STATE OF NEW HAMPSHIRE

Plan to Generate PFAS Surface Water Quality Standards

(Prepared for the New Hampshire Legislature in Accordance with Chapter 368, Laws of 2018)

December 30, 2019

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

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Acronyms

303(d)	Section 303(d) of the Clean Water Act, impaired waters that require a TMDL
304(a)	Section 304(a) of the Clean Water Act, EPA guidance on specific WQCs
305(b)	Section 305(b) of the Clean Water Act, an assessment of the health of all waters
AFB	Air Force Base
AGQS	Ambient Groundwater Quality Standards
AT	Averaging Time
BACT	Best Available Control Technology
BAF	Bioaccumulation Factor
BAF_{TL}	Bioaccumulation Factor, Trophic Level
BCF	Bioconcentration Factor
BCF_{l}	Baseline BAF of a sample
BCF_{T}^{t}	Total BAF from field sample
BMF	Biomagnification Factor
BW	Body Weight
CALM	Consolidated Assessment and Listing Methodology
CCC	Criterion Continuous Concentration
CF	Correction Factor
C_{m}	Consumption Rate Measured
CMC	Criterion Maximum Concentration
CR_{lim}	Consumption Rate maximum that limits
C_{w}	Water Concentration
DD	Dermal Absorbed Dose
DOC	Dissolved Organic Carbon
DPHS	Division of Public Health Services
EC_{50}	Effect Concentration – 50% Effected
ED	Exposure Duration
EF	Exposure Frequency
EHP	Environmental Health Program
EPA	Environmental Protection Agency
EV	Exposure Events
FCM	Food Chain Multiplier
FCV	Final Chronic Value
FERC	Federal Energy Regulatory Commission
f_{fd}	Fraction, Freely Dissolved
f_{l}	Fraction in Lipids
ID	Incidental Oral Dose
IIR	Incidental Water Ingestion Rate
IPP	Industrial Pretreatment Program
IR	Ingestion Rate
IU	Industrial Users

Acronyms

JLCAR	Joint Legislative Committee on Administrative Rules
K_{ow}	n-Octanol-Water Partition Coefficient
K_p	Skin Permeability Coefficient
LC_{50}	Lethal Concentration – 50% Mortality
LHA	Lifetime Health Advisory
LL	Local Limits
LPC	Loon Preservation Committee
MCL	Maximum Contaminant Level
MDR	Minimum Data Requirements
NHANES	National Health and Nutrition Examination Survey
NHDES	New Hampshire Department of Environmental Services
NPDES	National Pollutant Discharge Elimination System
NHDHHS	New Hampshire Department of Health and Human Services
PFAS	Per- and Poly-fluorinated Substances
PFBS	Perfluorobutane sulfonic acids
PFC	Perfluorinated Compounds
PFHpA	Perfluoroheptanoic acid
PFHx	Perfluorohexane sulfonic acid
PFNA	Perfluorononanoic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonate
POC	Particulate Organic Carbon
POTW	Publically Owned Treatment Works
ppb	Parts Per Billion = µg/L or micrograms per liter
ppt	Parts Per Trillion = ng/L or nanograms per liter
RfD	Reference Dose
RSC	Relative Source Contribution
SA	Surface Area
SETAC	Society of Environmental Toxicology and Chemistry
SiteNo	Site Number
SL	Screening Level
SMB	Smallmouth Bass
SQC	Sludge Quality Certification
SSD	Species Sensitivity Distribution
SUO	Sewer Use Ordinance
SWQS	Surface Water Quality Standards
TCC	Tissue Concentration Criteria
T&E	Threatened and Endangered [species]
T_e	Time of direct dermal exposure
TL	Trophic Level
TMDL	Total Maximum Daily Load
VTDNR	Vermont Department of Natural Resources
WCC	Water Concentration Criteria
WQC	Water Quality Certification
WWTF	Waste Water Treatment Facility
YP	Yellow Perch

1. Executive Summary

Chapter 368 laws of 2018 required a series of actions by the New Hampshire Department of Environmental Services (NHDES). Under this law NHDES is required to develop a plan to establish surface water quality standards for four per- and polyfluoroalkyl substances (PFAS). This plan which contains a schedule and cost estimates, is required to be delivered to the legislature for their consideration by no later than January 1, 2020. This report completes all of NHDES work under Chapter 368, further action regarding this plan, if any, will await enabling legislation and funding.

PFAS are a group of manufactured chemicals that are used in a variety of industrial and commercial products from house-hold products (such as stain repellant fabrics) to various manufacturing processes. PFAS are known as "forever chemicals" because of their persistence in the environment. These chemicals have been in production since the 1940s and are widespread in the environment. Only in the last couple of decades have the potential human and aquatic health impacts appeared in the open scientific literature. PFAS contamination of drinking water has been a particular concern in New Hampshire. Recently, as directed by the State legislature, the State adopted Maximum Contaminant Levels (MCL) for drinking water for four PFAS compounds: perfluorooctanoic acid (PFOA), perfluorooctane sulfonic acid (PFOS), perfluorohexane sulfonic acid (PFHxS), and perfluorononanoic acid (PFNA). This plan addresses the adoption of surface water quality standards for those same compounds and satisfies the requirements of Chapter 368 laws of 2018.

A great deal of scientific research goes into setting water quality criteria. To help states, and create a level of national consistency, EPA typically provides recommendations to states in the form of National Recommended Water Quality Criteria 304(a) Guidance. Presently, there is no EPA 304(a) guidance for PFAS compounds and NHDES has never created a surface water criterion for toxics.

Full surface water quality standards for PFAS could yield nine different criteria for each PFAS compound depending upon the end-point to be protected (human health or aquatic life health), the route of exposure (water consumption, tissue consumption or both), and the criteria type (acute or chronic for aquatic life health). Some of the possible criteria are fairly straight forward to calculate, some require a moderate amount of additional data collection, and some require a great deal of data collection and research. This plan presents the development cost, time for development and subsequent assessment costs for each of the possible nine criteria. Per the Clean Water Act, development of numeric water quality criteria must accurately reflect the latest scientific knowledge but does not consider the cost of implementation.

The table below summarizes of the criteria. It is important to note that the development of a criteria does not ensure the criteria will be met. In order to understand whether or not a waterbody meets a new criterion, assessment sampling data would be needed. As the table below shows, some of the criteria have lower development costs but very high assessment costs, while others have higher development costs but lower assessment costs. The costs in the table below are not additive. Each criterion is presented in the table as if it is the only criterion to be developed and then assessed. Some of the work on one criterion may also be used on other criterion. NHDES anticipates that the final decision on which criterion to pursue will be a matter of discussion and debate in the legislature, and will impact the cost estimates below. The total development and assessment costs will largely be determined by two factors – 1) the type of criteria chosen, and 2) how many waterbodies are assessed. As assessment is likely to identify some waterbodies with PFAS impacts, the investigation of the sources of PFAS will become a future, unquantified cost, and is not estimated as a part of this plan. It is important to note that this report does not include cost to regulated entities impacted by these potential standards. Such an analysis will require additional resources not included in the table below.

<table>
<tr><th>Criteria</th><th>Estimated Development Costs *</th><th>Estimated Time to Initiate Rulemaking</th><th>Estimated Assessment Costs to Determine Compliance with Criteria*</th></tr>
<tr><td>MCL adoption as Water Consumption Criteria
- Applied to waters within 20 miles upstream of surface drinking water supplies</td><td>$25,000</td><td>4-8 months</td><td>$92,000 for two-rounds of samples
Covers the 59 surface water supplies and subsequent outreach.</td></tr>
<tr><td>Establish Fish Consumption Advisory
- Determines how many fish meals are safe to eat in a week or month</td><td>$9,000</td><td>2-3 months</td><td>$547,000 - $4,747,000
Based on a 100 waterbodies probabilistic survey sampling strategy and added sampling costs based on initial sampling results and subsequent outreach.</td></tr>
<tr><td>Fish/Shellfish Tissue Criteria
- Assess tissue consumption safety based on amount of PFAS in fish/shellfish tissue</td><td>$34,000 - $120,000
Based National or New Hampshire consumption rates.</td><td>5-24 months</td><td>$547,000 - $4,747,000
Based on a 100 waterbodies targeting at-risk and high-use waterbodies and subsequent outreach.</td></tr>
<tr><td>Fish/Shellfish Water Criteria
- Assess tissue consumption safety based on a water sample</td><td>$75,000 - $741,000
Based on literature or New Hampshire specific bioaccumulation factors.</td><td>18-36 months</td><td>$153,000 for two-rounds of samples
Covers 100 waterbodies targeting at-risk and high-use waterbodies and subsequent outreach.</td></tr>
<tr><td rowspan="2">Fish/Shellfish Consumption PLUS Water Consumption Criteria
- Assess water samples based on amount of fish AND water that is safe to consume</td><td colspan="3">Combination of MCL adoption as Water and Fish/Shellfish Consumption Criteria (line 1) and Water Concentration Criteria to Protect Fish Consumption (line 4).</td></tr>
<tr><td>$75,000 - $741,000
Based on literature or New Hampshire specific bioaccumulation factors.</td><td>18-36 months</td><td>$153,000 for two-rounds of samples
Covers 100 waterbodies targeting at-risk and high-use waterbodies and subsequent outreach.</td></tr>
<tr><td>Recreational Contact
- Assess water samples for acceptable levels for physical contact with surface water</td><td>$34,000 - $120,000
Based on literature or New Hampshire specific recreation rates.</td><td>6-18 months</td><td>$540,000 for two-rounds of samples
Covers the 381 designated beaches and subsequent outreach.</td></tr>
<tr><td>Aquatic Life Use
- Assesses levels of PFAS that will impact fish and other aquatic life**</td><td>$2,525,000 - $43,225,000
Contributing or filling all data gaps.</td><td>3-8 years</td><td>$153,000 for two-rounds of samples
Covers 100 waterbodies targeting at-risk and high-use waterbodies and subsequent outreach.</td></tr>
</table>

* Approximately 8,500 distinct waterbodies in the state.

**There are four aquatic life criteria; freshwater acute, freshwater chronic, marine water acute, and marine water chronic.

The final section of this plan contains a series of specific recommendations beyond those needed to implement the plan for the development of human health and aquatic life use water quality standards. Those recommendations pertain to: the capacity to perform ongoing state-wide screening for a broad array of toxics in waters and fish tissue, the capacity of the New Hampshire state lab, action on exposure reduction approaches and outreach, costs which may be borne by regulated entities, requirements for electronic submission of sampling data to the Environmental Monitoring Database, and evaluation of a class-based approach to managing PFAS.

Given the potential costs involved in developing, assessing and complying with surface water standards we anticipate significant debate on the best use of funds to address PFAs contamination. To further this discussion, we suggest the development of a PFAS mitigation strategy to minimize further introduction of these compounds into our environment and ultimately begin to remove those currently in our waste stream.

2. Introduction

2.1. Overview of Information Presented in this Document

This plan is intended to both inform and educate the reader of the costs, timelines and possible implications of developing various PFAS surface water quality standards. To that end, the document starts with an overview of why PFAS have become a national issue and the charge presented by the New Hampshire Legislature in 2018 by the passage of HB 1101 and SB 309. Next, the reader is briefed on New Hampshire's water quality standards and typical processes of adopting new standards before there is a discussion of programs that would be impacted by any additional standards and those programs' processes. PFAS have rapidly become a nationwide issue and there are discussions about standards development in other states with whom collaboration may be of mutual benefit. A brief review of existing surface water and fish tissue sampling efforts in New Hampshire is provided to help understand the scale of the surface water issues while providing guidance on finding site specific information. The next section (section 5) addresses the human health water quality standards approaches, each with a discussion of data needs and possible timelines for studies and criteria development. The human health section is followed by a discussion of methodologies and data needs to generate robust criteria to protect aquatic life. The document closes with a section on specific recommendations to aid the State in addressing contaminants such as PFAS and a recommended order of standards development with costs and timelines for the individual components.

2.2. What are PFAS chemicals and why are they a concern

PFAS are a group of synthetic chemicals that have been used for many decades to manufacture household and commercial products that resist heat, oil, stains, grease and water. PFAS have been used in consumer products, such as non-stick cookware, stain-resistant furniture and carpets, waterproof clothing, microwave popcorn bags, fast food wrappers, pizza boxes, shampoo and dental floss. They have also been used in certain firefighting foams, known as aqueous film forming foams (AFFF) and industrial processes such as metal plating, textile coating and wire coating. Because of their widespread use, many PFAS, including PFOA, PFOS, PFHxS and PFNA, are found in our environment.

