Technical Summary Report

Proposed Soil Remediation Standards (SRS) for Perfluorooctanoic Acid (PFOA), Perfluorooctane Sulfonic Acid (PFOS), Perfluorohexane Sulfonic Acid (PFHxS), and Perfluorononanoic Acid (PFNA)

October 6, 2023

NEW HAMPSHIRE
DEPARTMENT OF
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Executive Summary

This report provides NHDES' technical summary of the derivation of proposed values for Soil Remediation Standards (SRS) for certain per- and polyfluoroalkyl substances (PFAS). The SRS values are listed in Env-Or 606.19(b) Table 600-2 of Chapter Env-Or 600 of the New Hampshire Administrative Code, Contaminated Site Management.

The proposed SRS values, in units of nanograms per gram (ng/g, equivalent to parts per billion [ppb]), are:

Chemical Name	CAS NO.	SRS Value
Perfluorooctanoic acid (PFOA)	CAS RN 335-67-1	0.2 ng/g
Perfluorooctane sulfonic acid (PFOS)	CAS RN 1763-23-1	0.4 ng/g
Perfluorohexane sulfonic acid (PFHxS)	CAS RN 355-46-4	0.2 ng/g
Perfluorononanoic acid (PFNA)	CAS RN 375-95-1	0.5 ng/g

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Attachment B   Interdepartmental Memorandum to Michael J. Wimsatt, P.G., Director, Waste Management Division from Jeffrey Marts, P.G., NHDES-HWRB Administrator Re: Recommended Leaching Values for Certain Per- and Polyfluoroalkyl Substances (PFAS) dated October 6, 2023.

Attachment C   Interdepartmental Memorandum to Michael J. Wimsatt, P.G., Director, Waste Management Division from Jeffrey Marts, P.G., NHDES-HWRB Administrator Re: Recommended Background Threshold Values (BTVs) for Certain Per- and Polyfluoroalkyl Substances (PFAS) in Shallow Soil in New Hampshire dated October 6, 2023.

Attachment D   Interdepartmental Memorandum to Jeffrey Marts, P.G., NHDES-HWRB Administrator from David B. Larson, M.P.H., Environmental Health Program Re: Recommended Ceiling Concentrations dated October 6, 2023.

Abbreviations

AGQS	Ambient Groundwater Quality Standards
BTVs	background threshold values
DCRB	direct contact risk-based
EQLs	estimated quantitation limits
ng/g	nanograms per gram
NHDES	New Hampshire Department of Environmental Services
PFAS	per- and polyfluoroalkyl substances
PFHxS	perfluorohexane sulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonic acid
ppb	parts per billion
RCMP	Risk Characterization and Management Policy
SRS	Soil Remediation Standards
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

1   Introduction

This report provides NHDES' technical summary of the derivation of proposed values for Soil Remediation Standards (SRS) for certain per- and polyfluoroalkyl substances (PFAS). The SRS values are listed in Env-Or 606.19(b) Table 600-2 of Chapter Env-Or 600 of the New Hampshire Administrative Code, Contaminated Site Management. SRS are proposed for the four PFAS for which Ambient Groundwater Quality Standards (AGQS) have been established in Env-Or 603.03 Table 600-1:

- Perfluorooctanoic acid (PFOA)   CAS RN 335-67-1
- Perfluorooctane sulfonic acid (PFOS)   CAS RN 1763-23-1
- Perfluorohexane sulfonic acid (PFHxS)   CAS RN 355-46-4
- Perfluorononanoic acid (PFNA)   CAS RN 375-95-1

NHDES is required to initiate rulemaking for SRS for these PFAS by November 1, 2023, pursuant to RSA 485-H:13 dated July 2022. Given the rapidly evolving science associated with PFAS, NHDES will monitor the emerging information to evaluate whether changes, updates, and/or clarifications to the approach and assumptions described herein may be appropriate.
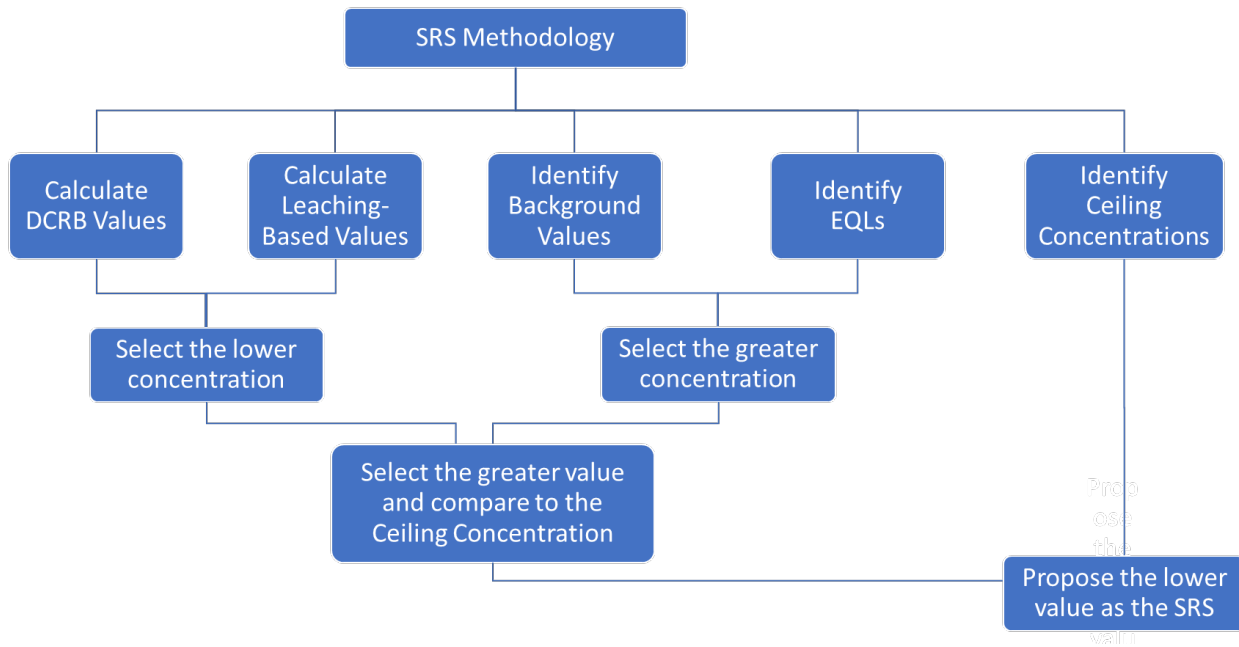
2   Approach

The approach for developing SRS for PFAS has generally followed the methodology used by NHDES to establish SRS for contaminants currently listed in Env-Or 606.19(b) Table 600-2, as outlined in the appendices to NHDES Risk Characterization and Management Policy (RCMP) and the 2018 update to RCMP appendices B and E.

This approach evaluates the influence of five criteria that include:

- Direct contact risk-based (DCRB) soil concentrations.
- Leaching-based soil concentrations protective of groundwater quality.
- Background concentrations.
- Estimated quantitation limits (EQLs).
- Ceiling concentrations.

The proposed SRS values are selected based on a comparison between the criteria as shown in Figure 1. The lowest, most protective value is selected between the direct contact and leaching-based risk criteria, and then that value is compared to the background value (where established) and the EQL values, with the greater of these three values compared to the ceiling concentration. The lower of the two values is proposed as the SRS. NHDES' intent is that an SRS will not be established at a level less than a statewide background value, and an SRS will not be established at a level less than that which can be reliably measured by an USEPA-approved analytical laboratory method. This approach is illustrated in Figure 1.

Figure 1: SRS Methodology

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                          │   SRS Methodology   │
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┌────────────┐  ┌────────────┐  ┌────────────┐  ┌──────────┐  ┌──────────────┐
│  Calculate │  │  Calculate │  │   Identify │  │ Identify │  │   Identify   │
│    DCRB    │  │  Leaching- │  │ Background │  │   EQLs   │  │    Ceiling   │
│   Values   │  │    Based   │  │   Values   │  │          │  │Concentrations│
│            │  │   Values   │  │            │  │          │  │              │
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      ┌──────────────────┐          ┌──────────────────┐
      │ Select the lower │          │ Select the greater│
      │  concentration   │          │  concentration    │
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              ┌──────────────────────────┐
              │  Select the greater value│
              │   and compare to the     │
              │   Ceiling Concentration  │
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                                              │ Propose the lower│
                                              │ value as the SRS │
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2.1   Direct Contact Risk-Based Soil Values

The derivation of direct contact risk-based (DCRB) soil values is described in the memorandum provided in Attachment A. DCRB soil values are developed for three exposure scenarios that differ based on exposure frequency and duration: S-1, S-2, and S-3. The DCRB S-1 values are the same as the values published by NHDES in December 2019, whereas the S-2 value has been updated and an S-3 value has been developed. As documented in the RCMP Appendix E: *"Category S-1 Direct Contact Risk-based Concentrations are based upon sensitive uses of property and accessible soils… Soil Category S-2 Direct Contact Risk-based Concentrations are based upon moderate exposure and accessible soil… [and] Soil Category S-3 Direct Contact Risk-based Concentrations are based upon restricted access property with limited potential for exposure…"*.

2.2   Leaching-Based Soil Values

The derivation of leaching-based soil values is described in the memorandum provided in Attachment B. Leaching-based soil values are based on a representative release scenario and hydrogeologic conditions considered to be conservatively protective of New Hampshire's drinking water aquifers. As described in the attachment, NHDES acknowledges that responsible parties might consider development of site-specific SRS with alternate leaching-based values for some PFAS release sites following the existing provision in Env-Or 606.19(c) and Env-Or 606.19(d), given: (i) that leaching potential may be greatly influenced by local, site-specific conditions; (ii) the emerging scientific knowledge associated with the degree of influence of various mechanisms that might influence leaching potential of these PFAS; and (iii) the emerging scientific knowledge associated with modeling approaches specific to PFAS.

2.3   Background Values

NHDES does not propose to identify statewide natural or anthropogenic ambient background values for consideration in the SRS derivation because, as described in the memorandum provided in Attachment C:

(i)   PFAS are anthropogenic contaminants and therefore are not naturally occurring in the environment.

(ii)   Although certain PFAS were detected in soil sampling locations across the state in the United States Geological Survey (USGS) "[Statewide Survey of Shallow Soil Concentrations of Per- and Polyfluoroalkyl Substances (PFAS) and Related Chemical and Physical Data Across New Hampshire](#)" (Statewide Survey), the presence of PFAS was generally limited to shallow soil (i.e., not distributed throughout the soil column) and the reported concentrations varied by location (i.e., were not spatially consistent).

As described in the attachment, NHDES recognizes the potential for certain PFAS to be present in shallow soil at or in the vicinity of a site, and thus NHDES acknowledges that responsible parties might consider development of site-specific background values for a portion of soils at their site pursuant to the existing provision in [Env-Or 606.19(f)](#), which states that SRS do not apply at sites where contamination is at or below background levels. To support these evaluations, NHDES developed background threshold values (BTVs) for shallow soil (0- to 12-inch subsurface interval only) that can be considered by responsible parties during their initial screening of PFAS data to evaluate whether soils are impacted solely due to anthropogenic ambient background conditions.

