

CSSAB PFAS Workgroup Update

**Presented at the
October 21, 2026
CSSAB Meeting**

Presented by CSSAB PFAS Workgroup Members
Colleen Costello, PG – CCC, LLC
Kevin Long - Terraphase

For Discussion Purposes at the October 21, 2026 CSSAB Meeting

Outline

- CSSAB Workgroup and Summary of Recent Activities
- Update from Modeling Subgroup
 - PFAS Input terms
 - Geologic Input Terms
- Next Steps
 - Sensitivity Analysis
 - Preparation of White Paper

For Discussion Purposes at the October 21, 2026 CSSAB Meeting

DISCLAIMER: The information in this presentation is for discussion purposes only. Calculations, formulas, and numeric values are illustrative only; they currently are being reviewed and discussed within the CSSAB PFAS Workgroup, and presentation of such information at this time is not an endorsement of its use.

PFAS CSSAB Workgroup Activities & Members

Workgroup Activities

- **CSSAB PFAS Workgroup** – Meets to review and discuss progress of subgroups.
- **Subgroup 1** – Defining the challenge of PFAS fate and transport in Act 2 process. Core group of text reviewers for other sections of White Paper.
- **Subgroup 2 & 3**- Completed summary of what other states/EPA/DOD doing, current Guidance and Current Research. Summary tables to be included as attachments to White Paper.
- **Subgroup 4** - Resource for other subgroups on PFAS fate and transport technical topics.
- **Subgroup 5** – Identified potential generic soil to groundwater equation modifications for PFAS and other Act 2 F&T models.
 - PFAS input parameters team
 - Geologic input parameters team
- **Subgroup 6** – Supporting items relating to PFAS fate and transport (PFAS sources, background and Site Conceptual Model).

Current Workgroup Members

Kevin Long, Terraphase	Harrison Roakes, Sanborn Head
Emily Strake, Blue Stone Env.	Andrew Furman, PADEP
Mike Penzone, DNREC	Chris Voci, Terraphase
David B. Farrington, Arm Group	Thomas Gluodenis, Lincoln Univ.
Sean Fullmer, Sanborn Head	Chuck Campbell, Leidos
Jishnu Adhikari, TetraTech	Mike Maddigan, PADEP
Will Hitchcock, Manko Gold	Matt Sabetta, PADEP
Michael Nines, Manko Gold	Dennis Low, PADEP
Stephen Zemba, Risk Insight	Pam Trowbridge, PADEP
Brie Sterling, PADEP	Frank Nemec, PADEP
Shay Decker, PADEP	Dana Marshall, PADEP
Aaron Yingling, KU Resources	Dustin Lipik, PADEP
Neil Ketchum, Verdantas	Ray Leese, Langan
Joel Bolstein, Fox Rothschild	Colleen Costello, CCC

PFAS Reviewed by Workgroup

PFBS

HFPO-DA
(GenX)

PFHxS

PFOA

PFNA

PFOS

PFBA

PFHxA

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PFAS-Adapted Soil to Groundwater Equation

As discussed in the July 15, 2026 meeting – $K_{aw}A_{aw}$ is the new term to address the air/water interface proposed to be added to the soil to groundwater equation.

Brusseau and Guo (2023)¹ adapted USEPA SSL equation:

$$C_{soil} = C_{gw} \times \left[K_d + (K_{aw}A_{aw} + \theta_w + \theta_a H) \frac{1}{\rho_b} \right] \times DAF$$
$$C_{soil} = C_{gw} \times [(K_{oc} * f_{oc}) + (K_{aw}A_{aw} + \theta_w)/\rho_b] \times DAF$$

Adapted § 250.308(a)(3) MSC for soil to groundwater:

(Unsaturated) $MSC_S = MSC_{GW} \times [(K_{oc} * f_{oc}) + (K_{aw}A_{aw} + \theta_w)/\rho_b] \times DF$

(Zone of GW saturation) $MSC_S = MSC_{GW} \times [(K_{oc} * f_{oc}) + (K_{aw}A_{aw} + \theta_w)/\rho_b] \times DF/10$

For Discussion Purposes at July 21, 2026 CSSAB Meeting

Adapted Equation Special Data Needs

- K_{oc} - *Organic carbon-water partition coefficient*
 - Chemical-specific
 - Assumed constant for given conditions
 - Already part of existing equation
 - Subgroup evaluated PFAS specific K_{oc} values based on current literature
- K_{aw} - *Air-water interfacial adsorption coefficient*
 - Chemical-specific
 - Assumed constant for given conditions
 - Subgroup evaluated PFAS specific values based on current literature
- A_{aw} - *Air-water interfacial area*
 - Not chemical-specific
 - Assumed constant for given conditions
 - Subgroup evaluated PADEP soil default values as inputs to determine A_{aw}

PFAS Leach Tool

What is PFAS Leach Tool and how is it being used for the Workgroup activities?