PFAS are problematic environmental contaminants because of their persistence and mobility. By design, PFAS resist degradation from heat, chemical and biochemical reactions leading to accumulation in the environment instead of decay like other organic chemical contaminants. These long-lived contaminants can mobilize through soil into groundwater and potentially local surface waters. New Hampshire's own experiences with PFAS demonstrate that these chemicals can also be released into the air by industrial processes, resulting in air deposition to soil and subsequently groundwater contamination. Together, the persistence and mobility of PFAS in environmental media has presented a significant challenge to protection of groundwater sources and these traits are expected to present novel challenges to surface water regulation.

Due to persistence and mobilization in the environment, people around the world have been exposed to PFAS. It is a recognized fact that PFAS are detected globally in the blood of people due to historical and ongoing exposure from various environmental sources. The Centers for Disease Control and Prevention (CDC) has tested for PFAS using the National Health and Nutrition Examination Survey (NHANES) and found that most people living in the United States have some detectable level of PFAS in their bodies. Similar to their persistence in the environment, PFAS are not significantly degraded by the human body nor are they readily excreted, with half-lives in the human body ranging from 2-8 years for compounds like PFOA, PFOS, PFHxS and PFNA. As such, these four PFAS are said to be highly bioaccumulative, meaning that low concentrations in food, water and the environment can result in higher concentrations in people. Thus, persistence in the environment results in ongoing exposure to humans who tend to retain PFAS in their body for years following initial exposure.

The health effects of PFOS, PFOA, PFHxS and PFNA have been more widely studied than other PFAS. Scientists are still learning about the health effects of exposures to mixtures of PFAS. The Agency for Toxic Substances and Disease Registry (ATSDR, 2018) has determined that some, but not all, studies in humans with PFAS exposure have shown that certain PFAS may:

- affect growth, learning and behavior of infants and older children.
- lower a woman's chance of getting pregnant.
- interfere with the body's natural hormones.
- increase cholesterol levels.
- affect the immune system.
- increase the risk of cancer.

For the most part, laboratory animals exposed to high doses of one or more of these PFAS have shown changes in liver, thyroid and pancreatic function, as well as some changes in hormone levels. Because animals and humans process these chemicals differently, more research will help scientists fully understand how PFAS affect human health (https://www.atsdr.cdc.gov/pfas/health-effects.html).

The broader impacts of PFAS on the health of aquatic life (for example, plants, fish, shellfish, water-fowl, aquatic mammals) have received less research than the human health impacts. There is sufficient evidence demonstrating that long-chain PFAS, such as PFOS and PFHxS, are bioaccumualtive in wildlife, leading to magnification of PFAS concentrations in aquatic food webs used by aquatic animals and humans alike. However, there is very limited information to determine what environmental concentrations of PFAS present direct health risks to wildlife.

Addressing PFAS requires acknowledgement of significant challenges including their unique chemistry and long-term persistence in the environment. PFAS have been with us for many decades and will be in the environment for potentially hundreds of years to come. Directing efforts to reduce exposure for the most susceptible species (for example, humans versus aquatic organisms) and their subpopulation (for example, offspring and future generation) is essential to ensuring adequate standards that are protective of surface water resources for all users. This document describes the possible steps to utilize surface water quality standards to address the risks associated with PFAS.

2.3. *Legislative Charge*

Chapter 368 laws of 2018 requires a series of actions to be taken by NHDES. Regarding Surface Water Quality Standards, the Legislature requires the commissioner to develop a plan, including a schedule and cost estimates, to establish surface water quality standards for PFOS, PFOA, PFNA and PFHxS in class A and class B waters for all designated uses. The plan is due to the house resources, recreation, and development committee and the senate energy and natural resources committee by January 1, 2020.

This plan is the response to that 2018 legislative charge.

2.4. *Overview of the Surface Water Quality Standards*

The principal objectives of the Federal Water Pollution Control Act (commonly referred to as the Clean Water Act, CWA)[1] are to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters.[2]" To meet these objectives, the CWA and federal regulations direct states and authorized tribes to adopt water quality standards – the foundation for protecting waters.[3]

Water quality standards are provisions of state law approved by EPA that describe 1) the desired uses (for example, swimming, aquatic life integrity) of a waterbody, 2) the water quality necessary to protect the uses, and 3) how to maintain the condition of high quality waters that currently support their desired use(s). Water quality *criteria* are specific measures in the standards that are used to determine if the desired uses are being attained. Criteria can be either numeric (for example, pH should be between 6.5 and 8.0) or narrative (for example, all surface waters shall be free from substances in kind or quantity that settle to form harmful benthic deposits). Water quality standards in New Hampshire are found in administrative rule Env-Wq 1700 and RSA 485-A:8. All existing water quality criteria in New Hampshire for toxics originate from EPA through CWA 304(a) guidance (see section 2.4.1). The reason for this is that EPA is staffed and resourced to develop such criteria and states are not. While a few states are looking into surface water quality criteria for PFAS, only two states, Minnesota and Michigan, have actually promulgated any water quality criteria for PFAS. NHDES needs to ensure that that any proposed criteria are developed with the latest science, addressing impacts to New Hampshire-specific uses (for example, the fish species that actually live here), and with the proper assumptions. Failure to adequately address all these issues could have unnecessary impacts. As such, both the proposed schedule and budgets in this document may seem conservative, but are best estimates and may have to be modified as new science is published or data are made available.

The process for adopting or updating water quality criteria in the standards is rigorous and typically occurs during the CWA required triennial review of the State's water quality standards. The process involves:

1) An evaluation of EPA's CWA Section 304(a) Guidance.
2) Review of data on the effects of pollutants of concern.
3) A process to receive public input including a public hearing.[4]
4) A submittal of the review to EPA.

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[1] 33 U.S.C. §§1251 et seq. (1972)
[2] 33 U.S.C. §1251(a), FWPCA, §101(a)
[3] 33 U.S.C. §1313(c), 40 CFR 131.11
[4] 33 U.S.C. §1313(c), FWPCA §303(c), 40 CFR 131.20

5) A formal state administrative rule-making process.
6) A submittal of the final new or revised water quality standards to EPA for review and approval.
7) The EPA must then approve proposed standards before they can be used in federal discharge permits and other federal actions.[5]

2.4.1. CWA 304(a)

A great deal of scientific research goes into setting water quality criteria. To help states and provide a level of national consistency, EPA provides recommended water quality criteria, as required under CWA Section 304(a), and referred to as the National Recommended Water Quality Criteria[6] 304(a) Guidance. Criteria in EPA's 304(a) guidance are the result of multidisciplinary task groups, public input and peer review. They are well vetted by the scientific and regulated community. The states are particularly reliant on EPA guidance for setting toxic criteria, given the complexity of the science and analysis. States can adopt 304(a) criteria as is or they can adjust those criteria to reflect the ecology and water chemistry of their state or they can adopt different criteria based on other scientifically-defensible methods so long as the adjusted criteria or criteria based on different methods are as, or more protective than, the 304(a) criteria. NHDES has never created a criterion for toxics from scratch. Presently, there is no EPA 304(a) guidance for PFAS compounds. The potential scope of a criteria document can be seen in the recent "Final Aquatic Life Ambient Water Quality Criteria for Aluminum – 2018" (EPA, 2018). The aluminum criteria document covers just one designated use, aquatic life, and only covered freshwater aquatic life. The final dataset used 60 species tests for chronic criteria, 118 species tests for acute criteria, and covered aquatic life including; fish, invertebrates, mollusks and an amphibian. Those tests produced final criteria that vary based on changes in pH, total hardness, and dissolved organic carbon (DOC). Additionally, there were hundreds of other species tests from the literature that could not be used in the derivation of the final criteria. The development of the aluminum criteria spanned three years without accounting for the acute and chronic toxicity lab studies. The aluminum process gives insight as to why states rely on EPA's 304(A) guidance for most standards.

The development of numeric water quality criteria must accurately reflect the latest scientific knowledge (CWA 33 U.S.C. §304(a)[7]) and as such, does not consider the cost of implementation. Federal regulations 40 CFR 131.11(a) states:

> *"States must adopt those water quality criteria that protect the designated use. Such criteria must be based on sound scientific rationale and must contain sufficient parameters or constituents to protect the designated use. For waters with multiple use designations, the criteria shall support the most sensitive use."*

The process by which water quality standards are implemented can accommodate for attainability and/or economics through: anti-degradation process (NH Env-Wq 1708, CWA 40 CFR § 131.12), compliance schedules (NH Env-Wq 1701.03, CWA 40 CFR § 122.47), and use attainability analysis (NH Env-Wq 1709.02, CWA 40 CFR § 131.10). The economic impacts considered are those that result from

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[5] EPA has 60 days to approve the state water quality standards or 90 days to disapprove and specify modifications. The state has 90 days following the EPA's notification of disapproval to adopt the modifications and resubmit for EPA approval. Otherwise, EPA must the promptly promulgate the necessary federal water quality standards. 33 U.S.C. §1313(c), FWPCA §303(c), 40 CFR 131.22

[6] 33 U.S.C. §1314(a), FWPCA, §304(a)

[7] 33 U.S.C. §1314(a), FWPCA, §304(a)

treatment beyond that required by technology-based regulations for point source discharges and reasonable Best Management Practices (BMP) applied to nonpoint sources (EPA, Interim Economic Guidance for Water Quaity Standards-Workbook, 1995). When numeric water quality standards are adopted by the State, only the latter two (compliance schedules and use attainability analysis) would apply to existing conditions and operations while anti-degradation could apply to any new discharge or increased activity. The development of these tools is independent of the criteria development process. How water quality standards might impact other programs is discussed in Section 2.5.

2.4.2. State Surface Water Quality Standards

In New Hampshire, the process for adopting or updating water quality criteria in the standards typically starts with a review of EPA 304(a) guidance. The process of changing a standard is normally a multi-year effort including a rigorous evaluation of data, informal discussion of criteria with the Water Quality Standards Advisory Committee (WQSAC) (Section 2.4.3), public input and a formal administrative rule-making.

Water quality standards are comprised of three main parts; 1) the designated uses (for example, swimming, aquatic life integrity) (Table 1), 2) numeric and/or narrative criteria to protect those uses, and 3) an antidegradation policy. Numeric criteria commonly have three components; magnitude, frequency and duration. For example, the chronic criteria for arsenic to protect freshwater aquatic life is set at a four-day average of 150 ug/L not to be exceeded more than once in every three years.

All surface waters of the state are legislatively classified as either Class A or B, with the majority of waters being Class B. Designated uses represent the uses that a waterbody should support. There are six designated uses in New Hampshire Administrative Rules Env-Wq 1707.17 (Table 1). Except for shellfish consumption, all designated uses apply to all waters of the state.

Table 1. Designated Uses for New Hampshire Surface Waters

Designated Use	NH Code of Administrative Rules (Env-Wq 1702.17) Description
Aquatic Life Integrity	The surface water can support aquatic life, including a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of similar natural habitats of the region.
Fish Consumption	The surface water can support a population of fish free from toxicants and pathogens that could pose a human health risk to consumers.
Shellfish Consumption	The tidal surface water can support a population of shellfish free from toxicants and pathogens that could pose a human health risk to consumers.
Potential Drinking Water Supply	The surface water could be suitable for human intake and meet state and federal drinking water requirements after adequate treatment.
Swimming and Other Recreation In and On The Water	The surface water is suitable for swimming, wading, boating of all types, fishing, surfing, and similar activities.
Wildlife	The surface water can provide habitat capable of supporting any life stage or activity of undomesticated fauna on a regular or periodic basis.

The second major component of the water quality standards is the *criteria*. Criteria are designed to protect the designated uses of all surface waters and may be expressed in either numeric or narrative form. A waterbody that meets the criteria for its assigned classification is considered to meet its intended use. The methodology to develop water quality criteria differs by designated use. Water quality criteria for each classification may be found in New Hampshire Revised Statutes Annotated RSA 485-A:8 and New Hampshire Administrative Rules Env-Wq 1700 (NHDES, 2016).

The third component of water quality standards is antidegradation, which is a provision designed to preserve and protect the existing beneficial uses and to minimize degradation of the state's surface waters. Antidegradation regulations are included in Part Env-Wq 1708 of the State's surface water quality regulations. According to Env-Wq 1708.03, antidegradation applies to the following:

- Any proposed new or increased activity, including point and nonpoint source discharges of pollutants that would lower water quality or effect the existing or designated uses.
- A proposed increase in loadings to a waterbody when the proposal is associated with existing activities.
- An increase in flow alteration over an existing alteration.
- All hydrologic modifications, such as dam construction and water withdrawals.