2.4   EQLs

NHDES selects Estimated Quantitation Limits (EQLs) from United States Environmental Protection Agency (USEPA)-approved laboratory methods; however, at this time, USEPA has not yet approved a laboratory method for analysis of these PFAS in solid matrices (e.g., soil). As such, the proposed EQLs have been selected from USEPA's 4th Draft of Method 1633 - Analysis of Per- and Polyfluoroalkyl Substances (PFAS) in Aqueous, Solid, Biosolids, and Tissue Samples by LC-MS/MS, dated July 2023. The proposed EQLs are subject to change when this method is finalized with the multi-laboratory validated reporting limits and published by USEPA. The proposed EQLs are presented in units of nanograms per gram (ng/g, equivalent to parts per billion [ppb]).

- PFOA   0.2 ng/g
- PFOS   0.2 ng/g
- PFHxS   0.2 ng/g
- PFNA   0.2 ng/g

2.5   Ceiling Concentrations

The derivation of ceiling concentrations is described in the memorandum provided in Attachment D. Ceiling concentrations provide upper limits for chemicals which might pose an inhalation risk and other significant risk to public welfare and the environment. These concentrations are determined based on the odor index of the chemical, the volatility of the chemical, and the soil exposure category (S-1, S-2, and S-3). There are limited data available for these PFAS, and thus ceiling values have been established for only two PFAS (PFOA and PFNA) at this time.

3   Summary of Criteria

The values for each category are summarized in Table 1. The proposed SRS values, in units of nanograms per gram (ng/g, equivalent to parts per billion [ppb]), are:

Table 1: Summary of SRS Derivation Criteria

PFAS	Proposed SRS S-1/ S-2/ S-3	Direct Contact			Leaching S-1/ S-2/ S-3	Back- ground S-1/ S-2/ S-3	EQL* S-1/ S-2/ S-3	Ceiling		
		S-1	S-2	S-3				S-1	S-2	S-3
PFOA	0.2	200	1,400	1,400	0.1	-	0.2	100,000	500,000	1,000,000
PFNA	0.4	100	1,000	1,000	0.4	-	0.2	100,000	500,000	1,000,000
PFHxS	0.2	100	900	900	0.2	-	0.2	-	-	-
PFOS	0.5	100	700	700	0.5	-	0.2	-	-	-

* Selected from USEPA's 4th Draft of Method 1633, dated July 2023. Subject to change when the draft method is finalized.

Attachment A

**Interdepartmental Memorandum
to Jeffrey Marts, P.G., NHDES-HWRB Administrator
from David B. Larson, M.P.H., Environmental Health Program
Re: Recommended Direct Contact Risk-Based Soil Concentrations
October 6, 2023**

To:	Jeffrey Marts, P.G., NHDES-HWRB Administrator
From:	David B. Larson, M.P.H., Environmental Health Program
RE:	Recommended Direct Contact Risk-Based Soil Concentrations (milligrams per kilogram [mg/kg] = parts per million [ppm]):

Perfluorooctanoic acid (PFOA)	(S-1 = 0.2)	(S-2 = 1.4)	(S-3 = 1.4)
Perfluorooctane sulfonic acid (PFOS)	(S-1 = 0.1)	(S-2 = 0.7)	(S-3 = 0.7)
Perfluorohexane sulfonic acid (PFHxS)	(S-1 = 0.1)	(S-2 = 0.9)	(S-3 = 0.9)
Perfluorononanoic acid (PFNA)	(S-1 = 0.1)	(S-2 = 1.0)	(S-3 = 1.0)

Date:	October 6, 2023

The Environmental Health Program (EHP) has developed revised recommendations for direct contact risk-based (DCRB) soil concentrations for four (4) per- and polyfluoroalkyl substances (PFAS) considered protective of potential human exposure in S-1, S-2, and S-3 scenarios. The designation of an "S" category is dependent on the accessibility of the soil and the receptor characteristics. In general, S-1 represents a residential scenario, S-2 an outdoor maintenance worker/passive recreator scenario and S-3 is for a construction/utility worker scenario. This revision of the recommended DCRB soil concentrations incorporates an adult body weight of eighty (80) kg to be consistent with the assumed adult body weight incorporated into the development of the maximum contaminant levels (MCL) for the four PFAS compounds; and the corresponding increase in the adult skin surface area available for soil contact. All other exposure assumptions are consistent with those assumed in the December 11, 2019, document.[a] The S-3 (construction/utility worker) scenario concentrations were also added to be consistent with the approach described in the NHDES Contaminated Sites Risk Characterization and Management Policy (RCMP).[b]

The recommended DCRB soil concentrations are not anticipated to present an appreciable increased health risk to receptors that are exposed through direct contact with impacted soil. The recommendations account for exposure that may result from incidental ingestion and dermal contact with impacted soil. The DCRB concentration recommendations do not account for potential exposure via inhalation, indirect exposure pathways such as migration via runoff to nearby surface water bodies or bioaccumulation in the food chain.

The DCRB concentration recommendations were derived using the methodology described in Appendix A (*Methodology for Calculating Direct Contact Risk-Based Soil Concentrations*) contained in the NHDES RCMP. In summary, dose-response information provides a quantitative evaluation of toxicity and describes the relationship between the dose of a chemical and the potential for adverse health effects in the exposed population. The EHP developed reference dose (RfD) values for the four (4) PFAS compounds[c] (Table 1) that were used to calculate the recommended DCRB concentrations to protect against non-carcinogenic health effects. The United States Environmental Protection Agency (USEPA) defines the reference dose as an estimate (with uncertainty spanning perhaps an order of magnitude) of

the daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.[d]

Table 1: Select PFAS RfDs and Calculated S-1, S-2 and S-3 DCRB Soil Concentrations.[e]

PFAS	CAS #	RfD (mg/kg-d)	S-1 (mg/kg)	S-2 (mg/kg)	S-3 (mg/kg)
Perfluorooctanoic acid (PFOA)	335-67-1	$6.1E^{-6}$	0.2	1.4	0.8
Perfluorooctane sulfonic acid (PFOS)	1763-23-1	$3.0E^{-6}$	0.1	0.7	0.4
Perfluorohexane sulfonic acid (PFHxS)	355-46-4	$4.0E^{-6}$	0.1	0.9	0.5
Perfluorononanoic acid (PFNA)	375-95-1	$4.3E^{-6}$	0.1	1.0	0.5

The methodology described in Appendix A was used to calculate the recommended DCRB concentration for the most sensitive receptor, young children aged 2 – 6 years in a residential scenario. The methodology for all scenarios contains a 20% relative source contribution factor (RSCF) for non-carcinogenic compounds. The RSCF is applied when the contribution from other potential sources of exposure to the compound is unknown. The DCRB methodology also assumes the absorption of PFAS from incidental ingestion of soil is 100%, whereas the absorption of PFAS from dermal contact is 10%. PFAS are not well absorbed through the skin[f,g,h] so dermal contact is not expected to be an important exposure route for the general public. However, the USEPA Regional Screening Level (RSL) Calculator assumes 10% dermal absorption for PFOA, PFOS, PFHxS and PFNA.[i] As a conservative measure it is assumed that the dermal absorption of PFOA, PFOS, PFHxS and PFNA are at 10% to avoid underestimating exposure from impacted soil. If additional studies provide information regarding dermal absorption, EHP will review the information to determine if a recalculation of recommended DCRB values are necessary.

Please note that the RfDs developed by the EHP are chronic toxicity values and the S-3 scenario uses an exposure duration less than chronic (1 year). If sub-chronic toxicity factors were available for these four PFAS compounds, EHP would likely use them to derive S-3 DCRB soil values. Using a chronic toxicity value with a sub-chronic exposure duration often results in the S-3 DCRB value being less than the S-2 DCRB soil value. In these situations, EHP adopts the S-2 value as the S-3 value. Table 1 provides the calculated DCRB soil values for the four PFAS compounds.

Example DCRB calculation for PFOA:

$$\text{Concentration in Soil (mg/kg)} = \frac{RSCF \times RfD \times CF}{[(IR \times RAF_o) + (SA \times AF \times RAF_d)] \times \left[\frac{EF \times ED}{AT \times BW}\right]}$$

$$S\text{-}1 = 0.2 \text{ mg/kg} = \frac{0.2 \times 6.1E^{-6} \text{ mg/kg-d} \times 1.0E^{6} \text{ mg/kg}}{[(200 \text{ mg/day} \times 1) + (2,632 \text{ cm}^2 \times 0.20 \text{ mg/cm}^2 \times 0.1)] \times \left[\frac{160 \text{ days/year} \times 5 \text{ years}}{1,825 \text{ days} \times 17 \text{ kg}}\right]}$$

$$S\text{-}2 = 1.4 \text{ mg/kg} = \frac{0.2 \times 6.1E^{-6} \text{ mg/kg-d} \times 1.0E^{6} \text{ mg/kg}}{[(100 \text{ mg/day} \times 1) + (3,527 \text{ cm}^2 \times 0.20 \text{ mg/cm}^2 \times 0.1)] \times \left[\frac{146 \text{ days/year} \times 25 \text{ years}}{9,125 \text{ days} \times 80 \text{ kg}}\right]}$$

$$S\text{-}3 = 0.8\ \text{mg/kg} = \frac{0.2 \times 6.1E^{-6}\ \text{mg/kg-d} \times 1.0E^{6}\ \text{mg/kg}}{[(480\ \text{mg/day} \times 1) + (3{,}527\ \text{cm}^2 \times 0.20\ \text{mg/cm}^2 \times 0.1)] \times \left[\frac{83\ \text{days/year} \times 1\ \text{years}}{365\ \text{days} \times 80\ \text{kg}}\right]}$$

Table 2: Parameters used for the Calculation of Direct Contact Risk-Based Concentrations (DCRB) for Select PFAS Compounds in Soil.

Parameter	Parameter Description	S-1	S-2	S-3
Sensitive receptor	Parameter	Young Child (residential)	Outdoor Maintenance Worker	Construction Worker
RSCF	Relative Source Contribution Factor	0.20	0.20	0.20
RfD (mg/kg-d)	Reference Dose (See Table 1)	Compound specific	Compound specific	Compound specific
CF (mg/kg)	Units Conversion Factor	$1.0E^{6}$	$1.0E^{6}$	$1.0E^{6}$
IR (mg/day)	Daily soil ingestion rate[j, k]	200	100	480
RAF_o (unitless)	Relative Absorption Factor for soil ingestion	1	1	1
$tRAF_d$ (unitless)	Relative Absorption Factor for dermal contact	0.1	0.1	0.1
SA (cm²)	Skin Surface Area available for soil contact	2,632	3,527	3,527
AF (mg/cm²)	Soil-to-skin Adherence Factor	0.36	0.20	0.20
EF (days/year)	Exposure Frequency	160	146	83
ED (years)	Exposure Duration	5	25	1
AT (days)	Averaging Time for non-carcinogens (ED x 365 days)	1,825	9,125	365
BW (kg)	Body Weight	17	80	80

[b] New Hampshire Department of Environmental Services (NHDES). January 1998. Contaminated Site Risk Characterization and Management Policy (RCMP).