The core of PFAS-LEACH-Analytical is a set of analytical solutions that solve the partial differential equations for the leaching of PFAS in the vadose zone (Guo et al., 2022). The vadose-zone analytical solutions are also coupled to a simple groundwater dilution factor model (Smith et al., 2024; USEPA, 1996), which allows for computing PFAS concentration in a receptor well and deriving site-specific soil screening levels (SSLs) for a given acceptable groundwater PFAS concentration².

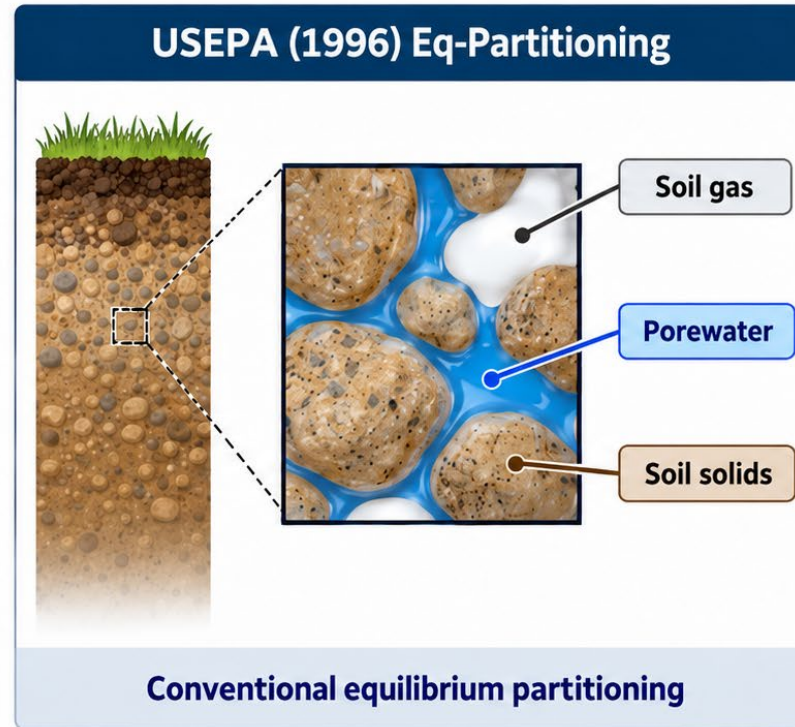


This is the part of the PFAS Leach Tool the Workgroup is using to determine K_{aw} and A_{aw} based on PFAS and PADEP specific input terms

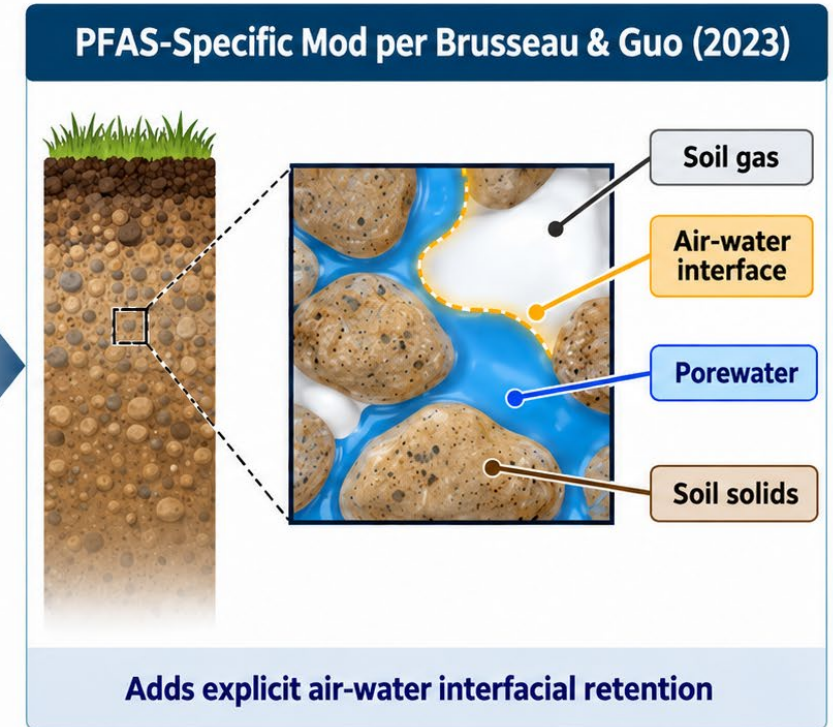
CSSAB PFAS Work Group (Subgroup 5)