2.4.3. Water Quality Standards Advisory Committee (WQSAC)

The Water Quality Standards Advisory Committee (WQSAC) was established in the fall of 2000 to assist the agency in drafting and revising water quality regulations. The purpose of the committee is to facilitate public input, solicit advice and provide a forum for the discussion of focused issues. According to the Organizational Principles, the WQSAC acts in an informal advisory capacity (for instance, no formal votes are taken) with meetings open to anyone who would like to attend. While there is no list of "members," NHDES does maintain a WQSAC distribution list, which is subject to change anytime someone requests to be added to or removed from that list. Those on the distribution list are notified of meetings by email. Most meetings have an attendance of 20 to 30 stakeholders either in person or remotely by phone/webinar. Meeting attendance varies depending on the topics for discussion that are sent out with a draft agenda in the days leading up to a given meeting. While the general WQSAC website[8] is informative the WQSAC meeting archive[9] gives the best sense of what the committee has been working on as it is the repository of the agendas, meeting hand-outs, presentations, and meeting summaries (including a list of attendees) going back to 2006.

This plan and any subsequent activities to establish surface water quality standards will be topics presented and discussed at future WQSAC meetings.

2.4.4. Joint Legislative Committee On Administrative Rules

The Joint Legislative Committee on Administrative Rules (JLCAR) was established in 1983 by the State legislature to provide legislative oversight in the area of administrative rulemaking by the agencies of the executive branch. The structure, powers and duties of JLCAR are set out in RSA 541-A:2 and RSA 541-A:13. Any proposed surface water standards will need to be presented to and approved by JLCAR before they can be implemented.

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[8] https://www.des.nh.gov/organization/divisions/water/wmb/wqs/index.htm

[9] https://www.des.nh.gov/organization/divisions/water/wmb/wqs/meetings/archives.htm

2.4.5. Triennial review, Federal submittal, and applicability

The CWA requires that states and authorized tribes, from time to time, but at least once every three years, hold public hearings to review applicable surface water quality standards (SWQS) and, as appropriate, modify and adopt SWQS under CWA Section 303(c)(1) and the EPA's implementing regulations at 40 CFR 131.20.

After public comment and within 30 days of approval by JLCAR), New Hampshire is required to submit new or revised SWQS to EPA for review and approval or disapproval. EPA then has 60 days to approve the states SWQS or 90 days to disapprove. If 90 days pass after disapproval and the state makes the necessary SWQS revisions, EPA may then approve the state SWQS. If the state does not make the necessary SWQS revisions, EPA must promptly promulgate the necessary federal SWQS.

Particularly relevant to this plan and potential future use of any developed criteria is that any such criteria will be unusable in any federal permit under the CWA until such time as EPA approves those standards. Should the situation arise wherein the State adopts a water quality standard and that standard is not approved by EPA, that standard would still be usable in any State permitting (for example, Groundwater Discharge Permitting) or could be added as a requirement in the State certification of a federal permit (for example, 401 certification of an EPA issued National Pollutant Discharge Elimination System (NPDES) permit).

2.5. Programs Affected by Surface Water Quality Standards

As described above, states establish SWQS to protect human health and aquatic life, and these standards describe the desired condition of water bodies by specific designated uses. These standards also become the legal basis for controlling pollutants from entering waterways. The three primary purposes for SWQS, planning, permitting and enforcement, are described in the sections below.

2.5.1. Planning

The typical planning cycle for the management of water quality revolves around the sampling, analysis, interpretation and response to water quality condition. The water quality standards help local organizations in the interpretation phase and then to identify targets in building management plans for their waters. Fundamentally, the development of watershed-based plans revolves around actions needed to meet standards.

2.5.1.1. New Hampshire Nonpoint Source Management Program Plan

The goal of New Hampshire's Nonpoint Source (NPS) Management Program is to protect and restore clean water in the state's rivers, lakes, estuaries and other waters from the negative impacts of NPS pollution. Specifically, the NPS Program works toward improving land management practices such that water quality in impaired watersheds is restored and water quality in healthy watersheds is not degraded as a result of land use activities. The New Hampshire NPS Management Program recognizes that NHDES must continue to work with its many partners on a watershed-by-watershed basis to improve, restore and protect New Hampshire's water resources. The 2020-2024 NPS Management Program Plan[10] (NHDES, 2019) identifies how the NPS Management Program is integrated with water quality monitoring programs, watershed management organizations, and municipalities across New Hampshire. One of the key updates for the 2020-2024 NPS Management Program Plan is a discussion of

[10] https://www.des.nh.gov/organization/divisions/water/wmb/was/documents/r-wd-19-22.pdf

emerging issues: perfluoroalkyl and polyfluoroalkyl substances (PFAS); pharmaceuticals and personal care products; and marine debris, trash and microplastics.

2.5.1.2. 305(b)/303(d) Assessments

The Surface Water Quality Assessment (SWQA) Program produces two surface water quality documents every two years, the "305(b) Report" and the "303(d) List." As the two documents use the same data, the 305(b) Report and 303(d) List were combined into one Integrated Report starting in 2002. The Integrated Report describes the quality of New Hampshire's surface waters and an analysis of the extent to which all such waters support their designated uses (section 2.4.1). While the water quality standards identify the acceptable concentration in a waterbody at a given point in time, the SWQA program produces a document called the Consolidated Assessment and Listing Methodology (CALM), which describes, in detail, how NHDES goes about interpreting real-world data as compared to those standards to make surface water quality attainment decisions for 305(b) reporting and 303(d) listing purposes. As water quality standards and scientific interpretations change, and our ability to mine and relate datasets grows, the CALM is updated to reflect those changes. During each biennial assessment cycle, the CALM is put out for public comment.

Should water quality standards be developed and approved for the suite of PFAS compounds, the SWQA program would integrate those standards into the CALM and would begin assessing all readily available surface water quality and/or fish tissue data in the following biennial report. Because the different components of the water quality standards aim to protect different designated uses, and those standards are likely to differ across the target designated uses, a given PFAS concentration can have varying impacts on the assessment outcomes. The 2018 CALM assessments of toxic substances outlines how NHDES would make those assessments (NHDES, 2019).

If a waterbody fails to meet the standards, and as PFAS would be considered a pollutant, a Total Maximum Daily Load (TMDL) study would be needed to determine the acceptable load of the PFAS compound(s), with a margin of safety, that could enter the waterbody and not exceed the water quality standard.

2.5.2. Permit Programs

Whether written by EPA, as in the case of National Pollutant Discharge Elimination System (NPDES) permits, or written by the State, which includes Water Quality Certifications and Groundwater discharge permits amongst others, permits must be written to meet the surface water quality standards. In many cases, the standards drive the technology needed to treat pollutants. There are other federal and State permits that regulate discharges to ensure that a proposed activity seeking a permit will meet State water quality standards, demonstrating the fundamental role of State water quality standards to achieve State clean water goals. These other permits are described in the following sections.

The cost of PFAS criteria to the regulated community will necessarily become a topic of future discussion. While not a factor in the development of criteria, it may be a good idea to identify funding for an analyses to quantify the expenses that the regulated community may need to spend. This will allow policy makers to explore cost-effective practices that could be employed by the regulated community to keep their concentrations below that which would trigger a permit limit. One approach to quantifying these costs would be to add a financial analyst to agency staff. The total cost of a full time Financial Analyst is about $100,000 (salary, benefits and expenses).

2.5.2.1. National Pollutant Discharge Elimination System (NPDES)

Once SWQS are established and approved by EPA for PFAS chemicals, NHDES and EPA would be in a position to regulate the discharge of these chemicals in point source discharges to surface waters under the State surface water discharge permitting program and the federal NPDES program (402 of the Clean Water Act). In New Hampshire, EPA-New England issues NPDES permits that must meet State surface water quality criteria. This means that if there is reasonable potential for a discharge to cause or contribute to an exceedance of a water quality criteria in a receiving water, a discharge limit for that parameter would be added to the NPDES permit. Permit limits are determined by considering a number of factors, including the level of contaminant in the ambient (receiving) water concentration, the concentration in the effluent (the discharge after treatment), and the dilution available in the receiving water.

Ambient data would be needed to accurately assess what is already present in the receiving water. Collecting ambient data will take time and could be costly. Without ambient data, assumptions would need to be made. If a permittee disagrees with the assumptions made, they could sample the ambient water upstream of their facility and submit it to the regulators for use in developing their site-specific permit as has been done for other parameters. Analysis of the collected samples will need to be done by a lab that can get as low a detection limit as possible.

Facilities will likely not have data that characterizes the concentration of PFAS chemicals in their effluent. Typically, four rounds of samples are needed as a minimum to characterize the effluent. Sampling for PFAS chemicals will be new and more involved for facilities relative to established sampling parameters. The parts per trillion (ppt) level of detection needed for PFAS chemicals poses a challenge in taking samples without introducing contamination. Facilities may end up contracting with a company that is specialized in sampling using clean technique protocols adapted specifically for PFAS. Analysis of the collected samples will need to be done by a lab that can get as low a detection limit as possible.

At this point in time, removal of PFAS from a water media is most commonly accomplished by carbon adsorption. Measurements taken to date indicate that treatment in a conventional wastewater treatment system does not remove PFAS and some PFAS may end up in residuals. Refer to Section 2.5.2.3 for further discussion on Residuals. At a municipal wastewater treatment facility, options for treatment of PFAS would most likely be technically challenging and cost prohibitive. Source elimination, waste stream isolation, and possibly pre-treatment at the source, are better means to deal with PFAS that would otherwise enter the surface waters through treatment facilities' discharges and through biosolids. Refer to Section 2.5.2.2 for further discussion on Pretreatment and Section 2.5.2.3 on Biosolids.

In addition to the NPDES permits issued for wastewater treatment facility discharges, the following permits also fall under the NPDES program.

- **Municipal Separate Storm Sewer System (MS4) General Permit**: Addresses stormwater discharges from regulated small Municipal Separate Storm Sewer Systems.[11]
- **Remediation General Permit (RGP)**: Addresses discharges from contaminated sites[12]
- **Construction General Permit (CGP)**: Addresses discharges associated with construction activity and certain non-stormwater related water discharges.[13]

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[11] 40 CFR §122.28(d)
[12] 33 USC §1342
[13] 40 CFR §122.26(a)(9)(i)

- **Multi-Sector General Permit (MSGP)**: Addresses new and existing discharges of stormwater and certain non-stormwater related water discharges from industrial facilities.[14]

2.5.2.2. Industrial Pre-treatment

The Industrial Pretreatment Program (IPP) regulates the discharge of industrial wastewater into Publically Owned Treatment Works (POTW). All other wastewater (for instance, residential) is outside the regulatory purview of the IPP. The purpose of the IPP is the prevention of pass-through or interference. Pass-through is when a pollutant is not removed sufficiently by the POTW, such that it violates the NPDES Permit effluent criteria for that pollutant. Interference is when a pollutant either disrupts the operation of the POTW such that it violates an effluent criterion, or that it prevents the POTW from disposing of its sludge in a prescribed manner.

In New Hampshire, all seventy-one POTWs and hundreds of industrial users (IU) must comply with the Env-Wq 305 Industrial Pretreatment Rules. An industrial discharge permit can have a term no longer than five-years and can be modified for cause at any time prior to expiration. NHDES does NOT issue permits to IU for the discharge of industrial wastewater to a POTW, rather, NHDES approves/validates that a particular industrial discharge is in compliance with the Rules given what the IU report will be in their wastewater discharge. All permits that regulate industrial discharges are issued and enforced by the local POTW. It is important to note that not all IU are currently controlled by a permit. While all POTWs have sewer use ordinances that give the POTW legal authority to issue and enforce permits, not all POTWs have calculated local limits for specific pollutants. These local limits are enforceable only by the POTW, unless there is a local limit exceedance that causes pass-through or interference. If pass-through or interference occurs, the State or EPA can take enforcement action against the IU (and possibly the POTW). For thirteen POTWs (Claremont, Concord, Derry, Dover, Franklin (the Winnipesaukee River Basin Program), Jaffrey, Keene, Manchester, Merrimack, Milford, Nashua, Rochester and Somersworth) that are EPA-approved IPPs, the local limits are enforceable by EPA as permit limits, regardless of whether interference or pass-through occurs.

Since an IPP permit is dependent on several hard factors (the size and nature of the IU), plus whether the IU discharge could cause pass-through or interference, this typically means that many smaller IU are not under a permit system. For those IU already in the IPP program, PFAS local limits could immediately appear in their permits. If local limits developed by a POTW are in the ppt range, it may require a larger universe of IU to be pulled into the permit program of a POTW.