[c] New Hampshire Department of Environmental Services (NHDES). June 2019 Report. Retrieved from: https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/r-wd-19-29.pdf

[d] United States Environmental Protection Agency (USEPA) 2014. Risk Assessment Glossary. Retrieved from: https://iaspub.epa.gov/sor_internet/registry/termreg/searchandretrieve/glossariesandkeywordlists/search.do?details=&vocabName=Risk%20Assessment%20Glossary

[e] The listed compounds and associated CAS numbers are for the acid forms of these PFAS compounds. The information presented in Table 1 are also applicable to the respective anionic forms of these compounds. These anions may form salts with any of a number of cations resulting in a variety of possible chemical species, each having a unique CAS number.

[f] Agency for Toxic Substances and Disease Registry (ATSDR). 2019. "How can I be exposed to PFAS?", webpage updated April 25, 2019. Retrieved from https://www.atsdr.cdc.gov/pfas/pfas-exposure.html

[g] United States Environmental Protection Agency (USEPA). 2016. Health Effects Support Document for Perfluorooctane Sulfonate (PFOS). Document # EPA 822-R-16-002. May 2016. Retrieved from https://www.epa.gov/sites/production/files/2016-05/documents/pfos_hesd_final_508.pdf

[h] United States Environmental Protection Agency (USEPA). 2016a. Health Effects Support Document for Perfluorooctanoic acid (PFOA). Document # EPA 822-R-16-003. May 2016. Retrieved from https://www.epa.gov/sites/production/files/2016-05/documents/pfoa_hesd_final_508.pdf

[i] United States Environmental Protection Agency (USEPA). 2019. Regional Screening Level (RSL) Calculator. Updated May 2023. Retrieved from: https://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search

[j] Resident soil ingestion rate-child. USEPA 2011A (Table 5-1); "Upper-bound values" accounting for both soil and dust ingestion. OSWER Directive 9200.1-120. Human Health Evaluation, Supplemental Guidance: Update of Standard Default Exposure Factors. February 6, 2014. Retrieved from: https://epa-prgs.ornl.gov/chemicals/help/documents/OSWER_Directive_corrected.pdf

[k] Outdoor worker soil ingestion rate. USEPA 1991a (pg. 15); OSWER Directive 9200.1-120. Human Health Evaluation, Supplemental Guidance: Update of Standard Default Exposure Factors. February 6, 2014. Retrieved from: https://epa-prgs.ornl.gov/chemicals/help/documents/OSWER_Directive_corrected.pdf

Attachment B

Interdepartmental Memorandum
to Michael J. Wimsatt, P.G., Director, Waste Management Division
from Jeffrey Marts, P.G., NHDES-HWRB Administrator
Re: Recommended Leaching Values for Certain Per- and Polyfluoroalkyl
Substances (PFAS)
October 6, 2023

To: Michael J. Wimsatt, P.G., Director, Waste Management Division

From: Jeffrey Marts, P.G., NHDES-HWRB Administrator

RE: Recommended Leaching Values for Certain Per- and Polyfluoroalkyl Substances (PFAS):

Perfluorooctanoic acid (PFOA)	CAS RN 335-67-1	0.1 ng/g[1]
Perfluorooctane sulfonic acid (PFOS)	CAS RN 1763-23-1	0.5 ng/g
Perfluorohexane sulfonic acid (PFHxS)	CAS RN 355-46-4	0.2 ng/g
Perfluorononanoic acid (PFNA)	CAS RN 375-95-1	0.4 ng/g

Date: October 6, 2023

The NHDES Hazardous Waste Remediation Bureau (HWRB) has calculated leaching-based soil values for PFOA, PFOS, PFHxS, and PFNA, and recommends consideration of these values in the development of statewide Soil Remediation Standards (SRS) pursuant to the New Hampshire Code of Administrative Rules Chapter Env-Or 600 Contaminated Site Management (Env-Or 600).

As described in Appendix B to NHDES' Risk Characterization and Management Policy (RCMP 2018), the objective of development of leaching-based values is "*to determine the allowable concentration of contaminants in soil such that soil contaminated at, or remediated to, these concentrations should not leach a sufficient mass of contaminant to result in a violation of a NHDES ambient groundwater quality standard (AGQS)."* The leaching values presented herein are for the four PFAS for which NHDES has established an AGQS in Env-Or 600 and are intended to be protective of groundwater quality for a range of hydrogeologic conditions including the most vulnerable aquifers.

Background

To calculate the leaching-based soil values, HWRB considered the following references and data:

- "Methodology to Develop Leaching-Based Soil Values" included in Appendix B of NHDES' RCMP (RCMP 2018).

- "Development of Leaching-Based Soil Value for Select Per- and Polyfluoroalkyl Substances (PFAS)" prepared by Sanborn, Head & Associates (Sanborn Head) for NHDES and dated September 29, 2023 (Sanborn Head 2023).

- "Statewide survey of shallow soil concentrations of per- and polyfluoroalkyl substances (PFAS) and related chemical and physical data across New Hampshire, 2021" prepared by the United States Geological Survey (USGS) and dated October 19, 2022 (USGS 2022).

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[1] Nanograms per gram (ng/kg), equivalent to parts per billion (ppb)

- "Solid/Water Partitioning of Per- and Polyfluoroalkyl Substances (PFAS) in New Hampshire Soils and Biosolids: Results from Laboratory Experiments at the U.S. Geological Survey" prepared by the USGS and dated February 9, 2023 (USGS 2023).

Method and Approach

HWRB calculated leaching-based values using the approach described in the RCMP Appendix B (RCMP 2018), which is consistent with the approach used by NHDES to develop leaching-based values for other contaminants for which an SRS is provided in Table 600-2 of Env-Or 600. HWRB used SEVIEW Transport and Fate modeling software, which includes vadose zone transport modeled by SESOIL and groundwater transport modeled by AT123D, and is developed and marketed by ESCI, LLC.

As described in RCMP 2018: *"SESOIL is used to determine the maximum concentration of contaminant at the water table interface and AT123D is used to determine the concentration of contaminant in the downgradient well. For each contaminant that is modeled, the maximum groundwater concentration is used to determine the dilution and attenuation factor (DAF), from which a leaching-based soil value is calculated. The DAF is the ratio of the initial soil concentration to the maximum groundwater concentration predicted to exist at the* [receptor] *well by the model."*

The leaching-based values are calculated using the following equations:

$$Leaching\ Based\ Soil\ Value\ (ppm) = DAF \times AGQS\ (ppm)$$

where

$$DAF = \frac{Initial\ Soil\ Concentration\ (ppm)}{Maximum\ Modeled\ Groundwater\ Concentration\ at\ Well\ (ppm)}$$

Method Applicability

HWRB elected to use SEVIEW to predict groundwater concentrations at the receptor well based on our review of the model evaluation presented in "Development of Leaching-Based Soil Values for Select Per- and Polyfluoroalkyl Substances (PFAS)" prepared by Sanborn Head (Sanborn Head 2023) and our understanding of the state of the science for PFAS fate and transport (ITRC 2023). According to Sanborn Head, none of the models reviewed for this work have been validated by the developers specifically for simulating PFAS fate and transport. Silva et al., 2020 noted that this may be due to a dearth of pilot-scale and field-scale PFAS data for representative conditions against which available models could be validated. Currently, HWRB recommends use of SEVIEW because it:

- Provides an "*efficient approach to effectively simulate state-wide conditions and address large-scale variability in site conditions for multiple input parameters*." (Sanborn Head 2023)

- "*Simulates protective leaching-based soil values despite the limitations of one-dimensional flow, simulating flow through the vadose zone using a water balance approach and lumped parameter, and not simulating air-water interface PFAS partitioning, since these limitations tend to increase the PFAS leached from the soil, downward transport of the contaminant will be quicker and at higher concentrations, and leaching of the contaminant will occur for a shorter period of time*." (Sanborn Head 2023)

- "*Use of a general model reduces the complexity of obtaining voluminous site-specific data or conducting substantial analysis of literature values to provide representative results over a wide variation of site conditions.*" (Sanborn Head 2023)

- Provides "*consistency with the process previously used by NHDES to develop existing leaching-based soil values and used by several other states to develop remediation soil standards.*" (Sanborn Head 2023)

- Is relatively accessible and easy to use relative to other leaching models, which allows the regulated community in New Hampshire to duplicate NHDES' derivation of the state-wide leaching-based values or use the model to derive site-specific leaching-based values.

SEVIEW does not have the capability to incorporate all PFAS fate and transport considerations, such as partitioning to the air-water interface; however, some of the fate and transport considerations not accounted for by SEVIEW are at least partially addressed in HWRB's calculations by the use of representative sorption coefficients derived as part of the USGS 2023 study. HWRB incorporated New Hampshire-specific data from the USGS 2023 study into the modeling effort, where appropriate.

Model Inputs

The following subsections summarize the inputs to the computer models: (i) generic site conditions for a conceptual release scenario; and (ii) chemical-specific parameters.

Generic Site Conditions – Soil, Climate, and Groundwater

Generic site conditions for a conceptual release scenario include information about soil, climate, and groundwater conditions.

SESOIL Soil Parameters

The soil parameters used for the modeling effort are the same as those described in RCMP 2018 (Appendix B) and used for prior modeling of other contaminants by NHDES for development of soil leaching values for consideration in the SRS development process. No change to these parameters is proposed based on HWRB's review of Sanborn Head 2023 and the results of HWRB's modeling efforts. The soil parameters are summarized in Table 1.

Table 1 SESOIL Soil Parameters

SESOIL Parameter	Value
Soil type	Sand
Intrinsic permeability	$1 \times 10^{-8}\,cm^2$
Porosity (n)	0.3
Soil pore disconnectedness index (dimensionless)	3.7
Soil bulk density	$1.3\,gm/cm^3$
Soil organic carbon (f$_{oc}$)	0.1%
Volatile fractions	0.2
Clay content	0%

SESOIL Parameter	Value
Source area	1,000,000 cm^2 (10 m x 10 m)
Contaminant concentration	10 ppm
Layer 1 thickness (10 sub-layers)	100 cm
Layer 2 thickness (10 sub-layers)	100 cm
Layer 3 thickness (10 sub-layers)	50 cm
Layer 4 thickness (10 sub-layers)	50 cm
Total soil thickness	300 cm (3 m)
Top of contamination	100 cm
Initial bottom of contamination	200 cm
Top of water table	300 cm
Distance to point of compliance (POC) (a drinking water well) from downgradient edge of source area	10 m

Abbreviations: square centimeters (cm^2); grams (g); cubic centimeters (cm^3); meters (m); parts per million (ppm, equivalent to milligrams per kilogram [mg/kg] in soil); centimeters (cm)

At NHDES' request, Sanborn Head considered a conceptual release scenario in which PFAS was released directly to the ground surface over an area larger than the default 10-meter by 10-meter source area, representing an aqueous film forming foam (AFFF) release or air deposition release scenario. NHDES chose to use a subsurface release scenario in the derivation of leaching-based values because the subsurface scenario resulted in more protective values. The subsurface release scenario results in more protective values than a surface release scenario because it occurs closer to the groundwater table and in soil associated with a low organic carbon content (Sanborn Head 2023). The size of the source area was therefore not increased from 10- by 10-meters, remaining consistent with the subsurface release scenario in RCMP 2018.

