3-MTN014.88	618	467	559	376
15	7/2/2014	3-MTN014.88	640	636	666	612
15	8/12/2014	3-MTN014.88	469	1,088	30,636	288
15	7/27/2015	3-MTN014.88	571	630	660	601
15	8/21/2015	3-MTN014.88	938	6,057	290,076	276
15	4/16/2018	3-MTN014.88	2,817	1,053	29,102	132
15	7/11/2018	3-MTN014.88	621	528	561	498
16	7/2/2014	3-MTN019.75	351	350	358	340
16	8/12/2014	3-MTN019.75	1,618	652	18,120	132
17	9/30/2015	3-XEH000.10	137	30	1,553	2
18	7/2/2014	3-MTN021.11	625	355	371	342
18	8/12/2014	3-MTN021.11	8,356	2,226	112,648	124
18	7/27/2015	3-MTN021.11	368	367	386	349
18	9/30/2015	3-MTN021.11	818	2,250	116,345	9
19	9/30/2015	3-XBE000.19	1,052	1,241	34,783	126

Sub-watershed	Date	Station	Observed Water Column PCB	Simulated 5-Day Average	Simulated 5-Day Max.	Simulated 5-Day Min.
19	4/16/2018	3-XBE000.19	1,327	1,589	34,802	657
19	7/11/2018	3-XBE000.19	722	720	731	712
20&21	7/2/2014	3-MTN022.01	385	446	504	407
20&21	8/12/2014	3-MTN022.01	2854	1,010	34,341	105
20&21	8/12/2014	3-MTN022.01	3434	983	34,341	105
20&21	7/27/2015	3-MTN022.01	410	446	503	398
20&21	9/30/2015	3-MTN022.01	496	1,109	51,638	20
20	9/30/2015	3-HID000.22	204	61	2,147	10
20	4/16/2018	3-HID000.22	207	80	2,350	34
20	7/11/2018	3-HID000.22	495	36	37	36
21	4/16/2018	3-MTN022.20	356	1,679	58,180	71
21	7/11/2018	3-MTN022.20	437	442	484	402
22	9/30/2015	3-BLS000.08	227	191	758	73
22	9/30/2015	3-BLS000.08	207	171	758	73
22	4/16/2018	3-BLS000.08	159	183	582	109
22	7/11/2018	3-BLS000.08	166	164	176	155
24	7/2/2014	3-MTN022.49	326	316	361	285
24	8/12/2014	3-MTN022.49	1,718	563	20,166	37
25	9/30/2015	3-XIH000.06	830	505	24,019	71
25	4/16/2018	3-XIH000.06	334	673	31,762	96
25	7/11/2018	3-XIH000.06	3,088	99	99	98
27	5/7/2013	3-MTN023.88	76	104	403	8
27	7/18/2013	3-MTN023.88	101	99	130	66
27	4/16/2018	3-MTN023.88	102	145	373	9
27	7/11/2018	3-MTN023.88	122	110	121	101
				Within 5-Day Range	**Above 5-Day Range**	**Below 5-Day Range**
			PERCENT	81%	14%	5%

E.2.2 Calibration Summary

The "weight-of-evidence" approach used for calibration sufficiency assessment included PCB concentration time series graphs and the 5-day calibration window assessment. Based on the evidence from these analyses, BSE concludes that the Mountain Run HSPF PCB model was sufficiently well calibrated to adequately simulate in-stream PCB concentrations. The PCB calibration parameters are shown in Table E-4.

Table E-4. Final calibrated parameters for the Mountain Run PCB Calibration.