The POTWs process for determining the local limits for PFAS starts with the POTW effluent or sludge concentration limit, then works backwards through removal efficiencies for the particular type of POTW (generally unknown for PFAS) to determine the allowable loading at the headworks of the POTW. Once this loading limit is established, the amount of pollutant that is from non-regulated sources is subtracted and any left-over is available for allocation to IU. This amount available for allocation is then used as a basis to develop the local limits for which a public participation/review process is required before adoption into the SUO. The local limit development process requires expertise that is beyond the realm of what the typical non-IPP-approved POTW possesses, and it typically requires the use of consultants. A complicating factor is that there is no approved test method for measuring PFAS in sludge or raw wastewater; the proposed test method currently out for public comment will only cover POTW effluent.

[14] 40 CFR §122.26

This means the established methodology for determining a regulatory local limit for PFAS is currently not applicable.

To reliably determine the universe of potentially impacted IU and POTWs will in and of itself be a substantial undertaking, requiring logistical coordination between State, federal and local government and industry.

2.5.2.3. *Septage/Sludge/Biosolids*

The Residuals Management Section regulates Sludge under Env-Wq 800 and Septage under Env-Wq 1600 in New Hampshire under the authority of RSA 485 A:4 XVI-a and RSA 485 A:4 XVI-b. Should water quality standards be established, these rules would be modified as necessary to provide protections of water quality as well as any changes required for surface water quality standards. These regulations depend on four main areas of control to address PFAS concerns.

The first control is via source reduction, as residuals (sludge and biosolids) do not generate PFAS but merely convey PFAS compounds from industrial and domestic sources. Because of this, the Residuals Management Section relies on the Pollution Prevention Program[15] and the Industrial Pretreatment Program to address the issue at the source. If the public and industry were not using PFAS-containing products, we would not have an issue with PFAS passing through into residuals. Through the Industrial Pretreatment Program, NHDES has the authority to limit PFAS discharges from industry (Section 2.5.2.2). The residuals program also has best management practices that facilities can use to reduce inputs of PFAS and, in 2019, published a factsheet on the, *Interim Best Management Practices for Emerging Contaminants in Certified Biosolids*.[16]

The second control is on residuals reuse based upon residuals quality. To ensure that material designated for beneficial reuse are not negatively impacted, the residuals regulations require certification of chemical quality of all residuals being land-applied through Sludge Quality Certification (SQC) per Env-Wq 809 or an Exceptional Quality Certification (EQC) for septage per Env-Wq 1613. These standards will be based upon Ambient Groundwater Quality Standards (AGQS) for soil and the Residuals Management Section is working with the NHDES Waste Management Division to set standards that are protective of groundwater based on soil leaching ability. All SQC holders began testing for PFAS in 2019 and are reporting to NHDES any pre-treatment efforts that are taken to improve sludge quality. There are currently no EQC holders, therefore, no testing has occurred related to that certification.

The third control provides an added level of safety by dictating acceptable land application setbacks. Both the Sludge and Septage rules contain setbacks from surface waters to eliminate or minimize any impacts to surface water.

Finally, the fourth control of PFAS contamination risk is through the residuals permit system. The Residuals Section has multiple site and facility permits in the Env-Wq 800 and Env-Wq 1600 rules, which allow NHDES to address any site-specific conditions to protect both ground water and surface water quality. Permits are issued for a period of five to 10 years, depending on the type of permit. NHDES has

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[15] The NHPPP is a free, confidential, nonenforcement, pollution prevention and compliance assistance program available to all New Hampshire businesses, institutions, municipalities and agencies. https://www.des.nh.gov/organization/commissioner/p2au/pps/ppp/index.htm

[16] https://www.des.nh.gov/organization/commissioner/pip/factsheets/wwt/documents/web-29.pdf NHDES Environmental Fact Sheet: Interim Best Management Practices for Emerging Contaminants in Certified Biosolids

the ability to reissue any permit to protect human health and the environment should the applicable standards change during the life of any individual permit.

The Residuals Management Section is taking action on source control and sludge quality in order to protect ground water while the sludge and septage permit system and setbacks are being researched and monitored to identify areas for improvement that will be addressed in the rule making process.

2.5.2.4. Water Quality Certification (CWA Section 401)

The purpose of water quality certifications is to ensure, with reasonable assurance, that certain activities will comply with State surface water quality standards. In New Hampshire, there are two types of Water Quality Certification (WQC).

Under section 401 of the federal Clean Water Act (CWA) and RSA 485-A:12, III, a section 401 WQC is required for any activity (including construction or operation) that requires a federal license or permit which may involve a discharge to a surface water. Examples of federal licenses or permits include the U.S. Army Corps of Engineers section 404 permit for dredged or fill material in navigable waters, licenses issued by the Federal Energy Regulatory Commission (FERC) for hydropower and other energy projects, and discharges of wastewater and/or stormwater that require an EPA NPDES permit.

The second type of WQC (commonly called a non-401 WQC) is required under RSA 485-A:12, IV, which states that a WQC is required for any withdrawal or diversion of surface water that; 1) does not require a section 401 WQC, 2) is required to register the withdrawal volume with NHDES in accordance with RSA 488:3, and 3) was not in active operation as of September 5, 2008. WQCs can include conditions to ensure compliance with State surface water quality standards, including monitoring requirements, and often include a condition, which allows the certification to be modified if there are any substantive changes to the project that may impact surface water quality. More information regarding the NHDES WQC program may be found on the WQC Program Overview webpage (https://www.des.nh.gov/organization/divisions/water/wmb/section401/categories/overview.htm).

Should surface water quality criteria be adopted for PFAS, applicants for WQCs would need to demonstrate that their activity will not result in a violation of PFAS water quality criteria. This may involve testing for PFAS in their discharges and the receiving surface water. Depending on testing results, some Applicants may also need to install some sort of treatment to ensure compliance with State surface water quality standards. In addition to new WQC Applicants, some existing WQCs may need to be reopened and modified to include additional conditions to ensure compliance with PFAS water quality criteria.

2.5.2.5. Groundwater Discharge Permits

Establishing a PFAS standard in surface water under Env-Wq 1700 may impact groundwater discharge permit holders. The administrative rules for Groundwater Discharge Permits and Registrations (Env-Wq 402.04 (c)) require that:

> *"… Groundwater shall not contain any regulated contaminant at a concentration such that the natural discharge of that groundwater to surface water will cause a violation of a surface water quality standard established in RSA 485-A or Env-Wq 1700…" [Source. (See RN at p. i) #8955, eff 7-26-07; ss by #11036, eff 3-1-16]*

Groundwater Discharge Permits are issued for a period of five years. However, the Drinking Water and Groundwater Bureau within NHDES will be revising some permits to add PFAS into permit sampling schedules rather than waiting until permit renewal.

If the water in a groundwater compliance monitoring well exceeds the AGQS, the permittee is required to develop and implement a Response Plan (Env-Wq 402.25), which includes a receptor survey and actions to identify the source and plans to remove, treat or contain the contaminant(s) to maintain compliance with AGQS. For 1,4-Dioxane, and PFAS as of September 30, 2019 in larger systems (for example, municipal treatment works), it also may include an expanded receptor survey and investigation of sewer system users to determine the source(s).

Currently, where a permitted discharge is adjacent to a surface water and recharge may influence surface water quality, the permit includes bracketed surface water sampling (up and down gradient) to determine if the recharge causes an exceedance of any surface water quality standard.

2.5.2.6. Sites regulated under Env-Or 600 Contaminated Site Management Rules

State and federal regulated sites consist of sites where petroleum products, hazardous substances, and/or waste has been released or has the potential to be released (for instance, contaminated sites). The purpose of the Env-Or 600 - *Contaminated Site Management* rules (Env-Or 600) is to establish procedures for investigation, management and remediation of contamination from a discharge of regulated contaminants that adversely affect human health or the environment. Within Env-Or 600, there are AGQS established for four PFAS that include PFOA, PFOS, PFHxS and PFNA.

Monitoring for PFAS contamination in groundwater is on-going at several contaminated sites across the state. Where PFAS have been found to exceed the applicable AGQS, responsible parties are required to investigate the nature and extent of PFAS contamination and develop and implement an appropriate remedy to restore groundwater quality to meet the AGQS. Surface water has been sampled for PFAS at a limited number of sites to date. The basis for requesting surface water sampling in the absence of a State standard, has been if it appears that surface water may be impacted and there is a risk of that surface water body being used a source of drinking water. At certain federal-lead sites, EPA has developed site-specific PFAS screening criteria that are being implemented at those sites only.

Should SWQS be established for certain PFAS, NHDES would be able to regulate the discharge of those PFAS to surface water at contaminated sites per Env-Or 603.01 (c), which states "*Groundwater shall not contain any regulated contaminant at a concentration such that the natural discharge of that groundwater to surface water will cause a violation of surface water quality standard established in Env-Wq 1700*".

The SWQS prospectively impact existing and future cleanup sites through the incorporation of the SWQS for PFAS into investigation and cleanup requirements. The extent of contamination from a site into a surface water from current and/or past discharges will need to be determined to be able to design and implement a remedy. At this time, sites are required to restore groundwater quality to meet the AGQS in groundwater. If SWQS are appreciably lower than the AGQS and no additional dilution occurs between the sites groundwater management zone and a surface waterbody, NHDES anticipates unquantifiable investigation and cleanup costs associated with Remedial Action Plan implementation and compliance at several sites, including municipally-owned sites (for example, closed unlined landfills).

2.5.2.7. *Air Pollution Control*

The Air Resources Division of NHDES regulates and limits air emissions from a variety of sources within New Hampshire through a statewide permitting program. The New Hampshire Administrative Rules Governing the Control of Air Pollution (Rules) outline the permitting process and lists sources that require permits for air emissions, either by overall source, specific device or by pollutant. In addition, NHDES is responsible for implementing most federal air pollution control regulations. The purpose of the permitting program is to achieve and maintain air quality standards throughout the state. The Rules include established standards, called National Ambient Air Quality Standards (NAAQS), for six criteria pollutants (ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, particulate matter and lead), as well as the basis for establishing ambient air limits for air toxic pollutants.

Sources of air emissions that require permits include point sources (major stationary commercial and industrial facilities), area sources (generally small, but numerous, stationary sources like dry cleaners and print shops) and devices (individual burners, furnaces, machines, etc.).

Effective September 8, 2018, RSA 125-C:10-e Requirements for Air Emissions of Perfluorinated Compounds Impacting Soil and Water[17] stipulates:

> *"A device that emits to the air any PFCs [Perfluorinated compounds] or precursors that have caused or contributed to an exceedance of an ambient groundwater quality standard or surface water quality standard as a result of the deposition of any such PFCs or precursors from the air, shall be subject to the determination and application of best available control technology."*[18]

At this time, AGQS are the driving factors in determining if a device at an existing air emission source has caused or contributed to an exceedance as a result of deposition of PFCs or precursors and is thus subject to RSA 125-C:10-e. If NHDES determines that a *device* is subject to this law, the owner or operator of the device will be informed of this determination. The owner or operator then has six months from the date of NHDES' determination to submit a best available control technology (BACT) analysis and application. AGQS dictate the allowable groundwater concentrations of PFAS compounds which in turn are used to calculate emission limitations for the device after a BACT has been installed.

When SWQS are adopted by the State, both AGQS and SWQS would be used to determine if an *air emission source* is subject to RSA 125-C:10-e. For a new facility or an existing facility for which NHDES has not made a determination of RSA 125-C:10-e applicability, the owner or operator of the device has six months from the date of the determination to submit a BACT analysis and application. For an existing facility already subject to the law, NHDES would have to decide if the BACT analysis needs updating based on the SWQS. If NHDES makes a determination that the facility needs to update the previous BACT analysis, the facility would have to submit the revised analysis and application within six months.

2.5.2.8. *Other Permitting Programs*

There are several other permitting programs that require compliance with the State's SWQS and address activities for which NHDES does not anticipate direct PFAS concerns. Exceptions may occur where alterations to site hydrology impact an already PFAS-impacted site.

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[17] http://www.gencourt.state.nh.us/rsa/html/X/125-C/125-C-10-e.htm

[18] 125-C:10-e (c) "Surface water quality standard" means "surface water quality standard" established in or pursuant to RSA 485-A.

- **Alteration of Terrain (Env-Wq 1500)**: Protects New Hampshire surface waters, drinking water supplies and groundwater by controlling soil erosion and managing stormwater runoff from developed areas. Addresses earth moving operations, such as industrial, commercial and residential developments as well as sand pits, gravel pits and rock quarries.
- **Shoreland Permit (Env-Wq 1400)**: Establishes minimum standards for the subdivision, use and development of shorelands adjacent to the state's public waterbodies. Addresses activities that may degrade water quality, habitat function and natural shoreline stability of waterbodies.
- **Wetlands (Env-Wt 100-900)**: Addresses activities that could affect the water quality and ecological functions of wetlands systems and includes review of proposed projects that fall under federal jurisdiction, as described in the Section 404 of the CWA.[19]

2.5.3. Enforcement

It is against the law to knowingly violate water quality standards. If a standard is violated, and a specific polluter can be identified, then NHDES has enforcement authority to require compliance with those standards. This enforcement authority exists under State law and is therefore not reliant upon EPA approval of the State water quality standards.