NHDES uses a default value of 10 ppm for the contaminant concentration when modeling leaching to groundwater. Although 10 ppm is greater than the concentrations generally detected in soil at PFAS sites, the ratio of the contaminant input concentration to the maximum modeled groundwater concentration (i.e., the DAF) is the same for each input concentration (all other variables held constant) as long as the input concentration is high enough for detectable concentrations to reach the point of compliance in the model. As such, NHDES retained a 10-ppm contaminant concentration in the modeling effort for ease of modeling and historical consistency.

SESOIL Climate Parameters

The climate parameters were updated for this modeling effort.

During the 2018 efforts to update SRS values, NHDES used the Massabesic Lake station (1971 to 2000 dataset) for the modeling effort. As shown in Table 2, NHDES updated the time period for the climate dataset from the 1971 to 2000 dataset used in RCMP 2018 to the 1991 to 2020 dataset. Sanborn Head calculated the annual precipitation for each of the 92 stations included in the 1991 to 2020 dataset and the median value for the annual precipitation. Based on NHDES' review, the two stations with annual precipitation closest to the median precipitation for the state of 119.53 centimeters per year

(cm/yr) are Walpole 2S NEPP (119.41 cm/yr) and Dunbarton 0.3 N (119.65 cm/yr). NHDES chose Dunbarton as the representative climate station to include in the leaching modeling because Dunbarton is located more centrally in the state than Walpole.

Table 2: SESOIL Climate Parameters

Climate Parameter	Value
Climate station	Dunbarton 0.3 N
Time span	1991 - 2020

Prior to selecting the final climate dataset and station, Sanborn Head and NHDES considered a snowmelt scenario in several modeling runs and compared the calculated leaching values to those derived from modeling runs performed with Massabesic Lake data without frozen ground and snowmelt considered. The leaching values calculated from snowmelt and non-snowmelt scenarios were very similar for each PFAS modeled. Because of the similar values produced and the relative complexity of considering a snowmelt scenario within the modeling software, NHDES did not incorporate snowmelt into the climate dataset for the derivation of the leaching-based values.

AT123D Groundwater Parameters

The groundwater parameters used for the modeling effort are the same as those described in RCMP 2018 and used for prior modeling of other contaminants by NHDES for development of SRS. No change to these parameters is proposed based on HWRB's review of Sanborn Head 2023. The parameters are summarized in Table 3.

Historically, NHDES has not incorporated degradation rates into soil leaching modeling for contaminants because an assumption of no or minimal chemical degradation (whether biotic or abiotic) is realistic under certain conditions and more of the chemical is thereby modeled to reach groundwater. The four PFAS currently regulated by NHDES are terminal PFAS end-members (i.e., no further degradation or transformation is anticipated in a natural environment); therefore, a degradation rate of zero is appropriate for the leaching-value model for these chemicals.

Table 3: AT123D Groundwater Parameters

Groundwater Parameter	Value
Soil bulk density	1.3 gm/cm^3
Porosity (n)	0.3
Hydraulic conductivity (K)	0.36 m/hr
Hydraulic gradient (*i*)	0.005
Longitudinal dispersivity	20.0 m
Transverse dispersivity	2.0 m
Vertical dispersivity	2.0 m
Degradation rates	0.0

Additional Abbreviations: square centimeters (cm^2); meters (m); hour (hr)

Chemical Parameters

The chemical parameters used for the modeling effort were selected based on HWRB's review of Sanborn Head 2023, the USGS Study, and HWRB's modeling efforts. The parameters are summarized in Table 4.

Table 4: Chemical-Specific Input Parameters

Parameter	PFOA	PFOS	PFHxS	PFNA
Molecular weight, g/mol	410	500	400	460
Organic carbon partition coefficient (K_{oc}), mL/g	17.3	292.9	31.2	75.3
Solid-liquid partition coefficient (Kd)	Calculated within SEVIEW from the K_{oc} and f_{oc} (0.1%)			
Solubility (S), mg/L	9,500	680	239.43	11.66
Henry's Law constant (H) at 25 °C, atm-m³/mol	3.57×10^{-6}	4.43×10^{-7}	6.10×10^{-5}	1.9×10^{-3}
Diffusion coefficient in air (Diffusivity, D_a), cm²/s	2.26×10^{-2}	2.07×10^{-2}	2.33×10^{-2}	2.13×10^{-2}
Diffusion coefficient in water (Diffusivity, D_w), cm²/s	5.79×10^{-6}	5.25×10^{-6}	6.01×10^{-6}	5.43×10^{-6}

Additional Abbreviations: mole (mol); mililiters (mL), liters (L), Celsius (C); atmospheres (atm); cubic meters (m³); seconds (s)

Sorption Partition Coefficient Selection (K_d versus K_{oc})

The USGS' "Solid/Water Partitioning of Per- and Polyfluoroalkyl Substances (PFAS) in New Hampshire Soils and Biosolids: Results from Laboratory Experiments at the U.S. Geological Survey" data release summarized laboratory testing by USGS of soils collected from New Hampshire locations to derive sample-specific solid-liquid partition coefficient (K_d) values. In their modeling efforts, Sanborn Head chose to use K_d values from USGS laboratory samples with no spiked PFAS "*because they were considered more representative of desorption (leaching) of PFAS introduced under field conditions. The spiked PFAS samples were spiked under laboratory conditions and are more representative of adsorption.*" HWRB concurred with the decision to use K_d values from unspiked samples.

Based on Sanborn Head's modeling runs and conclusions (refer to Appendix A of Sanborn Head 2023) and the complementary modeling runs performed by HWRB, HWRB chose to normalize to soil organic carbon and use K_{oc} values calculated from the USGS K_d dataset for the conceptual release scenario for derivation of the leaching-based soil value. Specifically, HWRB calculated K_{oc} values for each non-spiked USGS sample using the equation: $K_{oc} = K_d / f_{oc}$. Values for f_{oc} were obtained from the sample-specific total organic carbon (TOC) data in the USGS 2023 dataset, after correcting TOC data for moisture content. HWRB then calculated the 10th percentile for the K_{oc} dataset. The 10th percentile from the K_{oc} dataset with a f_{oc} of 0.1% (consistent with RCMP methodology) was used to derive the leaching-based soil values (refer to Table 4, above).

Limitations of the K_{oc} model for solid-phase partitioning "*include extrapolation of laboratory data for use in modeling field conditions, which may not reflect partitioning in lower f_{oc} soils, kinetics, and hysteresis*" (Sanborn Head 2023). In general, these chemical-specific limitations result in the development of lower (more protective) leaching-based values through the use of SEVIEW.

Precursor Transformation

SEVIEW, similar to other models currently available for modeling soil to groundwater leaching of PFAS, is not capable of incorporating precursor transformation to terminal compounds into the model at this time. The inability to account for precursor transformation is further rationale for to the development of protective leaching-based values; however, precursor transformation could be an important consideration in the use of site-specific leaching-based values.

Model Results and Leaching Value Calculation

Based on the modeling results and the calculation presented above, Table 5 presents a summary of model findings and calculated leaching values.

Table 5: Calculated Leaching Values

Parameter	PFOA	PFOS	PFHxS	PFNA
Maximum predicted groundwater concentration, mg/L (ppm)	1.47	0.328	1.05	0.258
Maximum predicted groundwater concentration, ng/L (ppt)	1,470,000	328,000	1,050,000	258,000
DAF	7	30	10	39
Time to reach the maximum groundwater concentration, years	0.17	1.08	0.17	1.25
AGQS, mg/L (ppm)	0.000012	0.000015	0.000018	0.000011
AGQS, ng/L (ppt)	12	15	18	11
Leaching-based soil value, mg/kg (ppm)	0.0001	0.0005	0.0002	0.0004
Leaching-based soil value, µg/kg (ppb)	**0.1**	**0.5**	**0.2**	**0.4**

Additional Abbreviations: milligrams per liter (mg/L, equivalent to ppm in water); nanograms per liter (ng/L, equivalent to parts per trillion [ppt] in water); micrograms per kilogram (µg/kg, equivalent to parts per billion [ppb] in soil)

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Attachment C

Interdepartmental Memorandum
to Michael J. Wimsatt, P.G., Director, Waste Management Division
from Jeffrey Marts, P.G., NHDES-HWRB Administrator
Re: Recommended Background Threshold Values (BTVs) for Certain Per- and
Polyfluoroalkyl Substances (PFAS) in Shallow Soil in New Hampshire
October 6, 2023

To: Michael J. Wimsatt, P.G., Director, Waste Management Division

From: Jeffrey Marts, P.G., NHDES-HWRB Administrator

RE: Recommended Background Threshold Values (BTVs) for Certain Per- and Polyfluoroalkyl Substances (PFAS) in Shallow Soil in New Hampshire:

Perfluorooctanoic acid (PFOA)	CAS RN 335-67-1	BTV = 3 ng/g[1]
Perfluorooctane sulfonic acid (PFOS)	CAS RN 1763-23-1	BTV = 3 ng/g
Perfluorohexane sulfonic acid (PFHxS)	CAS RN 355-46-4	BTV = 0.1 ng/g
Perfluorononanoic acid (PFNA)	CAS RN 375-95-1	BTV = 1 ng/g

Date: October 6, 2023

The Hazardous Waste Remediation Bureau (HWRB) considered establishing background values for per- and polyfluoroalkyl substances (PFAS). Because PFAS are anthropogenic contaminants and therefore are not naturally occurring in the environment, HWRB recommends that NHDES should not include natural background values for PFAS in the derivation of statewide Soil Remediation Standards (SRS)[2]. However, HWRB recognizes the potential for shallow soil in New Hampshire to contain ambient concentrations of PFAS, and that these PFAS concentrations vary spatially, based on the findings of a joint study between the NHDES and the United States Geological Survey (USGS) published as "Statewide Survey of Shallow Soil Concentrations of Per- and Polyfluoroalkyl Substances (PFAS) and Related Chemical and Physical Data Across New Hampshire" (Statewide Survey). Pursuant to Env-Or 606.19 (f), there are exemptions to the applicability of SRS when an ambient background condition is established at a site. As such, HWRB anticipates that parties completing site investigation and remediation pursuant to the requirements of Env-Or 600 Contaminated Site Management (Env-Or 600) rules might consider the potential for some PFAS detected in shallow soil to be related to an ambient condition and not associated with a discrete release or discharge from that site.