Selecting Defensible Parameters for PFAS S-GW Calculation

- EqP accounts for distribution among soil, porewater, and soil gas
- Brusseau and Guo (2023) expanded to account for PFAS adsorption at air-water interface
- Group tasked with identifying representative K_{oc} and K_{aw} values



$$C_{soil} = C_w \times DAF \left[K_{oc}f_{oc} + \frac{\theta_w + \theta_a H'}{\rho_b} \right]$$



$$C_{soil} = C_w \times DAF \left[K_{oc}f_{oc} + \frac{K_{aw}A_{aw} + \theta_w + \theta_a H'}{\rho_b} \right]$$

CSSAB PFAS Work Group (Subgroup 5)

K_{oc}: Structured Evaluation of Published PFAS Partitioning Data

- ITRC-based compilation of values and supplemental sources
- Critical review of underlying information/data
 - Experimental methodology
 - Soil/sediment characteristics
 - Solution chemistry
 - Confounding sorption mechanisms
 - Field vs. laboratory derived
- Selected primary applicable values
- Retained supporting data/values to support uncertainty assessment

Table 1

Organic Carbon-Water Partition Coefficient Values for Select PFAS

Modified from ITRC (2025) PFAS Technical and Regulatory Guidance Document (Table 4-1)

Pennsylvania Cleanup Standards Scientific Advisory Board, PFAS Work Group, Subgroup 5

Chemical Name	Acronym	CASRN	Isomer	LogK _{oc} (± St. Dev.)	Type
Perfluorooctanoic acid	PFOA	335-67-1	Not available	2.06 to 2.11	LE
Perfluorooctanoic acid	PFOA	335-67-1	Not available	1.9 (±0.1) to 3.5 (±0.1)	FE
Perfluorooctanoic acid	PFOA	335-67-1	Not available	0.041 to 1.6	LE
Perfluorooctanoic acid	PFOA	335-67-1	Not available	2.63 (±0.34)	FE
Perfluorooctanoic acid	PFOA	335-67-1	Not available	2.4 (±0.12)	LE
Perfluorooctanoic acid	PFOA	335-67-1	Not available	2.63 (±0.45)	FE
Perfluorooctanoic acid	PFOA	335-67-1	Not available	2.09 (±0.01) to 2.17 (±0.01)	LE
Perfluorooctanoic acid	PFOA	335-67-1	Not available	3.3 (±0.3)	FE
Perfluorooctanoic acid	PFOA	335-67-1	Not available	1.99 to 2.65	LE
Perfluorooctanoic acid	PFOA	335-67-1	Not available	1.89 (±0.02)	LE
Perfluorooctanoic acid	PFOA	335-67-1	linear	3.11 (±0.38)	FE
Perfluorooctanoic acid	PFOA	335-67-1	linear	3.68 (±0.81)	FE
Perfluorooctanoic acid	PFOA	335-67-1	branched (multiple)	2.77 (±0.53) to 2.96 (±0.48)	FE
Perfluorooctanoic acid	PFOA	335-67-1	branched (multiple)	2.44 (±0.78) to 3.11 (±0.79)	FE
Perfluorooctanoic acid	PFOA	335-67-1	Sum of all isomers	1.98 (±0.06)	LE
Perfluorooctanoic acid	PFOA	335-67-1	Not available	2.9 to 3.0 (±0.6)	FE
Perfluorooctanoic acid	PFOA	335-67-1	Not available	3.4 (±0.2)	FE
Perfluorooctanoic acid	PFOA	335-67-1	Not available	2.82	M
Perfluorooctanoic acid	PFOA	335-67-1	Sum of all isomers	2.61 (±0.69)	FE
Perfluorooctanoic acid	PFOA	335-67-1	Sum of all isomers	5.0 (±0.5)	FE
Perfluorooctanoic acid	PFOA	335-67-1	Not available	1.7 to 2.9	LE
Perfluorooctanoic acid	PFOA	335-67-1	Not available	2.77 (±0.2) to 3.21 (±0.2)	LE
Perfluorooctanoic acid	PFOA	335-67-1	Sum of all isomers	2.92	FM
Perfluorooctanoic acid	PFOA	335-67-1	Not available	4.1 (±0.2)	FE
Perfluorooctanoic acid	PFOA	335-67-1	Not available	2.15 (±2.4)	FE
Perfluorooctanoic acid	PFOA	335-67-1	Not available	1.85 to 3.77	E
Perfluorononanoic acid	PFNA	375-95-1	Not available	2.39 (±0.09) to 2.50 (±0.12)	LE
Perfluorononanoic acid	PFNA	375-95-1	Not available	0.62 to 1.9	LE
Perfluorononanoic acid	PFNA	375-95-1	Not available	3.69 (±0.52)	FE
Perfluorononanoic acid	PFNA	375-95-1	Not available	2.4 (±0.1) to 4.0 (±0.1)	FE
Perfluorononanoic acid	PFNA	375-95-1	Not available	2.9 (±0.1)	FE
Perfluorononanoic acid	PFNA	375-95-1	Not available	2.75 (±0.22)	FE
Perfluorononanoic acid	PFNA	375-95-1	Not available	2.35 (±0.01) to 2.50 (±0.01)	LE
Perfluorononanoic acid	PFNA	375-95-1	Not available	2.36 (±0.04)	LE
Perfluorononanoic acid	PFNA	375-95-1	Not available	3.71 (±0.51) to 3.87 (±0.46)	FE