3. Other States Overview

A 2016 study estimates that over 16 million residents in 33 states were exposed to PFAS in drinking water (Hu, et al., 2016). Approximately six million of these residents are exposed to drinking water contamination above the EPA lifetime health advisory limit of 70 ng/L for two compounds, PFOA and PFOS, individually or combined (Hu, et al., 2016). Currently, there are no federal drinking water or surface water standards for PFAS (Cordner, et al., 2019), although several states, like New Hampshire, have taken steps to address this gap.

The growing concern over PFAS found in drinking water across the country has prompted actions to evaluate other environmental media for PFAS contamination, including surface water, fish tissue, soil and sediment, and consider establishing SWQS. The lack of enforceable federal standards leaves states to pursue developing their own standards. Differences between state-level standards reflect existing policies and practices for developing environmental standards, along with the final application of standards to different environmental media.

3.1. Other States

The Interstate Technology and Regulatory Council (ITRC), has compiled information on current (2018) PFAS water values established by EPA, states and some countries.[20] To date, only two states have surface water quality criteria, Michigan and Minnesota. Section 6.4 discusses aquatic life use criteria developed by Michigan and Minnesota as well as other, and in some cases more recent, criteria developed for aquatic life from around the world.

Michigan derived its human health and aquatic life values for PFOS in 2014, the human health values for PFOA in 2011 and aquatic life values for PFOA in 2010. Michigan became aware of PFAS contamination

[19] 33 U.S.C. §1344; See: US EPA, Permit Program under CWA Section 404; See: NHDES Wetlands

[20] See: Table 4-1 contains PFAS water values in website ITRC PFAS Fact Sheets, https://itrcweb.org

in 2010 at the Wurtsmith Air Force Basin in Iosco County and recognized the need to continue to investigate the presence and sources of PFAS contamination through monitoring (Workgroup, August 2017).

Minnesota began investigating PFAS contamination in 2004, when drinking water contamination was discovered near the 3M Cottage Grove plant and related waste disposal sites in Washington County. Minnesota's site-specific criteria for PFOS and PFOA are specific to Lake Calhoon and the Mississippi River.[21] It is our understanding that Minnesota has begun to review their existing PFAS standards with an eye toward revising those criteria given the advances in the PFAS science.

At this time, no other New England state has SWQS for PFAS.

3.2. Cost Share Potential

In their 2018 legislative session, Vermont passed S-0049, which included requirements for SWQS, and stated;

> Sec. 5. VERMONT WATER QUALITY STANDARDS; PER AND POLYFLUOROALKYL SUBSTANCES
>
> (a) On or before January 15, 2020, the Secretary of Natural Resources shall publish a plan for public review and comment for adoption of surface water quality standards for per and polyfluoroalkyl substances (PFAS) that shall include, at a minimum, a proposal for standards for:
>
> (1) perfluorooctanoic acid; perfluorooctane sulfonic acid; perfluorohexane sulfonic acid; perfluorononanoic acid; and perfluoroheptanoic acid; and
>
> (2) the PFAS class of compounds or subgroups of the PFAS class of compounds.
>
> (b) On or before January 1, 2024, the Secretary of Natural Resources shall file a final rule with the Secretary of State to adopt surface water quality standards for, at a minimum, perfluorooctanoic acid, perfluorooctane sulfonic acid, perfluorohexane sulfonic acid, perfluorononanoic acid, and perfluoroheptanoic acid.

In developing this plan, New Hampshire and Vermont have been working collaboratively to: a) conduct a literature review of peer-reviewed data and reports regarding bioaccumulation factors (BAFs) and bioconcentration factors (BCFs) in aquatic organisms; and b) scope out the field of aquatic organism toxicity studies available for the states' PFAS chemicals of concern. Both New Hampshire and Vermont have discussed sharing the data and costs associated with developing SWQS to the extent practicable. It is expected that other New England states will be interested in collaborating on sampling efforts to develop regionally-relevant and scientifically-defensible BAFs.

4. Surface Water Quality Data Review

4.1. Overview

The discovery of PFAS contamination in the groundwater at multiple sites in New Hampshire led NHDES to evaluate various environmental media for PFAS contamination, including drinking water, surface water, fish tissue, soil and sediment. The documented impacts to groundwater and its potential for interactions with surface water was one of the drivers behind the 2018 legislation to build this plan to establish SWQS. More recent data from various programs across New Hampshire indicate that PFAS

[21] See: MN Department of Health, History of Perfluoroalkyl Substances (PFAS) in Minnesota.

contamination *has* occurred in other media, including soil, fish, shellfish and even the eggs of predatory birds. This section will broadly summarize available occurrence data from multiple state, federal and academic partners.

Much of this work has relied on continuously evolving laboratory methodologies for detecting PFAS at remarkably low concentrations in environmental media. EPA has approved laboratory Method 537, version 1.1 (Method 537.1) to measure some PFAS analytes in drinking water. While there are no federal standards for measuring PFAS analytes in surface waters, some laboratories across the country have modified EPA Method 537 to test surface water, fish and other environmental media, and EPA is working on validating those methods. Due to the low detection limits, risks of contamination and complex chemistry, single samples commonly run from $200-650.

4.2. Field Data at Investigation Sites

To date, most of the field data collected for PFAS have come from sites suspected to have PFAS contamination. Predictably, a number of those sites suspected to have elevated PFAS have indeed reported measurable concentrations. As such, a simple review of available data would lead one to believe that there is more PFAS contamination in surface waters than may really exist. As described in Section 4.3, there has only been one round of state-wide distributed surface water sampling. For those interested in the spatial distribution of samples, and subject to the limitations described below in Section 4.2.1, NHDES maintains a PFAS Sampling web mapping tool[22] displaying all of the investigation sites as well as samples from groundwater and surface waters. Within that map, one quickly sees that while there are areas with impacts, there are also investigation sites that yield low or no detections of PFAS.

4.2.1. Areas and Sites Being Investigated

NHDES is currently investigating a number of sites across New Hampshire for the presence of PFAS in groundwater and surface waters. Categorically, sampling is occurring based on:

- investigations into industrial uses.
- stockpiles of fire-fighting foams.
- investigations into sites suspected of intensive PFAS use, such as car wash facilities.
- waste streams including leachate from landfills and residuals from wastewater treatment facilities including both sludge and beneficial reuse biosolids.
- public water supply sampling.
- surface water sampling in the vicinity of investigation sites.

Investigation documents related to each site are available online. At this time, a simple way to identify the site number (SiteNo) of any site is to use the PFAS Sampling mapper. Navigate to your area of interest and click on the star at the site. You will then see a pop-up that includes the SiteNo.

To access the information for investigation sites from OneStop:

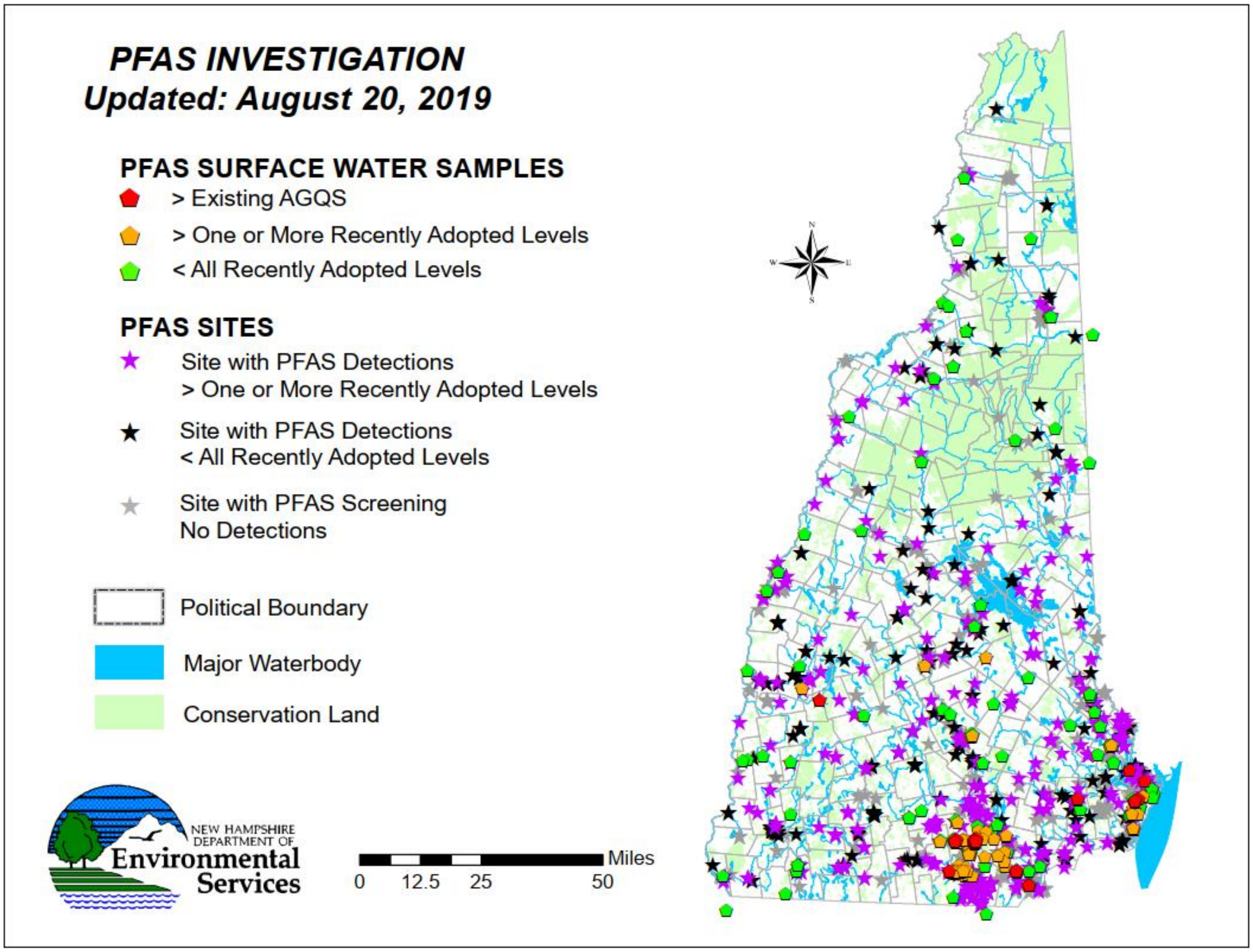
1. Visit the OneStop Data Search webpage[23].
2. In the first fill-in field: Any DES Interest Id – enter the site number

[22] http://nhdes.maps.arcgis.com/apps/View/index.html?appid=66770bef141c43a98a445c54a17720e2
[23] https://www.des.nh.gov/onestop/index.htm

3. Click “Enter”

Each of the investigation sites has its own collection of reports and findings that will not be summarized here beyond to say that the available surface water quality data in those reports will be used to the extent practicable in the ongoing development of SWQS.

Figure 1. All surface water samples (pentagons) collected as of August 20, 2019 as they relate to all of the PFAS investigation sites in New Hampshire at that time.



NHDES maintains the Environmental Monitoring Database (EMD), which was first developed in 2003 to store lake, river, estuary and ocean data. The goal was to standardize the wide variety of data sets into one database system built according to existing national data standards for use in surface water quality assessments. The EMD has been expanded over the years to include groundwater, soil and air data, with contributions from the Site Remediation, Superfund, and Air programs, as well as data from agencies outside of the NHDES, such as the Department of Transportation, University of New Hampshire, and Upper Merrimack Monitoring Program. Other organizations with New Hampshire monitoring data are encouraged to contribute data to this database. The goal of the database has been expanded toward developing a statewide repository of environmental monitoring data in a format that may be accessed by anyone over the internet. However, submission of electronic datasets is not a requirement of many of the programs and as such, it is challenging to synthesize and report on the number and nature of samples collected around the state. Table 2 summarizes the surface water quality sampling events by year at the PFAS investigation sites described in this section. The actual count of sampling results will be much higher depending upon which PFAS samples were collected during the 377 surface water sampling events in Table 2.

Table 2. Surface water sample dates count by year collected at investigation sites submitted to the department's Environmental Monitoring Database (EMD) as of August 2019.

Sample Year	Number of Surface Water Sample Dates
2016	31
2017	88
2018	219
2019*	39*

*Many labs run up to 90 days between a sampling event until data can be electronically submitted to the EMD, as such, the 2019 count as of August 2019 really represents data collected up through May while the majority of sampling occurs in the summer months.