Based on the foregoing, HWRB calculated anthropogenic ambient background threshold values (BTVs) for PFOA, PFOS, PFHxS, and PFNA in shallow soil in New Hampshire for consideration by those working to comply with Env-Or 600 requirements. The BTVs can be used as an initial screening tool to evaluate whether detected concentrations may be attributable to background conditions in a larger area (Interstate Technology Regulatory Council "Soil Background and Risk Assessment" guidance document [ITRC 2021]). Since the distribution is variable in soil across the state, HWRB anticipates that PFAS BTVs will be one of several lines of evidence that could be used to identify potential background conditions. Other lines of evidence may include, but not be limited to, an assessment of site history, development of

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[1] Nanograms per gram (ng/kg), equivalent to parts per billion (ppb)

[2] SRS are found in the New Hampshire Code of Administrative Rules Chapter Env-Or 600 Contaminated Site Management

a site conceptual model, targeted sampling and analysis of soil horizons, and evaluation of new and existing analytical data.

To calculate BTVs, HRWB used PFAS data for shallow soil in New Hampshire available from the Statewide Survey. HWRB compared the methodology for and data from USGS' Statewide Survey to the guidance for a soil background study provided in the ITRC "Soil Background and Risk Assessment" guidance document and found the Statewide Survey data to be acceptable to use for the development of BTVs.

The calculated BTVs are derived from laboratory analytical results for shallow soil. Shallow soil is represented by soil samples collected within the top 6 inches (0.5 feet) of the soil column and the underlying 6 to 12-inch interval and are, therefore, only applicable to soils shallower than 12 inches below grade in New Hampshire. HWRB has not calculated anthropogenic ambient BTVs for deeper soil intervals, generally because (i) Statewide Survey data collected from deeper soils (i.e., soils at depths greater than 12 inches below ground surface) indicate that deeper soils in areas studied generally contain low-to-non-detectable concentrations of PFOA, PFOS, PFNA, and PFHxS; and (ii) the Statewide Survey dataset did not include a sufficient number of samples collected from deeper soils to achieve HWRB's selected confidence (95%) for the statistical analyses described in this memo.

Prior to working with the Statewide Survey data to develop a background dataset for deriving BTVs, HWRB reviewed recent publications from other states documenting derivation of statewide background values and PFAS-specific background values. These publications included: Minnesota Pollution Control Agency's "Soil Background Threshold Value Evaluation"; Sanborn, Head & Associates, Inc.'s (Sanborn Head's) "Background Levels of PFAS and PAHs in Maine Shallow Soils" prepared for the Maine Department of Environmental Protection; and the University of Vermont and Sanborn Head's "PFAS Background in Vermont Shallow Soils" prepared for the Vermont Department of Environmental Conservation.

The following sections describe HWRB's decision process to prepare the Statewide Survey data for statistical analysis of BTVs. After preparation of the dataset, statewide BTVs were estimated for the four PFAS (PFOA, PFOS, PFHxS, and PFNA) using the ProUCL 5.1/5.2 statistical software package developed by the United States Environmental Protection Agency (EPA) for analysis of environmental data sets with and without non-detect (ND) observations.

Replicate Samples

For quality assurance purposes, USGS collected field duplicate and triplicate samples for laboratory analysis from a subset of sampling locations included in the Statewide Survey. Relative percent difference (RPD) calculations for the duplicate samples were within acceptance criteria for solid samples (<50%), except for PFOA in Sample 41 (RPD of 55 %) and Sample 38 (RPD of 109%). For each sample location with replicate data (except for Sample 38 due to the very high RPD), HWRB chose to use the primary sample results for the statistical analysis dataset. HWRB used field duplicate and triplicate samples for quality assurance purposes but these samples were not included in the primary dataset for deriving BTVs. Due to the very high calculated RPD, USGS had the laboratory reanalyze Sample 38 and its duplicate sample. The RPD for the reanalyzed samples were within acceptance criteria; therefore, HWRB used the primary resample result for Sample 38 within the background dataset.

USGS collected additional soil samples from 15 locations where the analytical data indicated the need for further investigation; the results are published by USGS in a Data Release "Confirmatory Sampling for Per- and Polyfluoroalkyl Substances (PFAS) in Shallow Soils across New Hampshire, 2022." HWRB used

the additional soil samples to support the outlier screening described later in this memo but did not use the additional soil sample data in our calculations of BTVs.

Non-Detect Observations and Estimated Values

The datasets for PFOA, PFOS, PFHxS, and PFNA include estimated values (as qualified by the laboratory) and non-detect (ND) observations (i.e., results below the laboratory's method detection limits [MDLs]), as shown the in the following table.

PFAS	Number of ND Observations	Type and Number of Estimated Values
Perfluorooctanoic acid (PFOA)	4	J = 1 I = 2 H = 1 *- = 1
Perfluorooctane sulfonic acid (PFOS)	0	H = 1
Perfluorohexane sulfonic acid (PFHxS)	42	J = 48 I = 1 H = 1
Perfluorononanoic acid (PFNA)	1	J = 2 I = 2 H = 1 *- = 1

Notes:

J = result is less than the reporting limit (RL) but greater than or equal to the MDL and the concentration is an approximate value

I = value is the estimated maximum possible concentration

H = sample was prepped or analyzed beyond the specified holding time

*- = the laboratory control sample (LCS) and/or LCS duplicate (LCSD) is outside acceptance limits, low biased

HWRB used regression on order statistics (ROS) and Kaplan-Meier (KM) estimation methods for handling non-detect data within ProUCL. Consistent with EPA guidance (ProUCL Version 5.2.0 Technical Guide, dated June 14, 2022), HWRB did not use substitution methods for handling ND observations (e.g., replacing non-detect observations with the detection limit value or ½ the detection limit) when computing summary statistics and BTVs. HWRB evaluated both ROS and KM methods, and, although both estimation methods yielded similar BTVs for some of the data, HWRB selected KM estimation methods based on the distribution and skewness of the datasets, and because KM estimates are generally less sensitive to potential outliers that could be present in the dataset (Singh, Maichle and Lee, 2006).

HWRB used estimated values as reported by the laboratory within the background dataset. The majority of those estimated values were qualified by the analytical laboratory because the parameter was

detected below the laboratory RL but above the MDL. When available, values for concentrations of analytes detected below the RL that have been estimated using analytical chemistry methods for quantifying low analyte concentrations generally result in less bias than purely statistically-derived estimates for non-detect values (George *et al.*, 2021).

As previously discussed, Sample 38 was reanalyzed due to a high RPD. HWRB used the Sample 38 reanalysis results even though the sample and duplicate sample were qualified with an H flag and considered estimated because the samples were reanalyzed outside of the method holding time due to a high RPD. HWRB concluded that this data was acceptable for use because: (i) the Total Oxidation Precursor Assay analyses performed during the Statewide Study indicated limited precursor PFAS concentrations within the soil samples; and (ii) the four PFAS included in this assessment are terminal PFAS that are not anticipated to degrade to a different chemical in natural conditions.

Outliers

HWRB performed outlier screening on the dataset using Rosner's Outlier Test in ProUCL and by reviewing boxplots and normal, gamma, and lognormal Q-Q plots, as appropriate for each PFAS. Several potential outliers were identified for each of the four PFAS considered. Based on ITRC guidance, outliers should only be excluded from the data set if they are "*demonstrably erroneous or belonging to populations not representative of background conditions…[a]ll other identified outliers should be retained and processed in the same manner as the other observations in the sample*" (ITRC, 2021).

PFOA

HWRB's analysis did not exclude sample data from the BTV calculation as outliers; however, HWRB notes that the dataset includes samples that may be located within the area of air deposition from local PFOA air emission sources which may skew the PFOA BTV with a high bias. The data were not eliminated because although the Statewide Survey was designed to avoid sampling proximate to areas of known or potential PFAS releases, excluding areas impacted by known or suspected PFOA air emissions would eliminate a large geographical area and thus not satisfy the primary objective of the Statewide Survey to obtain representative statewide coverage.

PFOS

HWRB identified no potential outliers in the PFOS dataset that were "*demonstrably erroneous or belonging to populations not representative of background conditions*" (ITRC, 2021) and, therefore, did not exclude potential outliers from the dataset.

PFHxS

In accordance with recommendations for treatment of non-detect observations in the ITRC 2021 guidance document, HRWB excluded PFHxS results for Sample 36 and Sample 67 from the dataset because PFHxS was not detected above the MDLs in these samples and the RLs for the samples were greater than the highest detected value of PFHxS. HWRB excluded these samples from the dataset as the use of such data may introduce uncertainty in the estimation methods for non-detect data (ITRC, 2021).

PFNA

HWRB excluded the PFNA value for Sample 96 for the following reasons:

- The detected value for PFNA at Sample 96 was an extreme outlier of the PFNA data set (7.2 ng/g compared to 1.8 ng/g for the second highest value in the data set).

- The elevated detected concentration of PFNA appeared inconsistent with (i.e., much greater than) the detected values of other PFAS in Sample 96.

- USGS collected two confirmatory and two duplicate confirmatory samples (for a total of four additional soil samples) from the Sample 96 locality. The four additional PFNA results were generally consistent with each other (detections ranging from 0.48 ng/g to 0.5 ng/g) but not with the original detected value of 7.2 ng/g. In addition, detected values for PFOA and PFHxS and, to a lesser extent, PFOS for each of the five samples collected from Sample 96 were relatively consistent with each other.

- The derived statewide BTV for PFNA including Sample 96 was twice the value of the BTV derived without Sample 96 (1.8 ng/g versus 0.9 ng/g), indicating that inclusion of Sample 96 skewed the BTV high.

Statistical Analysis

As stated previously, BTVs were estimated for PFOA, PFOS, PFHxS, and PFNA using EPA's ProUCL 5.1/5.2 statistical software package.

Dataset distributions were determined using stand-alone goodness-of-fit (GOF) tests in ProUCL prior to calculations of summary statistics and BTVs. GOF summaries are also included with ProUCL's BTV output summaries. Options for dataset distribution include parametric (normal, gamma, or lognormal distribution) or nonparametric, with preference for distributions in that order.

HWRB evaluated the following methods for calculating BTVs (USEPA 2022):

- 95% Upper Percentile

- 95% Upper Prediction Limit (UPL95)

- 95% Upper Simultaneous Limit (USL95)

- 95% Upper Tolerance Limit with a 95% confidence level (UTL95-95)

The UPL95 represents an upper limit below which (or equal to which) a single sample collected from the representative (i.e., background) population/environment would fall with 95% confidence. With many samples compared to this value (in this case, an unknown number [n] of future samples may be compared to a BTV for the entirety of the state), use of a UPL can lead to high false positive rates. Similarly, use of the 95% upper percentile can also lead to high false positive rates.

The USL95 represents an upper limit where all current or future samples collected from the representative (i.e., background) population/environment would be equal to or less than the USL95 with 95% confidence. The USL95 has the lowest false positive rate of the potential BTVs, and calculation of this value accounts for data variability; however, it has the potential for a large number of false negatives (i.e., a large number of soil concentrations collected from sites that are actually contaminated would not exceed the USL and be classified as background). USLs are not recommended if a dataset represents several geological formations and/or soil types or may contain outliers (USLs have a high sensitivity to outliers).