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CSSAB PFAS Work Group (Subgroup 5)

K_{aw} : Experimental Evidence Serves as Primary Basis

For 7 of the 8 PFAS

- Recommended K_{aw} from compound-specific experimental surface tension relationships
- Original sources for these experimental data, including Silva et al. (2019, 2021) and Yan et al. (2020), reviewed

For 1 of the 8 PFAS

- QSPR method used
- Data regarding surface tension relationships not available

Module0 Input Screen - Basic Analysis				
READ BEFORE START:				
Read Section 2 of the User Guide for parameter descriptions and work through Boxes ① to ⑨ sequentially.				
<u>Blue cells</u> can be filled with reference values using the <u>dropdown buttons</u> or manually entered by users.				
<u>White cells</u> can be either estimated using the <u>functional button</u> on the right or manually entered by users.				
Default values for all cells can be set by clicking the <u>green buttons</u> .				
Parameters with asterisks (*) are the bare minimum to run the solvers.				
When copying and pasting, please paste values only to avoid changing the sheet's formatting.				
			Values	
Surface tension parameter	a	mg/L	62.1	PFAS Type  PFOA
Surface tension parameter	b	(-)	0.19	
Surface tension parameter	σ_0	dyn/cm	71.0	
Molar mass*	M	g/mol	414.07	
Molecular diffusion coefficient*	D_0	cm ² /s	4.90E-06	
Molar volume	V_m	cm ³ /mol	231.07	
Organic carbon-water partition coefficient	K_{oc}	cm ³ /g	120.0	
Solid-phase adsorption coefficient*	K_d	cm ³ /g	41.56	
Air-water interfacial adsorption coefficient*	K_{aw}	cm ³ /cm ²	3.69E-03	Estimate K_d Estimate K_{aw}
NOTE: F_s and α_s are only needed for using the advanced solver.				
Instantaneous solid-phase sorption fraction*	F_s	(-)	0.50	
Kinetic solid-phase sorption rate constant*	α_s	1/hour	1.00E-04	

User Guide: Excel tool for Tiers 3 and 4
models of PFAS-LEACH
(PFAS-LEACH-Analytical and
PFAS-LEACH-DAF)



CSSAB PFAS Work Group (Subgroup 5)

Recommended Chemical-Specific Inputs

DRAFT

Recommended Chemical Specific Parameters

PFAS	Recommended K_{oc} (L/kg)	Recommended K_{aw} (cm ³ /cm ²)
PFBS	45	5.45E-05
HFPO-DA (GenX)	30	9.28E-04
PFHxS	120	1.02E-03
PFOA	100	3.69E-03
PFNA	250	4.24E-02
PFOS	600	4.79E-02
PFBA	75	2.40E-05
PFHxA	20	1.42E-04

Technical Basis for Selection of K_{aw} and K_{oc} Values for Development of PFAS Soil-to-Groundwater Medium-Specific Concentrations

By: Pennsylvania Cleanup Standards Scientific Advisory Board, PFAS Work Group, Subgroup 5
Kevin L. Long (Terraphase Engineering Inc.), J. Michael Penzone, P.G. (Delaware Department of Natural Resources and Environmental Control), & Christopher Voci, P.G. (Terraphase Engineering Inc.)