4.3. *Statewide surface water sampling at river trend monitoring stations*

The NHDES Watershed Management Bureau maintains a river trend monitoring network encompassing 40 sites that are spatially distributed around New Hampshire (Figure 2). The trend sites were chosen to encompass a range of river sizes and a range of development pressures spread across the different geological settings of New Hampshire. From August 14-21, 2017, those sites were sampled for a suite of 26 PFAS compounds. While ancillary analytes (hardness, alkalinity, and dissolved organic carbon) were not collected on the day of the 2017 sampling for PFAS, each of these sites has, and continues to have, those analytes measured. Encouragingly, 27 of the 40 sites were nondetect for any of the tested 26 compounds (Table 3). Of the 13 sites with detections, most had few detected compounds at low concentrations and only one site, Hodgson Brook flowing from the former Pease Air Force Base (AFB), had elevated concentrations (Table 4, Figure 2). If we were to use the NHDES July 2019 Maximum Contaminant Levels as a guide, only Hodgson Brook would be flagged.

Table 3. Trend surface water sites with no detections in 2017 (n=27) across the 26 PFAS compounds.

Station ID	Waterbody Name
01-AND	ANDROSCOGGIN RIVER
01-CNT	CONNECTICUT RIVER
01-SAC	SACO RIVER
01T-SOP	SOUTH BRANCH PISCATAQUOG RIVER
01-TYB	TULLY BROOK
01X-OTB	OTTER BROOK
02-BBO	BEAR BROOK
02-CLD	COLD RIVER
02-CTC	CONTOOCOOK RIVER
02E-NSR	NORTH BRANCH SUGAR RIVER

Station ID	Waterbody Name
05-NWL	NEWELL BROOK
05-SMS	SIMMS STREAM
06-EBS	EAST BRANCH SACO RIVER
07-BLM	BELLAMY RIVER
07-FLT	FLINT BROOK
07T-ISG	ISINGLASS RIVER
08-MER	MERRIMACK RIVER
10-WNR	WARNER RIVER
14-ISR	ISRAEL RIVER
22-AMM	AMMONOOSUC RIVER

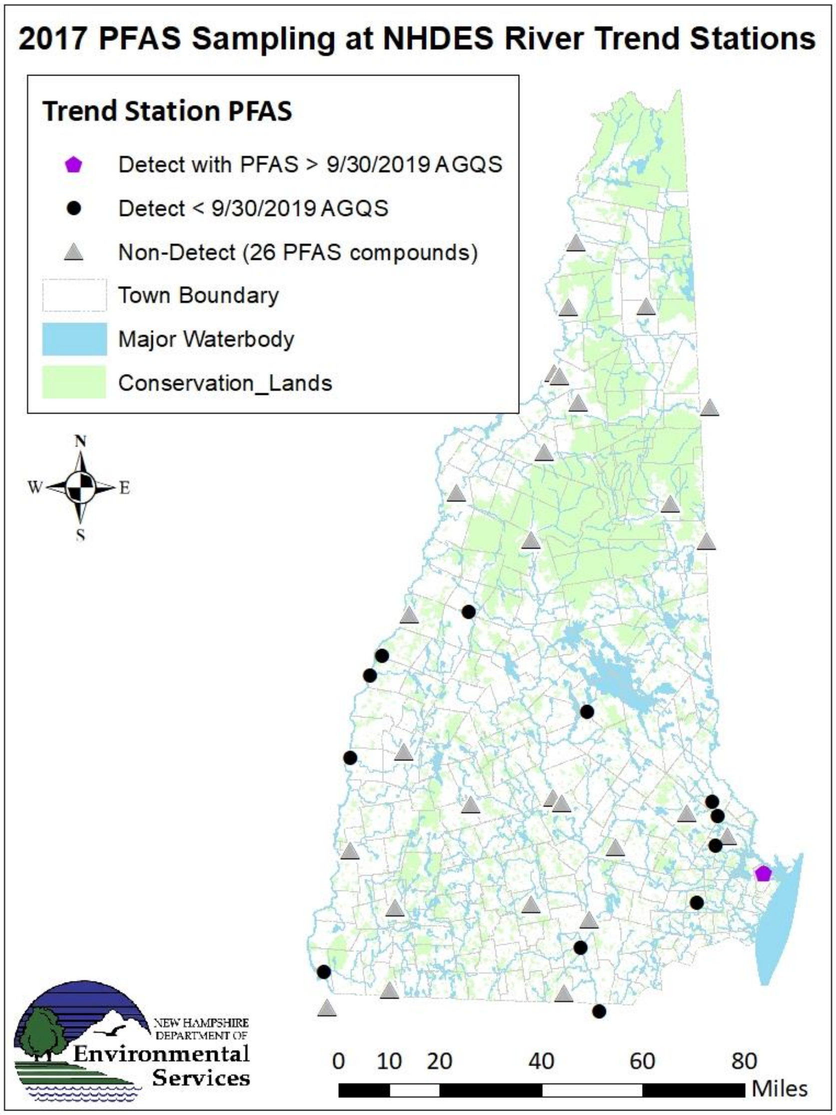
Station ID	Waterbody Name
02-GNB	GRANT BROOK
02-ISR	ISRAEL RIVER
03-AMM	AMMONOOSUC RIVER
04-SBB	STRATFORD BOG BROOK

Station ID	Waterbody Name
23-PMI	PEMIGEWASSET RIVER
27-MER	MERRIMACK RIVER
58-CNT	CONNECTICUT RIVER

Table 4. Trend surface water sites with detections in 2017 (n=13). All results are in ng/L and blanks are nondetects. Highlighted values exceed the 9/30/2019 AGQS values.

Station ID	Town	Waterbody Name	Fluorotelomer Sulfonate 6:2 – 6:2 FTS	Perfluorobutanoic Acid – PFBA	Perfluoroheptane Sulfonate – PFHpS	Perfluoroheptanoic Acid – PFHpA	Perfluorobutanesulfonic Acid – PFBS	Perfluorohexylsulfonic Acid – PFHxS	Perfluorohexanoic Acid – PFHxA	Perfluorononanoic Acid – PFNA	Perfluorooctanoic Acid – PFOA	Perfluorooctylsulfonic Acid – PFOS	Perfluoropentanoic Acid – PFPEA	TOTAL PFAS
01K-HOB	Portsmouth	Hodgson Brook	23.9	16.0	11.4	20.4	10.5	132	62.7	2.2	47.4	494	54.7	875.2
01-JWT	Laconia	Jewett Brook		2.2			14.6		2.1		2.5	5.9	2.7	29.9
02-ISG	Rochester	Isinglass River		2.7		3.6		2.1	4.5		10.8	2.3	2.8	28.7
15-EXT	Brentwood	Exeter River		3.0		2.3	3.9	3.1			5.7	4.6	4.1	26.7
01T-MKB	Hanover	Mink Brook		16.0							3.0	2	2.9	23.8
01-MER	Tyngsboro, MA	Merrimack River		2.7					4.7		5.0	2.9	3.4	18.7
18-CCH	Gonic	Cocheco River		2.3						2.6	5.5	5.1	2.9	18.3
02-SHG	Merrimack	Souhegan River							3.9		4.4	2.4	2.1	12.9
01-MSC	Lebanon	Mascoma River	2.1	4.0										6.0
09-OYS	Lee	Oyster River		2.2									3.5	5.7
02-ASH	Hinsdale	Ashuelot River		2.5								2.3		4.8
06-SBR	Wentworth	South Branch Baker River	2.4											2.4
01-SGR	Claremont	Sugar River									2.3			2.3
		Count Of Detects	3	10	1	3	3	3	5	2	9	9	9	13

Figure 2. Trend stations across New Hampshire and the detect/non-detect status of the 2017 PFAS sampling for 26 compounds.



4.4. *Key and Ongoing Studies that include Fish Tissue Sampling*

As noted above, there are many active PFAS investigation sites in the state. While all of those sites likely have groundwater data, few have surface water data and fewer still have aquatic life (for example, fish, shellfish, etc.) tissue data. Fish/shellfish tissue information is needed to understand the BAFs by species. Additionally, information on the water column pH, carbon fractions (for example, DOC, total organic carbon, percent-carbon), hardness, and alkalinity may play a factor in differing BAFs around the state and as such the presence of such data is noted in the following sections. Finally, fish/shellfish tissue information is critical in determining which waters may, or may not, need any PFAS related fish/shellfish consumption advisories. In the sections below, we have outlined instances of fish/shellfish tissue sampling that has occurred and may help in the ongoing standards development or advisory development processes.

4.4.1. Dumpling Brook

Related to the Saint-Gobain investigation in Merrimack, NH, Dumpling Brook and the Merrimack River were sampled in August 2019 for fish tissue in general accordance with a work plan submitted on October 26, 2018 and a NHDES approval letter dated March 1, 2019. As part of the work plan, the sampling occurred on August 6, 2019 after a two-week low-flow period as higher flows in Dumpling Brook are anticipated to reduce water column concentrations (fish tissue may equilibrate to the water column in a matter of weeks). In the initial August 2019 fish tissue collection effort, only the Merrimack River yielded target species of suitable size. The whole-body fish samples were submitted to a laboratory for an analysis of 16 PFAS analytes in the fillets. A preliminary fish sampling report from Saint-Gobain containing unvalidated results was submitted to NHDES on October 4, 2019.

While surface water samples from both Dumpling Brook and the Merrimack River were collected in 2017 and 2018, surface water was not sampled on the day of fish tissue collection. During the 2017 and 2018 surface water sampling, carbon fractions were not evaluated for Dumpling Brook and the Merrimack River however, previous sampling included total suspended solids, principal ions (including alkalinity as bicarbonate, ammonium, calcium, chloride, iron, magnesium, manganese, nitrate, nitrite, potassium, sodium, sulfate, and sulfite), and phosphorous (Golder Associates Inc., January 30, 2018) (Golder Associates Inc., March 15, 2019). To date, no paired water/sediment sampling has occurred; however, sediment samples were collected from the Merrimack River bank near the confluence of Dumpling Brook on September 6, 2018.

4.4.2. Berrys Brook

Berrys Brook is a waterway located on New Hampshire's Seacoast region. The headwaters of Berrys Brook receive inputs originating in the Coakley Landfill. There are water quality data for a limited number of sampling locations that were collected between 2016-2017. Some of the surface water samples include supporting water quality parameters such as temperature, pH, specific conductance, dissolved oxygen, turbidity, and oxidation reduction potential.

In June 2018, fish tissue from Berrys Brook were sampled for PFAS out of concern that PFAS runoff presented a risk for human exposure due to uptake into fish. The results of this sampling effort were compared to fish consumption screening levels (SLs) for PFOA, PFOS, and perfluorobutane sulfonic acids (PFBS), all of which were developed by EPA for site-specific and risk-based exposure conditions. A total of 178 samples were collected from nine different fish species (number of samples by species varied), but none of these were matched to water concentrations at the time of sampling. Fillets were analyzed for six PFAS compounds (PFBS, perfluoroheptanoic acid (PFHpA), PFHxS, PFOA, PFNA, and PFOS) where only PFOS was found to occur in fish tissues above the risk-based site-specific screening level (SL). In response to this observation, EPA reviewed the results and determined that exceedance of the PFOS SL indicates only that further risk assessment is appropriate. Further site-specific risk assessment concluded that the risk of consuming recreational fish from Berrys Brook is lower than EPA's risk limit (for instance, consumption of recreational fish from Berrys Brook does not pose an unacceptable risk). Read the full report of the 2018 fish tissue sampling[24] and EPA's response[25] to this report.

[24] http://www4.des.state.nh.us/IISProxy/IISProxy.dll?ContentId=4736116

[25] http://www4.des.state.nh.us/IISProxy/IISProxy.dll?ContentId=4763817

4.4.3. Pease AFB

The Pease AFB is amongst the most notable PFAS investigation sites within New Hampshire where the contamination is primarily due to historical use of aqueous film forming foam (AFFF). Fresh surface water sampling for the presence of PFAS began around the former Pease AFB in 2015 as part of the ongoing Air Force PFAS response actions following the 2014 discovery of PFOS/PFOA in an on-base municipal water supply well. Since then, additional sampling for marine surface water, sediments and shellfish has been conducted as a part of an Extended Site Inspection (ESI).