The UTL95-95 represents an upper limit where 95% of current or future samples collected from the representative (i.e., background) population or environment would be equal to or less than the UTL95-95 with 95% confidence. Parametric (i.e., based on a known distribution) UTLs account for data variability, whereas nonparametric (i.e., based on an unknown distribution) do not. When using a

UTL95-95 as a BTV, the false positive error rate is no more than 5% regardless of the number of future observations that will be compared to the BTV.

Based on the above considerations, HWRB chose the UTL95-95 to calculate the New Hampshire statewide BTVs for PFOA, PFNA, PFOS, and PFHxS.

Calculated BTVs

HWRB selected a statewide shallow soil BTV (UTL95-95) to represent BTVs in the 0-to-6-inch soil sample depth for each of the four regulated PFAS. HWRB selected the statewide dataset because after calculating BTVs for several different subsets of PFAS data from the USGS Statewide Study (0-to-6-inch sample depth) relatively limited variation was observed between BTVs calculated for each PFAS data subset. The data subsets included:

- For PFOS, PFOA, PFHxS, and PFNA:

    o The entire state.

    o Considering total organic carbon (TOC) concentrations from each Statewide Survey sample location.

    o Considering mean population density around each sample location.

- For PFOS and PFOA only:

    o the northern portion of New Hampshire (Coos, Grafton, Carroll, Belknap, Sullivan, and Merrimack Counties) and for the southern portion of New Hampshire (Strafford, Cheshire, Hillsborough, and Rockingham Counties).

- For PFOS only:

    o Considering mountain versus lowland regions.

In addition, HWRB calculated BTVs for the 6-to-12-inch sample depth datasets for PFOA, PFOS, and PFNA. In summary:

- BTVs calculated for the 6-to-12-inch depth interval for PFOA and PFNA were approximately the same as their respective 0-6-inch depth interval BTVs.

- BTVs calculated for the 0-to-6-inch and 6-to-12-inch depth intervals for PFOS were similar.

- There were not enough detected concentrations of PFHxS to support the derivation of a 6-to-12-inch BTV for PFHxS.

Based on these calculations, HWRB considers that the statewide shallow soil BTVs calculated for samples collected from the 0-to-6-inch depth interval also may be used as an initial screening tool to assess potential anthropogenic ambient background impacts to soil samples collected from 0-to-12-inch depth intervals.

Refer to Table 1 for the BTVs calculated for each of the above data subsets. Refer to the attached Figures 1 through 4 for visual depictions of the USGS 0-to-6-inch soil data for PFOA, PFOS, PFHxS and PFNA, respectively, used in the background assessment.

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TABLE 1 - SUMMARY OF CALCLUATED BACKGROUND THRESHOLD VALUES (BTVs) FOR SELECT DATASETS

Data Subset		BTV [1,2] Perfluorooctane sulfonic acid (PFOS) (ng/g, ppb)	BTV [1,2] Perfluorooctanoic Acid (PFOA) (ng/g, ppb)	BTV [1,2] Perfluorohexane sulfonic acid (PFHxS) (ng/g, ppb)	BTV [1,2] Perfluorononanoic acid (PFNA) (ng/g, ppb)
Full State 0-6 in (100 samples)	-	3	3	0.1	1
Full State 6-12 in (50 samples)	-	2	3	-	1
Region split	Southern 6[3]	4	4	-	-
	Northern 4[4]	3	2	-	-
Physiography Split	Lowlands	4	-	-	-
	Mountains	3	-	-	-
Considering Total Organic Carbon (TOC) (median 36,000 mg/kg)	Above median	4	3	0.2	1
	Below median	2	3	0.1	1
	Above 62,000 mg/kg[5]	4	3	-	2
	Below 62,000 mg/kg[5]	3	3	-	1
Considering Population Density (median 14.4 persons/sq. km)[6]	Above median	3	3	0.1	1
	Below median	3	2	0.1	1

Notes:

1. Data used for the calculation of BTVs, including TOC data for evaluating TOC data subsets, are from the "Statewide Survey of Shallow Soil Concentrations of Per- and Polyfluoroalkyl Substances (PFAS) and Related Chemical and Physical Data Across New Hampshire" prepared by the United States Geological Survey (USGS), available at: https://www.sciencebase.gov/catalog/item/61f43d6cd34e622189bbb0c4.

2. BTVs shown represent 95% one-sided Upper Tolerance Limits (UTLs) with 95% coverage calculated using ProUCL 5.1/5.2 software (https://www.epa.gov/land-research/proucl-software).

3. "Southern 6" refers to six counties in southern New Hampshire that include: Cheshire, Hillsborough, Merrimack, Rockingham, Strafford, and Sullivan.

4. "Northern 4" refers to four counties in central and northern New Hampshire that include: Belknap, Carroll, Coos, and Grafton.

5. Value selected from the USGS Statewide Survey dataset as representing a cutoff value for high concentrations of TOC relative to the remaining dataset.

6. Population density data are the 2010 United States Census data from the "U.S. block-level population density rasters for 1990, 2000, and 2010," prepared by USGS and available at: https://www.sciencebase.gov/catalog/item/57753ebee4b07dd077c70868.

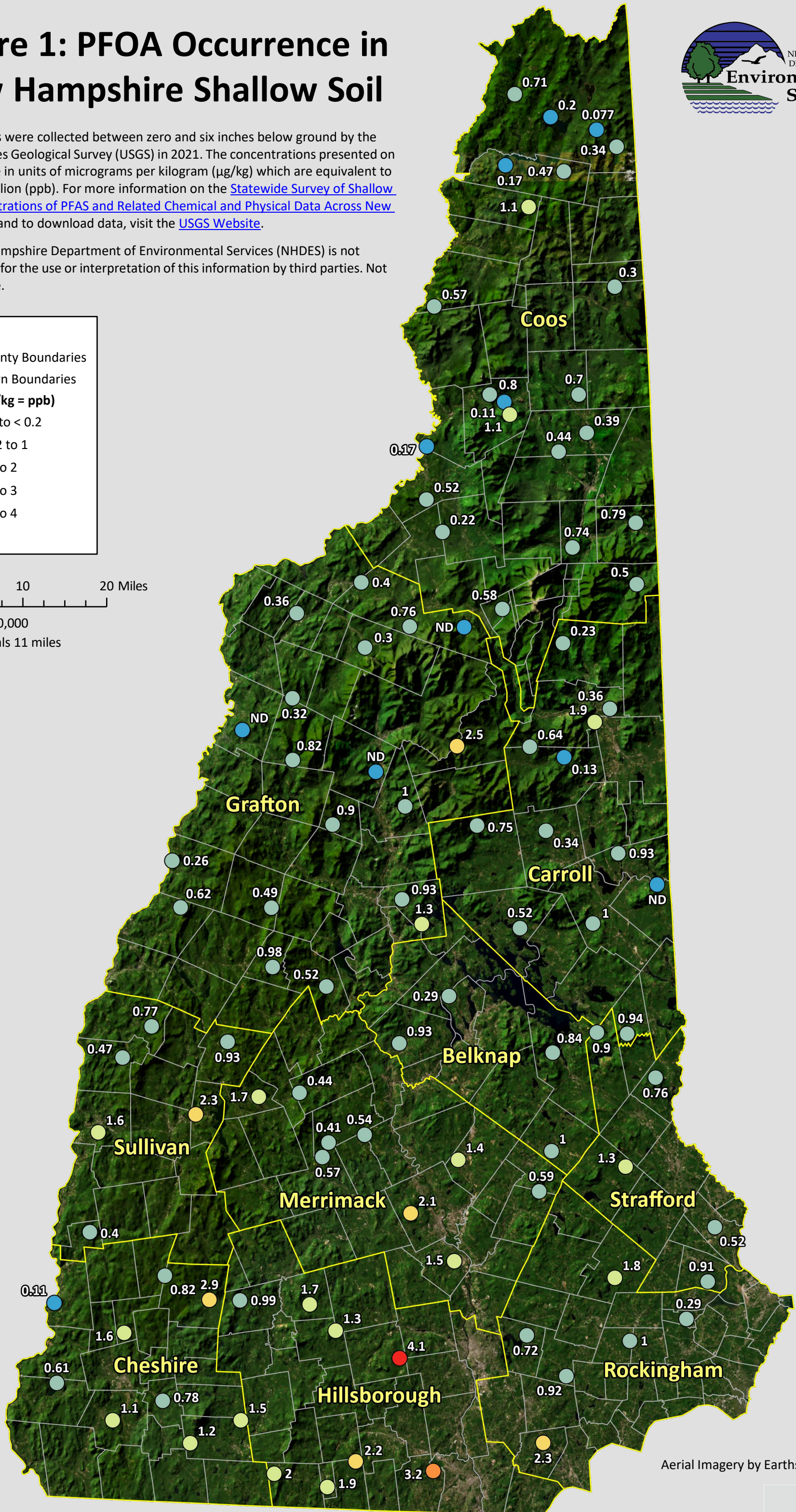7. Values are rounded to the nearest integer.

Figure 1: PFOA Occurrence in New Hampshire Shallow Soil

Soil samples were collected between zero and six inches below ground by the United States Geological Survey (USGS) in 2021. The concentrations presented on the map are in units of micrograms per kilogram (µg/kg) which are equivalent to parts per billion (ppb). For more information on the Statewide Survey of Shallow Soil Concentrations of PFAS and Related Chemical and Physical Data Across New Hampshire and to download data, visit the USGS Website.

The New Hampshire Department of Environmental Services (NHDES) is not responsible for the use or interpretation of this information by third parties. Not for legal use.

Legend

- ▭ County Boundaries
- ▭ Town Boundaries

PFOA (µg/kg = ppb)

- ● ND to < 0.2
- ● >0.2 to 1
- ● >1 to 2
- ● >2 to 3
- ● >3 to 4
- ● >4

0   5   10   20 Miles

Scale: 1:700,000
1 inch equals 11 miles

Aerial Imagery by Earthstar Geographics

Figure 2: PFOS Occurrence in New Hampshire Shallow Soil

Soil samples were collected between zero and six inches below ground by the United States Geological Survey (USGS) in 2021. The concentrations presented on the map are in units of micrograms per kilogram (µg/kg) which are equivalent to parts per billion (ppb). For more information on the Statewide Survey of Shallow Soil Concentrations of PFAS and Related Chemical and Physical Data Across New Hampshire and to download data, visit the USGS Website.