1 Introduction and Objective

1.1 Introduction

The Pennsylvania Department of Environmental Protection (PADEP) Cleanup Standards Scientific Advisory Board (CSSAB) PFAS Work Group (Work Group) is evaluating an approach for developing soil-to-groundwater medium-specific concentrations (S-GW MSCs) for selected per- and polyfluoroalkyl substances (PFAS). The approach under consideration builds upon the equilibrium-partitioning methodology presented in the United States Environmental Protection Agency's (USEPA; 1996) *Soil Screening Guidance: Technical Background Document* for evaluating the potential migration of chemicals from vadose-zone soil to groundwater. For PFAS, the Work Group is evaluating a modification to this methodology that explicitly accounts for adsorption of PFAS at the air-water interface within unsaturated soil, consistent with the approach proposed by Brusseau and Guo (2023).

The methodology used by USEPA (1996) to help evaluate the migration-to-groundwater pathway was developed as a screening approach for use during the early stages of site evaluation, when detailed information regarding source characteristics and subsurface conditions may be limited. The methodology therefore incorporates simplifying and generally protective assumptions, including an effectively infinite contaminant source, uniform contamination extending through the contaminated zone to the water table, no biological or chemical degradation, and placement of the groundwater receptor at the downgradient edge of the source. USEPA recognized that the infinite-source assumption is highly conservative and may, under some conditions, predict release of more contaminant mass than is actually present. These assumptions were intended by USEPA to support screening-level decision making rather than to simulate site-specific, transient contaminant release and transport. USEPA's migration-to-groundwater formulation likewise minimizes credit for subsurface attenuation by assuming contamination extends to the water table, and the receptor is located at the plume edge.

The PFAS-specific modification under consideration retains this broader screening framework while adding an equilibrium retention mechanism that is not represented in the soil-water partitioning equation used by USEPA (1996). Section 2 describes the underlying screening assumptions and the PFAS-specific modification in greater detail.

CSSAB PFAS Work Group (Subgroup 5)

Next Step: Evaluating Influence of Parameter Uncertainty



Literature compilation, critical source review, evaluation of applicability, statistical treatment, and development of recommended K_{oc} and K_{aw} values



Quantify how alternative K_{oc} and K_{aw} inputs affect calculated S-GW MSCs



Graphical sensitivity analyses for all eight PFAS to show relative importance of modeled retention mechanisms and the effect on S-GW concentrations

Selection of Input Parameters for A_{aw}

- A_{aw} (Air-water interfacial area) is approximated by the thermodynamic based method using the soil water characteristics (Leverett, 1941, Morrow, 1970) in the PFAS Leach Model as discussed in Brusseau, 2023.

$$A_{aw} = SF \frac{\phi}{\sigma_0} \int_{S_w}^1 p_c dS_w,$$

where $S_w = \theta/\theta_s$ is water saturation. $\phi = \theta_s$ is soil porosity. σ_0 is the surface tension of porewater when no PFAS are present. p_c (cm) is capillary pressure, which is a function of water saturation via the van Genuchten model. The standard thermodynamic-based approach (Leverett, 1941; Morrow, 1970) does not account for the impact of microscale surface roughness (i.e., $SF = 1$).

(adapted from Smith (2025) PFAS Leach user Guide)

The input parameters related to soil-water properties used to calculate A_{aw} in PFAS Leach are:

- Residual Water Content (θ_r)
- Saturated Water Content (θ_s)
- Van Genuchten parameters (α and n) -empirical parameters of the van Genuchten model for soil-water characteristics

The Rosetta 3 model (Zhang and Schaap, 2017) can be used to determine these input values based on soil properties (i.e., sand, silt, and clay fractions) and/or bulk density.

Various versions of the Rosetta model can be found in <https://soil-modeling.org/resources-links/model-portal/rosetta>

(adapted from Smith (2025) PFAS Leach user Guide)

Rosetta Model

ROSETTA3 Tool

Use this tool to estimate the soil saturated hydraulic conductivity (ROSETTA3 code is from [Zhang and Schaap, 2017](#)).

Enter the following soil inputs. Providing the optional inputs, improves the tool's estimate.