Parameter	Definition	Units	FINAL CALIBRATION VALUE	POSSIBLE RANGE OF VALUES‡	CALCULATION METHOD‡
PERLND/IMPLND[a]					
QUAL-INPUT (Nonseasonal Sediment-Associated Quality Constituent Parameters)					
POTFW[b]	Washoff potency factor (unregulated surface sources[1])	pg/ton	2.39E+09 – 2.21E+13	0.0 - Inf.	Estimated from contaminated sites, **Calibrated**
POTFW[b]	Washoff potency factor (contaminated sites)	pg/ton	7.02E+10 – 3.03E+13	0.0 - Inf.	Approximated from previous TMDLs[c], Estimated from observed sampling data
RCHRES[e]					
GQ-KD (Adsorption Coefficients of PCB Quality Constituent)					
ADPM1-ADPM3	Adsorption coefficients for suspended sediment	L/mg	Sand: 0.0004 – 0.2266; Silt: 0.0059 – 3.8418; Clay: 0.0100 – 6.5310	1.0E-10 - Inf.	Derived from observed water column samples with PCB homolog and TOC data
ADPM4-ADPM6	Adsorption coefficients for bed sediment	L/mg	Sand: 0.0003 -0.1815, Silt: 0.0055 – 3.0768; Clay: 0.0094– 5.2306	1.0E-10 - Inf.	Derived from observed sediment samples with PCB homolog and TOC data
GQ-ADRATE (Adsorption/Desorption Rate Parameters)					
ADPM1-ADPM3	Adsorption/desorption rates for suspended sediment	1/day	0.79	1.0E-05 - Inf.	Derived from observed water column samples with PCB homolog data, Applied to entire calibration segment
ADPM4-ADPM6	Adsorption/desorption rates for bed sediment	1/day	1.0E-05	1.0E-05 - Inf.	Assumed approx. zero as in previous TMDLs[c]
GQ-SEDCONC (Initial PCB Concentrations on Sediment)					
ADPM1-ADPM4	Initial PCB concentrations on suspended sediment	pg/mg	0.0	0.0 - Inf.	Assumed zero as in previous TMDLs[c]
ADPM5-ADPM6	Initial PCB concentrations on bed sediment	pg/mg	7.08 – 63.14[f]	0.0 - Inf.	Estimated in observed sediment sample data, **Calibrated**
MONTH-DATA	PCB atmospheric deposition rate on water surface	pg/ac/mo-nth	3.0E+06	N/A	Approximated from New River PCB TMDL[c]

‡ Acquired from HSPF Version 12.2 User's Manual
[1] Unregulated surface sources represent the sum of net atmospheric deposition to land surfaces, loads from small tributaries that are not specified in the model, unregulated stormwater runoff, loads from unidentified contaminated sites, and unspecified point source discharges
[a] Pervious and Impervious land segment
[b] Includes the atmospheric deposition on the land surface
[c] DEQ, 2009. Roanoke River PCB TMDL., 2018 New River PCB TMDL
[d] Varies between contaminated sites
[e] Main stem of stream in each subwatershed
[f] Varies by calibration segment reach

Table E-5 provides an estimate of the contributions from the different source categories to the annual PCB loading (mg/yr) in the stream. These contributions include loadings to unregulated land surface (atmospheric deposition, unregulated stormwater runoff, loads from unidentified contaminated sites, and unspecified point source discharges), contaminated sites, direct loading to the stream (atmospheric deposition to water surfaces and permitted sources), and instream contaminated streambed sediment.

Table E-5 does not identify which source categories contribute the most to the simulated instream PCB concentrations. The 'percent of total load' column illustrates the portion of the PCB load (mg) that originates from a particular PCB source, but it does not describe the fate of the PCBs once they enter the stream/river reach.

Table E-5. Estimated annual source PCB loads for Mountain Run during the allocation period (2008).

Source	Estimated Load (mg/yr)	Percent of total load (%)
Streambed Sediment	28,899	28
Atmospheric Deposition	<1	<1
Known Contaminated Sites	7,812	7
Permitted	289	<1
Surface Load - Unregulated[1]	67,793	65
Total	104,793	–

[1] Unregulated surface sources represent the sum of net atmospheric deposition to land surfaces, loads from small tributaries that are not specified in the model, unregulated stormwater runoff, loads from unidentified contaminated sites, and unspecified point source discharges

Table E-6 shows the magnitude of the instream PCB concentration (pg/L) caused by each PCB source and its relative contribution. Inputs from instream bed sediment (i.e., legacy sources) are the primary contributors to instream PCB concentrations. The second most prominent source are surface loads including atmospheric deposition to land surfaces, unregulated stormwater runoff, loads from unidentified contaminated sites, and unspecified point source discharges.

Table E-6. Estimated relative contributions of different PCB sources to the overall tPCB concentration at the Mountain Run outlet during the allocation period (2008).

Source	Mean Daily Water Column tPCB Concentrations by Source (pg/L)	Relative Contribution by Source (%)
All	669	–
Streambed Sediment	262	39
Atmospheric Deposition	<1	<1
Known Contaminated Sites	23	3
Permitted	2	<1
Surface Load - Unregulated[1]	382	57

[1] Unregulated surface sources represent the sum of net atmospheric deposition to land surfaces, loads from small tributaries that are not specified in the model, unregulated stormwater runoff, loads from unidentified contaminated sites, and unspecified point source discharges.

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