The New Hampshire Department of Environmental Services (NHDES) is not responsible for the use or interpretation of this information by third parties. Not for legal use.
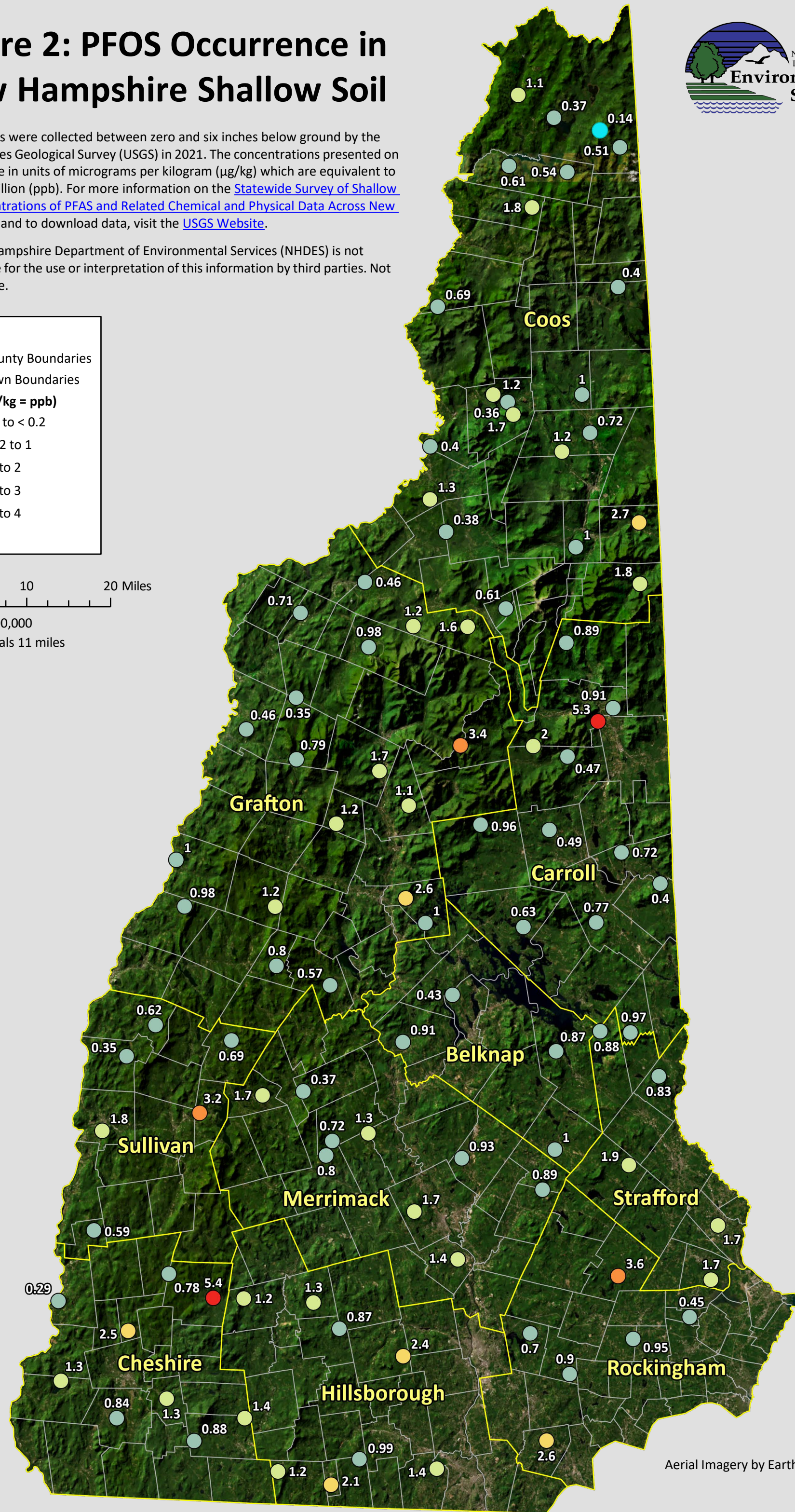
Legend

- County Boundaries
- Town Boundaries

PFOS (µg/kg = ppb)
- ND to < 0.2
- >0.2 to 1
- >1 to 2
- >2 to 3
- >3 to 4
- >4

Scale: 1:700,000
1 inch equals 11 miles

Aerial Imagery by Earthstar Geographics

Figure 3: PFHxS Occurrence in New Hampshire Shallow Soil

Soil samples were collected between zero and six inches below ground by the United States Geological Survey (USGS) in 2021. The concentrations presented on the map are in units of micrograms per kilogram (μg/kg) which are equivalent to parts per billion (ppb). For more information on the Statewide Survey of Shallow Soil Concentrations of PFAS and Related Chemical and Physical Data Across New Hampshire and to download data, visit the USGS Website.

The New Hampshire Department of Environmental Services (NHDES) is not responsible for the use or interpretation of this information by third parties. Not for legal use.
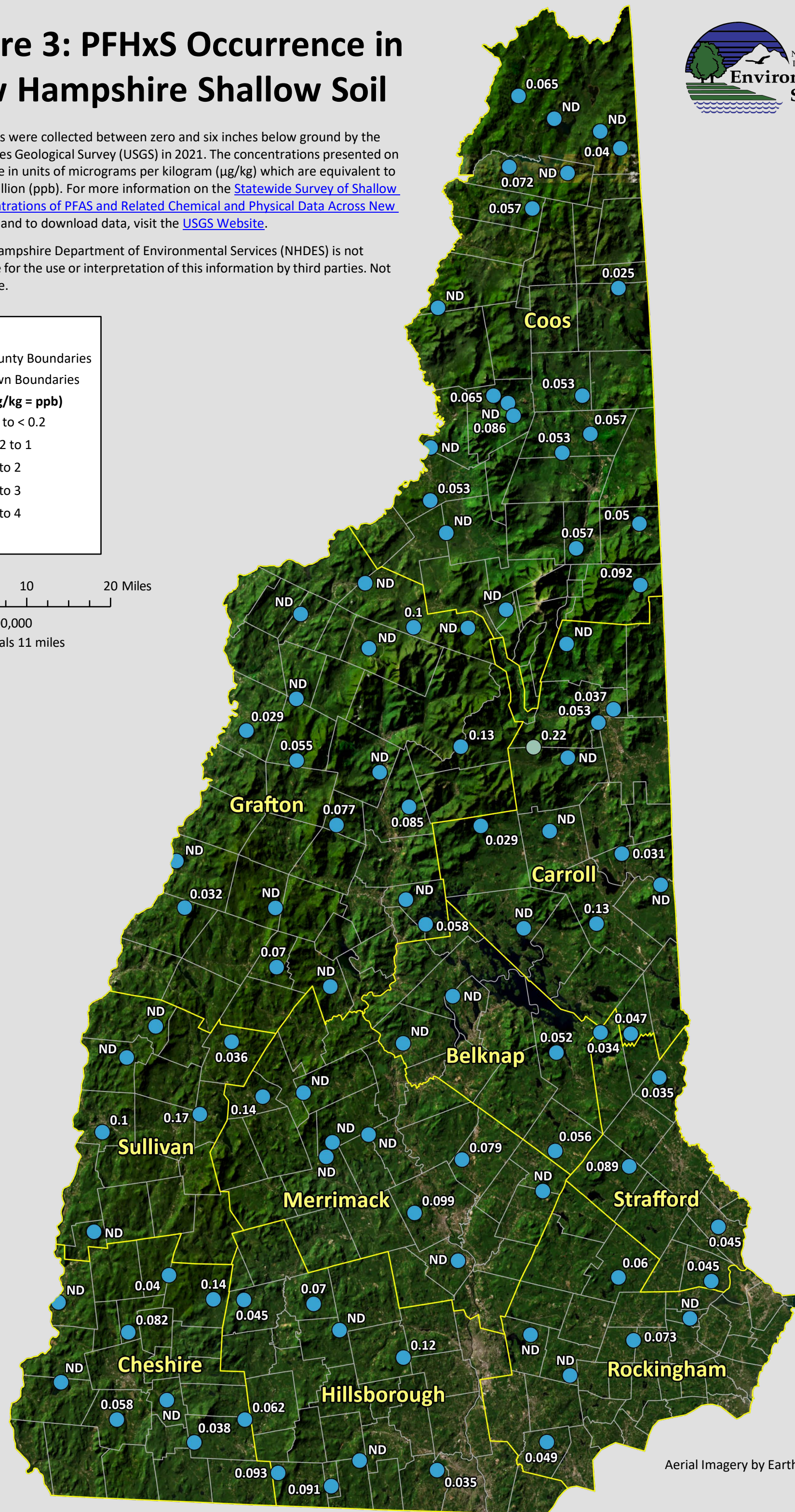
Legend

- ▭ County Boundaries
- ▭ Town Boundaries

PFHxS (μg/kg = ppb)

- 🔵 ND to < 0.2
- 🟢 >0.2 to 1
- 🟢 >1 to 2
- 🟡 >2 to 3
- 🟠 >3 to 4
- 🔴 >4

```
0   5   10        20 Miles
|—|—|—|—|—————|
```

Scale: 1:700,000
1 inch equals 11 miles

Aerial Imagery by Earthstar Geographics

Figure 4: PFNA Occurrence in New Hampshire Shallow Soil

Soil samples were collected between zero and six inches below ground by the United States Geological Survey (USGS) in 2021. The concentrations presented on the map are in units of micrograms per kilogram (µg/kg) which are equivalent to parts per billion (ppb). For more information on the Statewide Survey of Shallow Soil Concentrations of PFAS and Related Chemical and Physical Data Across New Hampshire and to download data, visit the USGS Website.

The New Hampshire Department of Environmental Services (NHDES) is not responsible for the use or interpretation of this information by third parties. Not for legal use.
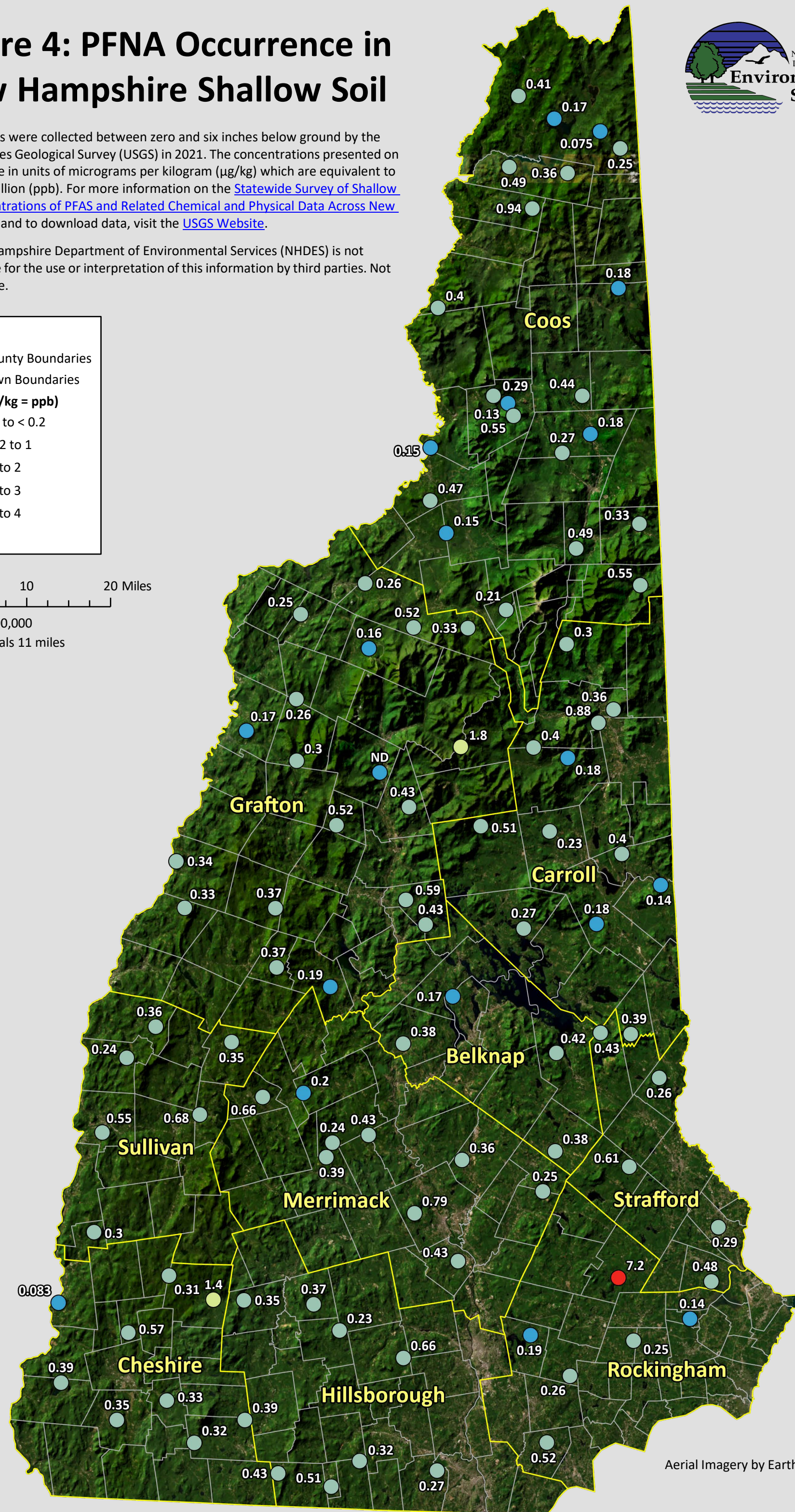
Legend