Percent sand, S (%)

Percent silt, Si (%)

Percent clay, C (%)

Bulk density, BD (g/cm³) (Optional)

Volumetric water content at field capacity,
33 kPa (cm³/cm³) (Optional)

Volumetric water content at permanent
wilting point, 1500 kPa (cm³/cm³) (Optional)

Results:

Saturated hydraulic conductivity,
K_s (cm/day)

Residual water content,
Θ_r (cm³/cm³)

Saturated water content,
Θ_s (cm³/cm³)

α

n

Act 2 regulations do not have a default soil type with specific percentages of sand, silt and clay, however using the soil description based on θ_w (water filled porosity) and ρ_b (bulk density) a default soil type of a loam with 40% sand, 40% silt and 20% clay is proposed which is consistent with what PADEP has used with other default parameters.

Language from the Act 2 TGM

ii) Site-Specific Requirements for All Analytical Tools

- θ_w (dimensionless): This is the water-filled porosity of the unsaturated zone soil. Appropriate values for this parameter generally range from 0.05 to 0.15 for sandy soils to 0.26 to 0.45 for clays. A default value of 0.2 has been used in the estimation of the soil to groundwater MSCs in Tables 3 and 4 in Appendix A of the Chapter 250 regulations.
- ρ_b in kg/L or g/mL: This is dry bulk density of unsaturated zone soil. Appropriate values for this parameter generally range from 1.3 to 2.0 for silts and clays to 1.6 to 2.2 for sandy soils to 1.8 to 2.3 for gravelly soils. A default value of 1.8 has been used in the estimation of the soil to groundwater MSCs in Tables 3 and 4 in Appendix A of the regulations.

Using PFAS Leach to Calculate A_{aw}

① Soil Properties and Site Conditions			Parameter Values	Set Default Values
Depth to groundwater*	Z_w	cm	300	Soil Type  User defined Inputs Estimate α_L Estimate θ Estimate SF Estimate A_{aw}
Contaminated site area (or unit area)	A	m ²	2500	
Temperature	T	°C	20.00	
Net infiltration*	I_f	cm/yr	33.00	
Soil bulk density*	ρ_b	g/cm ³	1.80	
Saturated hydraulic conductivity	K_s	cm/day	2.85	
Residual water content	θ_r	cm ³ /cm ³	0.080	
Saturated water content*	θ_s	cm ³ /cm ³	0.314	
Median grain size	d_{50}	cm	0.002	
Organic carbon fraction	f_{oc}	%	0.25	
van Genuchten parameter	α	cm ⁻¹	0.010	
van Genuchten parameter	n	(-)	1.28	
Longitudinal dispersivity*	α_L	cm	212.91	
Water content*	θ	cm ³ /cm ³	0.254	
Air–water interfacial area scaling factor	SF	(-)	4.7	
Air–water interfacial area*	A_{aw}	cm ² /cm ³	384.8	

Output

Using K_{oc} , K_{aw} and A_{aw} in Soil to Groundwater Equation

$$MSC_S = MSC_{GW} \times [(K_{oc} * f_{oc}) + (K_{aw}A_{aw} + \theta_w)/\rho_b] \times DF$$

$A_{aw} - 384.8 \text{ cm}^2/\text{cm}^3$
PFOA $K_{oc} - 100 \text{ cm}^3/\text{g}$
PFOA $K_{aw} - 3.69\text{e}^{-3} \text{ cm}^3/\text{cm}^2$

	PFOA	
100x MSC:	0.40	µg/kg
No AWIA MSC:	0.10	µg/kg
Default AWIA MSC:	0.5	µg/kg
No AWIA MSC (1/10th):	0.010	µg/kg
AWIA MSC (1/10th):	0.05	µg/kg

$A_{aw} - 384.8 \text{ cm}^2/\text{cm}^3$
PFOS $K_{oc} - 600 \text{ cm}^3/\text{g}$
PFOS $K_{aw} - 4.79\text{e}^{-2} \text{ cm}^3/\text{cm}^2$

	PFOS	
100x MSC:	0.40	µg/kg
No AWIA MSC:	0.60	µg/kg
Default AWIA MSC:	4.7	µg/kg
No AWIA MSC (1/10th):	0.060	µg/kg
AWIA MSC (1/10th):	0.47	µg/kg

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Next Steps

- Sensitivity analyses for K_{oc} , K_{aw} and A_{aw}
- Preparation of White Paper
 - Completion of sensitivity analysis – October 2026
 - Completion of initial draft – November/December 2026
 - Completion of final draft – January 2027