The most recent phase of fresh surface water sampling for PFAS was conducted in summer and fall 2018 as part of the ESI and included co-located sediment and water column samples within the major drainages that originate on the former base. The areas sampled included six target locations around the Newington Peninsula and three "reference" locations: two elsewhere in the Great Bay watershed beyond the influence of Pease, and one location in Hampton Harbor. Those samples included analysis for the 13 PFAS most commonly detected in thousands of Pease groundwater samples as part of initial investigations with a full laboratory analyte list of 23 PFAS. The ESI investigation did not include analysis for other water quality parameters, such as dissolved/total organic carbon, hardness, or alkalinity but did include pH, oxidation reduction potential, dissolved oxygen, temperature, conductivity and salinity.

Regarding biological sampling, shellfish species sampled from areas in the ESI included blue mussels, oysters, and softshell clams where encountered at each location in 2018 and 2019. No freshwater, estuarine or marine finfish have been sampled for PFAS as part of the Air Force's investigations. It is anticipated that the final expanded site inspection report will be published to the Air Force Civil Engineer Center Administrative Record[26] in the winter of 2019/20.

4.4.1. National Rivers and Streams Assessment

The National Rivers and Streams Assessment (NRSA) aims to evaluate the health of the nation's rivers and streams once every five years from a probabilistic survey. Probabilistic surveys are a practical and economic approach to conduct a sample survey, which involves sampling a portion of the population through probability (or random) sampling. Random sampling ensures that no particular portion of the population being sampled is favored (or biased) over another. The NRSA survey focuses on obtaining fish species that are commonly consumed by humans, that satisfy legal requirements of harvestable size for each river site (or at least consumable size if no legal harvest requirements exist), and that are sufficiently abundant within a sampling reach. For consistency across surveys, whole fish tissue samples are submitted to the laboratory for filleting and homogenization. Each whole fish tissue sample consists of five adult fish of the same species that are similar in size (for instance, the smallest individual in the sample is no less than 75% of the total length of the largest individual). Due to the multi-fish homogenizing, these data will not give a sense of variability within a waterbody/species. Results of sample surveys can be used to make statistically based inferences (for instance, probabilistic assessments) about the condition of the population as a whole.

The NRSA has included PFAS compounds in three rounds of the fish sampling protocols. First in the 2008-2009 sampling, again in the 2013-2014 sampling, and then again in the 2018-2019. In each of the three sampling rounds, 13 sites around the state were evaluated. Due to the portions of the fish likely to accumulate PFAS and the portions of fish eaten by an angler, this is likely to properly estimate the PFAS

[26] http://afcec.publicadmin-record.us.af.mil/Search.aspx

load to the consumer, unlike whole fish analysis, which is likely to overestimate PFAS load to the consumer (Dong, et al., 2019; Fliedner, Rudel, Lohmann, Buchmeier, & Koschorreck, 2018). At this time, NHDES does not have the PFAS data for those surveys but once complete, the data should be available from EPA on its National Aquatic Resource Surveys webpage[27]. Any missing pieces (for example, contaminant data for fish from the rivers and streams surveys) will require tracking down via EPA contacts.

4.4.2. Harvard Lake Fish Tissue Sampling

A research team from Harvard collected paired freshwater fish and surface water samples from nine lakes, ponds and rivers in southern New Hampshire in October 2017. The following summary of the data was provided to NHDES by the lab of Dr. Elsie Sunderland. Sampling sites included Great Pond in Kingston, Hedgehog Pond in Salem, Pine Island Pond in Manchester, Baboosic Lake in Amherst, Cocheco River in Rochester, Horseshoe Pond and Merrimack River in Merrimack, and Nashua River and Merrimack River in Nashua, NH. Eight fish species were sampled including Bluegill, Pumpkinseed, Yellow Perch, Chain Pickerel, Brown Bullhead, Lake Whitefish, Smallmouth Bass and Largemouth Bass. These fish represent two trophic levels of both pelagic and benthic species. The surface water and fish muscle (fillet) were both extracted and analyzed using LC-MS/MS for 24 PFAS compounds. Of the 24 compounds, 21 were detected in the surface water samples and 22 in the fish samples. The most abundant PFAS in the surface waters were C4-C8 perflurocarboxylic acids (for example, perfluorobutanoic acid and PFOA), PFBS, PFHxS, PFOS, and 6:2 fluorotelomer alcohol. The most abundant PFAS in the fish samples were C8-C13 PFCAs, and PFOS. The PFAS composition profiles differed between the surface water and fish samples as the long-chain PFAS and were detected at higher concentrations in the biota than the water, indicating bioaccumulation. Concentrations of PFAS in surface water and fish muscle ranged from nondetect to 650 ng/L and nondetect to 100 ng/g, respectively. Bioaccumulation factors were calculated for the paired fish and water samples and the long-chain PFCAs (C11-C14) were found to be very bioaccumulative in all eight fish species (BAF>5000). As of this time, the results of this research have not yet been published. Once published, this dataset will be helpful to supplement the information needed to understand the bioaccumulation factors of these species in these water bodies that were sampled.

4.4.3. Squam Lake

In September 2018, 55 fish were collected via hook-and-line from Squam Lake, New Hampshire for tissue analysis of 209 polychlorinated biphenyl (PCB) congeners and 14 PFAS compounds. This included 21 smallmouth bass (SMB) and 34 yellow perch (YP), which are commonly sought game fish by recreational fishers. Tissue analysis is to be conducted by EPA Office of Research and Development (EPA-ORD). For SMB, four composite samples consisting of four fish each and one composite sample of five fish were submitted to EPA-ORD for contaminant analysis representative of fillets. Similarly, six composites consisting of five YP each and one composite of four YP were submitted to EPA-ORD. As of November 2019 EPA reported that the PFAS analysis could begin by end of 2019 pending execution of the federal contract. The list of 14 PFAS analytes list expected as a part of the analysis includes:

- PFBA (Perfluorobutyric acid)
- PFBS (Perfluorobutane sulfonate)
- PFPeA (Perfluoropentanoic acid)
- PFHxA (Perfluorohexanoic acid)
- PFHxS (Perfluorohexane sulfonate)
- PFHpA (Perfluoroheptanoic acid)

[27] https://www.epa.gov/national-aquatic-resource-surveys/data-national-aquatic-resource-surveys

- PFOA (Perfluorooctanoic acid)
- PFOS (Perfluorooctane sulfonate)
- PFOSA (Perfluorooctanesulfonamide)
- PFNA (Perfluorononanoic acid)
- PFDA (Perfluorodecanoic acid)
- PFUnA (Perfluoroundecanoic acid)
- PFDoA (Perfluorododecanoic acid)
- GenX

4.5. Loon Eggs

To date, the only known PFAS wildlife sampling in aquatic birds in New Hampshire has been from collaboration with the Loon Preservation Committee (LPC). As a part of ongoing conservation and monitoring programs, the LPC collects livers from dead loons as well as eggs that have failed to hatch. Historically, their biomonitoring program measured mercury, PCBs, and flame retardants like polybrominated diphenyl ethers (PBDEs), but more recently has included PFAS in their analyses.

As a species that feeds at the top of the aquatic food chain, loons are at high risk of bioaccumulating certain contaminants found in fish. Furthermore, PFAS preferentially associate with protein-rich tissues and are therefore found at high concentration in loon eggs. This means that transfer from loons to their eggs can result in adverse effects on loon chicks. It is important to note that the presence of PFAS in unhatched loon eggs does not by itself indicate that PFAS are the causative agent. As stated by the LPC:

> "Few laboratory studies on the effects of contaminants have been conducted on loons because of the difficulty in keeping loons alive in captivity. However, these and other contaminants are present in loons in concentrations that have been shown to affect the health and/or reproductive success of other bird species. Within the next year, LPC will be releasing a comprehensive report on these contaminants and their effects on loons as part of its Squam Lake Loon Study." (Loon Preservation Committee)

Due to a lack of definitive ecotoxicity data, there is significant uncertainty about the exact levels of PFAS that may present a risks to native species, such as loons. Furthermore, the lack of regional data on the bioaccumulation and biomagnification of PFAS in aquatic food webs makes ecological risk assessment tenuous at best. This underscores a need for additional data to develop PFAS-specific criteria that would be sufficient protective of native species across all life stages.

4.6. Data/Additional Sampling Needs

Given the examples above, the existing sampling of surface water and biological tissues have various degrees of overlap, and limited supporting ancillary data. An obvious area for improvement in ongoing efforts is to pair fish tissue sampling with water column analysis. This would facilitate the calculation of bioaccumulation from the environment into various aquatic organisms. Additionally, analyses of water should, at a minimum, also include measurement of dissolved organic carbon, total organic carbon, hardness, alkalinity, water temperature, and pH to better understand how these variables may influence exposure and uptake by animal and plant life. Sediment sampling is an additional piece of supporting data that has not been thoroughly characterized in New Hampshire waters. This is partially due to a limited understanding of the role sediments play in the fate and transport of PFAS, as well as the lack or validated methods for measuring PFAS in sediments which, as an environmental matrix, can vary significantly.

5. Protection of Human Health

5.1. Human Health Water Quality Standard Criteria Options Overview

As defined by EPA, Human Health Criteria (HHC) specify the amount of a chemical that may be present in surface water, sediments or frequently consumed aquatic organisms before there is a threat to human health. This means that HHC are derived to be protective of humans, not aquatic organisms or other life that may utilize a waterbody or its resources. Section 6 of this report discusses the considerations for deriving criteria protective of aquatic organisms known as Aquatic Life Use Criteria (ALUC). Subsections 5.2 through 0 of this report review key considerations, data needs and potential challenges associated with developing HHC for PFAS.

Table 5 provides an overview of the different HHC, estimated costs and timelines for development and implementation. Each of these HHC have their own utility and limitations related to the development and implementation.

Section 5.2 provides background on the routes of exposure and key human physiology considerations for developing HHC. This includes an explanation of toxicity values used to derive criteria for PFAS and their relation to existing drinking water standards known as Maximum Contaminant Limits (MCLs). There is also an explanation of why, for biological reasons, HHC will likely range in the low parts-per-trillion (ng/L) in surface waters.

There is currently no existing parameter in Env-Wq 1700 that has criteria for all of the approaches in Table 5 and most parameters only have criteria for the first three water quality standard approaches.

Table 5: Five Human Health Criteria Approaches to Development of PFAS Water Quality Standards and One Consumption Limit Advisory Approach.

<table>
<tr><th>Criteria*
(Section Number)</th><th>Target</th><th>Pro's (+) and Con's (-)</th><th>Estimated Development Costs of Approach</th><th>Estimated Time to Initiate Rulemaking</th><th>Estimated Assessment Costs to Determine Compliance with Criteria**</th></tr>
<tr><td>MCL adoption as Water Consumption Criteria (5.3)
Applied to waters within 20 miles upstream of surface drinking water supplies</td><td>Ensure water will be acceptable for human consumption</td><td>+ Low costs for monitoring
+ Low costs and time requirements for criteria development
- Limited applicability state-wide</td><td>$25,000</td><td>4-8 months</td><td>$92,000 for two-rounds of samples
Covers the 59 surface water supplies and subsequent outreach.</td></tr>
<tr><td>Establish Fish Consumption Advisory (5.4)
Determines how many fish meals are safe to eat in a week or month</td><td>Recommend catch and consumption limits for fish and shellfish</td><td>+ Low costs and time requirements for criteria development (similar to Hg Advisories)
- High costs for monitoring
- Does not inform water concentration limits</td><td>$9,000</td><td>2-3 months</td><td>$547,000 - $4,747,000
Based on a 100 waterbodies probabilistic survey sampling strategy and added sampling costs based on initial sampling results and subsequent outreach.</td></tr>
<tr><td>Fish/Shellfish Tissue Criteria (5.5)
Assess tissue consumption safety based on amount of PFAS in fish/shellfish tissue</td><td>Ensure fish/shellfish tissues will be acceptable for human consumption</td><td>+ Low costs and time requirements for criteria development
- High costs for monitoring
- Does not inform water concentration limits</td><td>$47,000</td><td>5-24 months</td><td>$547,000 - $4,747,000
Based on a 100 waterbodies targeting at-risk and high-use waterbodies and subsequent outreach.</td></tr>
<tr><td>Fish/Shellfish Water Criteria (5.6)
Assess tissue consumption safety based on a water sample</td><td>Ensure water concentrations will allow for fish/shellfish tissues that are acceptable for human consumption</td><td>+ Low costs for monitoring
+ Opportunity for cost-sharing for criteria development with other states
+ Informs water concentration limits
- High cost and time requirements for criteria development due to data needs</td><td>$75,000 - $741,000
Based on literature or New Hampshire specific bioaccumulation factors</td><td>18-36 months</td><td>$153,000 for two-rounds of samples
Covers 100 waterbodies targeting at-risk and high-use waterbodies and subsequent outreach.</td></tr>
<tr><td rowspan="2">Fish/Shellfish Consumption PLUS Water Consumption Criteria (5.7)
Assess water samples based on amount of fish AND water that is safe to consume</td><td rowspan="2">Ensure water concentrations will allow for fish/shellfish tissues PLUS water that are acceptable for human consumption</td><td rowspan="2">+ Low costs for monitoring
+ Opportunity for cost-sharing for criteria development with other states
+ Informs water concentration limits
- High cost and time requirements for criteria development due to data needs</td><td colspan="3">Combination of MCL adoption as Water and Fish/Shellfish Consumption Criteria (5.3) and Water Concentration Criteria to Protect Fish Consumption (5.6).</td></tr>
<tr><td>$75,000 - $741,000
Based on literature or New Hampshire specific bioaccumulation factors</td><td>18-36 months</td><td>$153,000 for two-rounds of samples
Covers 100 waterbodies targeting at-risk and high-use waterbodies and subsequent outreach.</td></tr>
<tr><td>Recreational Contact (5.8)
Assess water samples for acceptable levels for physical contact with surface water</td><td>Ensure that water will be acceptable for incidental ingestion and dermal contact</td><td>+ Addresses concerns about swimming and contact-related exposure
+ Low costs for criteria development
+ Low cost for monitoring
- Very likely to be less protective than other criteria described above (for example, high water concentration limit)</td><td>$34,000 - $120,000
Based on literature or New Hampshire specific recreation rates.</td><td>6-18 months</td><td>$540,000 for two-rounds of samples
Covers the 381 designated beaches and subsequent outreach.</td></tr>
</table>