County Boundaries
Town Boundaries

PFNA (µg/kg = ppb)

- ND to < 0.2
- >0.2 to 1
- >1 to 2
- >2 to 3
- >3 to 4
- >4

0   5   10   20 Miles

Scale: 1:700,000
1 inch equals 11 miles

Aerial Imagery by Earthstar Geographics

Attachment D

Interdepartmental Memorandum
to Jeffrey Marts, P.G., NHDES-HWRB Administrator
from David B. Larson, M.P.H., Environmental Health Program
Re: Recommended Ceiling Concentrations
October 6, 2023

To: Jeffrey Marts, P.G., NHDES-HWRB Administrator

From: David B. Larson, M.P.H., Environmental Health Program

RE: Recommended Ceiling Concentrations
(milligrams per kilogram [mg/kg] = parts per million [ppm]):

Perfluorooctanoic acid (PFOA)	(S-1 = 100)	(S-2 = 500)	(S-3 = 1,000)
Perfluorooctane sulfonate (PFOS)	(S-1 = NA)	(S-2 = NA)	(S-3 = NA)
Perfluorohexane sulfonic acid (PFHxS)	(S-1 = NA)	(S-2 = NA)	(S-3 = NA)
Perfluorononanoic acid (PFNA)	(S-1 = 100)	(S-2 = 500)	(S-3 = 1,000)

Date: October 6, 2023

The Environmental Health Program (EHP) is assisting with the development of soil remediation standards (SRS) for the four PFAS compounds that have New Hampshire specific maximum contaminant levels (MCLs) and Ambient Groundwater Quality Standards (AGQS) in drinking water. One of the components of selecting an SRS for each PFAS includes the identification of a ceiling concentration. The following details the development of the soil ceiling concentration component of the SRS selection process.

The soil ceiling concentration is determined based on the odor index of the chemical, the volatility of the chemical and the soil category. The odor index for a chemical is the ratio of the vapor pressure (VP) for the chemical measured at approximately 20° to 30° Celsius (C) and the 50th percentile odor recognition threshold ($ORT_{50\%}$). Chemicals with a relatively high odor index have correspondingly lower ceiling concentrations.

$$\text{Odor Index} = VP_{20^\circ - 30^\circ C} / ORT_{50\%}$$

Volatile chemicals (those with vapor pressure greater than 1 Torr (1 mmHg) at approximately 20° to 30° C are also assigned relatively low ceiling concentrations.

The ceiling concentrations serve two main purposes: 1.) in high exposure potential areas (S-1), the ceiling concentration provides an upper limit for chemicals which may pose a risk to public health through an inhalation pathway; 2.) the ceiling concentrations provides an upper limit on allowable soil contamination which may pose a risk to public welfare and the environment. Table 1 summarizes how ceiling concentrations are assigned pursuant to the RCMP.[1]

Table 1: Assignment of Ceiling Concentrations (mg/kg = ppm)

Soil Category	Criteria	Ceiling Value Adopted
Category S-1	Odor Index > 100	100
	Vapor Pressure > 1 Torr	100
	1.0 < Odor Index < 100	500
	Odor Index < 1	1,000
Category S-2	Odor Index > 100	500
	Vapor Pressure > 1 Torr	500
	1.0 < Odor Index < 100	1,000
	Odor Index < 1	2,500
Category S-3	Odor Index > 100	500
	Vapor Pressure > 1 Torr	1,000
	1.0 < Odor Index < 100	2,500
	Odor Index < 1	5,000

Odor Index

EHP has reviewed several databases available on ToxPlanet[2] for the odor thresholds of the four PFAS compounds being considered. ToxPlanet is a content-as-a-service that provides access to content and data which encompasses hundreds of databases and has coverage of over 100 million unique compounds. The specific databases reviewed by EHP were the Hazardous Substances Database (HSDB), Haz-Map, NIOSH, and OSHA. EHP also reviewed the USEPA's CompTox Chemicals Dashboard[3] and the Agency for Toxic Substances and Disease Registry's (ATSDR) Toxicological Profile for Perfluoroalkyls[4]: Table 4-2 (Physical and Chemical Properties of Perfluoroalkyls) for information related to odor thresholds. All sources reviewed by EHP did not identify an odor threshold for PFOA, PFOS, PFHxS or PFNA. Due to the lack of an $ORT_{50\%}$ for each of the four PFAS compounds, an Odor Index cannot be used to assign a ceiling concentration at this time.

Vapor Pressure

EHP reviewed the latest version of the USEPA's Regional Screening Level (RSL) table's[5] Chemical Specific Parameters, the Interstate Technology & Regulatory Council (ITRC)[6] PFAS document's Section 4: Chemical and Physical Properties Table 4.1 and the Agency for Toxic Substances and Disease Registry's (ATSDR) Toxicological Profile for Perfluoroalkyls [7] that contain vapor pressure (VP) values. Based on the review of these sources there is a variety of methods (modeling, experimental) and conditions used in determining VPs that result in a wide range of values.

Also, many of the VPs are from secondary reference sources, including clearinghouses or chemical supply website and these Individual values have not been validated. ITRC advises "*Care must be taken when using values of vapor pressure for the PFAAs. While efforts were taken to only report values for the acid forms of these chemicals, many references are ambiguous and values for anionic forms may be reported here.*"

Table 2 provides a summary of the VPs identified. Table 2: Vapor Pressures (mmHg = Torr)

PFOA	Ref	PFOS	Ref	PFHxS	Ref	PFNA	Ref
3.0E-2	RSL[8]	6.5E-4	RSL	No value	RSL	9.5E-3	RSL
0.09	ITRC	0.002	ITRC	0.02	ITRC	0.03	ITRC
13	ITRC	0.127	ITRC	0.36	ITRC	0.15	ITRC
0.24	ITRC	2.5E-06	ITRC	0.44	ITRC	8.4	ITRC
0.03	ITRC	0.03	ITRC	8.1E-09	ITRC	0.010	ITRC
0.002	ITRC	0.25	ITRC	8.2E-09	ITRC	0.009	ITRC
2.3E-04	ITRC	0.01	ITRC	No data	ATSDR	0.002	ITRC
7.9E-04	ITRC	0.05	ITRC			1.2E-04	ITRC
0.53	ITRC	2.48E-6	ATSDR			0.001	ITRC
0.40	ITRC					3.0	ITRC
0.67	ITRC					0.14	ITRC
10	ITRC					0.07	ITRC
0.96	ITRC					0.17	ITRC
0.03	ITRC					0.008	ITRC
0.04	ITRC					0.005	ITRC
0.02	ITRC					0.010	ITRC
0.35	ITRC					4.83E-3	ATSDR
0.27	ITRC					0.133	ATSDR
0.11	ITRC					8.4	ATSDR
0.02	ITRC						
0.02	ITRC						
0.017	ATSDR						
0.962	ATSDR						
0.0316	ATSDR						

Note:

Shading indicates a Torr greater than 1.0.

Recommendations

Due to the lack of odor thresholds for the four PFAS compounds under consideration, an odor index cannot be calculated to determine a ceiling concentration. However, VPs can be used to assign a ceiling concentration. VPs greater than 1 Torr were not identified for PFOS and PFHxS, thus EHP does not recommend a ceiling concentration be assigned to these two compounds. There is a wide range of VPs available for PFOA (0.00023 to 13 Torr) and PFNA (0.001 to 8.4 Torr), with the majority being less than 1 Torr indicating a ceiling concentration should not be assigned at this time. However, there are several VPs reported for PFOA and PFNA greater than 1 Torr. To be conservative until more information about

the appropriate use of the vapor pressure data is available, EHP recommends that ceiling concentrations be assigned to PFOA and PFNA according to Table 1.

[1] New Hampshire Department of Environmental Services (NHDES). 1998. Contaminated Site Risk Characterization and Management Policy (RCMP). Appendix D: Methodology for the Determination of Ceiling Concentrations.

[2] ChemExpert. ToxPlanet, a division of Timberlake Ventures, Inc. Wilmington, NC. https://www.toxplanet.com/ (accessed April 21, 2023).

[3] United States Environmental Protection Agency (USEPA). CompTox Chemicals Dashboard. https://www.epa.gov/chemical-research/comptox-chemicals-dashboard (Last updated February 3, 2023).

[4] Agency for Toxic Substances and Disease Registry (ATSDR) (Last update March 2020, released May 2021). https://www.atsdr.cdc.gov/toxprofiles/tp200.pdf

[5] United States Environmental Protection Agency (USEPA). Regional Screening Level tables (RSL). https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables (Last updated May 2023).

[6] Interstate Technology & Regulatory Council (ITRC). *Technical Resources for Addressing Environmental Releases of Per- and Polyfluoroalkyl Substances (PFAS)*. https://pfas-1.itrcweb.org/ (Last revised October 2021).

[7] Agency for Toxic Substances and Disease Registry (ATSDR) (Last update March 2020, released May 2021). https://www.atsdr.cdc.gov/toxprofiles/tp200.pdf

[8] United States Environmental Protection Agency (USEPA). Regional Screening Level (RSL) Chemical-specific Parameters Supporting Table (Last updated May 2023).