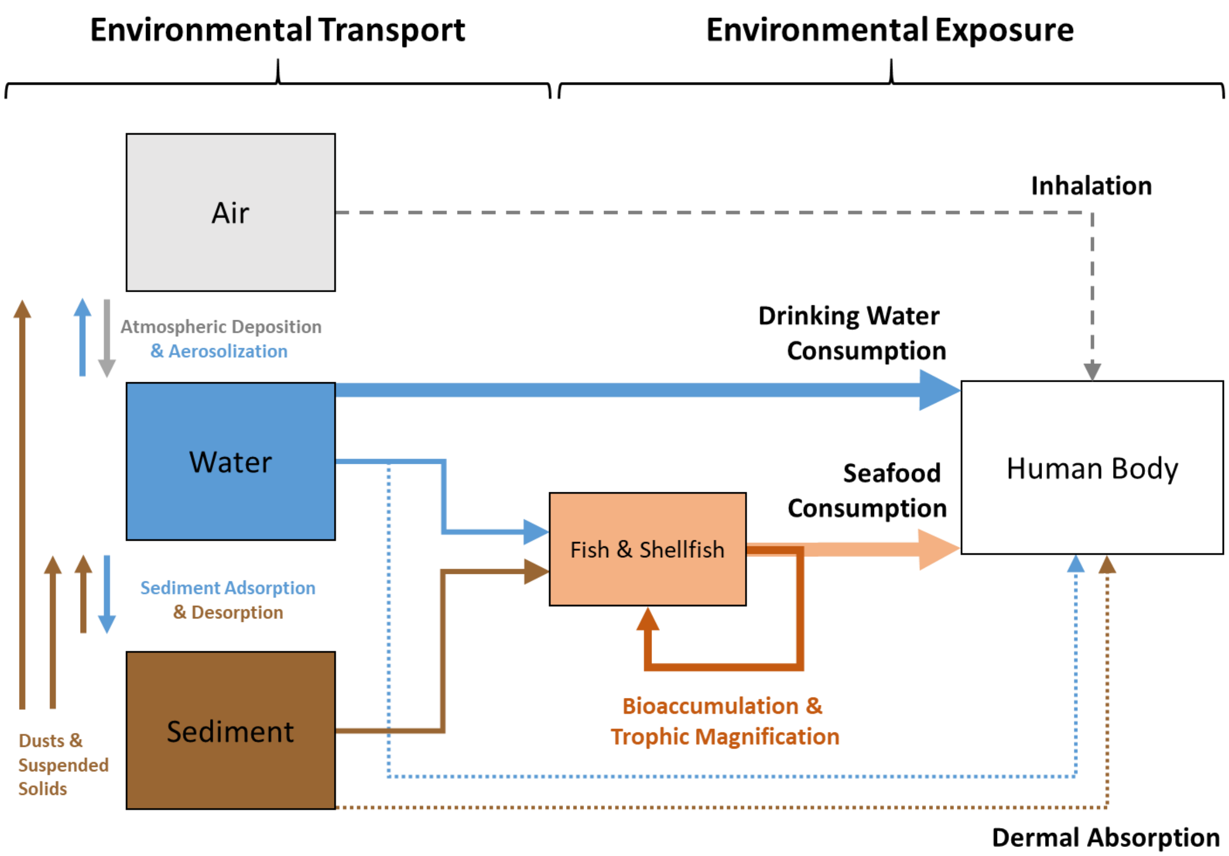
Notes:

* These are just the human health approaches. The four possible aquatic life criteria (acute and chronic criteria for fresh and marine waters) are covered in Section 6.
** Approximately 8,500 distinct waterbodies in the state.

5.2. Overview of Routes of Exposure

The routes of exposure are the pathways and mechanisms through which chemicals, such as PFAS, enter the body where they then elicit their potential health effects. This is relevant to surface water standards as the major routes of exposure dictate which environmental media (for example, water, sediments, fish and shellfish tissue) are considered significant sources of exposure for humans, and therefore require regulatory standards. Based on currently available information, the primary route of PFAS exposure for humans is through consumption (or ingestion) of contaminated fluids and food, with lesser contributions from the inhalation of contaminated dusts and dermal absorption (ATSDR, 2018). In the sections below, the main routes of exposure and how this relates to surface water quality standards are explored.

Figure 3. Model of exposure pathways of PFAS relevant to surface water criteria.



5.2.1. Ingestion

Ingestion of PFAS contaminated food and water is currently considered to be the major route of exposure to PFAS. Absorption of PFAS following ingestion of contaminated food or fluids has been documented across a wide-array of organisms including fish (Fair, et al., 2019), rodents (Sundström et al. 2012), birds (Letcher, et al., 2015), predatory mammals (Bytingsvik, et al., 2012) (Boisvert, Sonne, Rigét, Dietz, & Letcher, 2019) and humans (Sunderland, et al., 2019; Hölzer, et al., 2008; Li, et al., 2018). The exact biological process(es) for the absorption of PFAS from the gastrointestinal tract into the body is currently unknown, making the efficiency of this process difficult to estimate in a quantitative manner (for example, % uptake efficiency). Rodent studies indicate that PFAS such as PFOA or PFOS have relatively high uptake efficiencies (>90%) when administered orally, as reviewed by ATSDR (ATSDR, 2018). However, little research has evaluated how differences in food composition affect absorption within the human gastrointestinal tract. Thus, risk assessors have typically assumed that most PFAS possess a 100% absorption efficiency, which results in more conservative, health-protective regulatory standards.

As this relates to surface water standards, fish and seafood are considered to be major dietary sources of exposure to certain PFAS, such as PFOS. The European Food Safety Authority (EFSA) has estimated that combined fish and seafood consumption may account for upwards of nearly 90% of dietary PFAS exposure in the general population (EFSA, 2018). It should be noted that the EFSA's methods to estimate such values are self-acknowledged to potentially overestimate the contribution of seafood as well as the total dietary exposure (EFSA, 2018). In a Swedish cohort of 1,616 pregnant women, fish consumption was significantly associated with increased blood concentrations of certain PFAS, including PFOS and PFNA (Shu, Lindh, Wikström, & Bornehag, 2018). This is corroborated by analyses of the 2007-2014 National Health and Nutrition Examination Survey, which found that fish and seafood consumption was significantly associated with higher blood concentrations of PFAS within the U.S. population (Christensen, et al., 2017). In both of these studies, associations between fish, shellfish and general seafood to PFAS were not uniform, suggesting specific exposure risk for individual PFAS with different types of seafood. Thus, contamination of surface water used as a source of drinking water or as habitat for harvested fish and shellfish presents a significant pathway of exposure for humans and wildlife.

5.2.2. Dermal Absorption

There is little evidence that dermal absorption of PFOA, PFOS, PFHxS or PFNA play a significant role in exposure, which was reviewed for human health implications by the ATSDR in the 2018 draft toxicological profile of perfluoroalkyl substances (ATSDR, 2018). The skin is the largest human organ, with considerable surface area for absorption of typically unionized chemicals via passive diffusion. Most PFAS are ionized under environmental conditions, which is expected to significantly reduce their potential to be absorbed across the skin, as exemplified in skin permeability tests with PFOA (Franko, Meade, Frasch, Barbero, & Anderson, 2012). Franko et al. (2012) estimated the dermal penetration coefficient of PFOA to be relatively low at 9.49×10^{-7} cm/hour. To put this in perspective, this dermal absorption coefficient for PFOA is orders of magnitude less than that of other chemicals such as methylmercury or other organic contaminants (~1×10^{-3} cm/hour) that are recognized to have more significant risks for dermal absorption (EPA, 2004). Dermal penetration coefficients have not been estimated for most PFAS, and remains a poorly characterized area of exposure science requiring additional study. Thus, exposure through recreational contact (for instance, swimming or wading) without accidental ingestion is not expected to result in significant exposure, but additional information is required to further quantify dermal absorption in humans.

5.2.3. Inhalation

Currently, exposure to long-chain PFAS from inhalation is not considered a major route of exposure relevant to deriving human health criteria for water quality. The potential pathways for inhalation exposure related to surface water quality would be the inhalation of dusts (for example, dried sediments) or volatile PFAS released from surface water. Indoor dusts and particulate matter are recognized to be sources of inhaled PFAS in domestic settings (Fu, et al., 2015; Winkens, et al., 2018), but there is lack of understanding how surface water concentrations translate into sediment concentrations and if there is meaningful exposure risks from dried sediments. To the point of volatilized PFAS, the volatility of these specific four PFAS and their suspected precursor compounds is poorly understood and is the subject of research by certain academic and private research groups.

5.2.4. Metabolism and Internal Exposure

Internal exposure to, PFAS is typically inferred by their serum concentrations, measured at the ng/mL or parts-per-billion (ppb) level. Cadaver and fetal tissues studies have highlighted the fact that certain PFAS display tissue-specific compartmentalization with higher partitioning ratios seen in the liver, lung and brain tissues of humans (Mamsen, et al., 2019; Pérez, et al., 2013), resulting in different internal doses in said tissues and organs. While tissue-specific concentrations of PFAS are recognized to vary, blood serum concentrations serve as the basis of most biomonitoring efforts such as those conducted by the New Hampshire Department of Health and Human Services (NHDHHS) and National Health and Nutrition Examination Survey (NHANES) (Daly, et al., 2018), as well as epidemiological studies that aim to relate to PFAS exposure to human health outcomes (ATSDR, 2018). Additionally, these internal serum estimates have become the basis for evaluating exposure thresholds for PFAS-related risk assessments (ATSDR, 2018; NHDES, 2019b; Goeden, Greene, & Jacobus, 2019; Bartell S. J., 2018; NJDWQI, 2017; NJDWQI, 2018; NHDES, 2019b; Goeden, Greene, & Jacobus, 2019; Bartell S. J., 2018).

The same chemical properties that make several PFAS highly persistent in the environment through resistance to degradation make them highly-resistant to break-down via metabolism. Certain PFAS (such as PFOA, PFOS, PFHxS and PFNA) can be released as dead-end “daughters” from the breakdown of precursor PFAS such as fluorotelomer alcohols (Butt, Muir, & Mabury, 2014). The exact contribution of fluorotelomer metabolism towards internal doses of PFOA, PFOS and other PFAS remains an area of ongoing study with some evidence of this process in humans (Nilsson, et al., 2013). Additional research is needed to accurately estimate how precursor compounds contribute to exposure of breakdown products, such as PFOA, PFOS, PFHxS and PFNA. In humans, the resistance to degradation and notable bioaccumulation of several specific PFAS result in prolonged (chronic) internal exposures.

5.2.5. Excretion

Following absorption in the human body, PFAS are primarily but slowly excreted in the urine and feces (ATSDR, 2018). The average physiological half-life estimates of certain long-chain PFAS in humans range from 2.3-2.7 years for PFOA and up to 3.4-8.5 years for PFHxS (Li, et al., 2018; Bartell, et al., 2010; Olsen, et al., 2007). These extraordinary half-lives are attributed to significant protein binding, accumulation in certain tissues, as well as the suspected reabsorption of PFAS by organic anion transport proteins found in the kidneys (Han, L., Russell, Kennedy, & Rickard, 2014). As a result of these long half-lives in humans, exposure to low-level contamination (ppt to ppb range) results in bioaccumulation to the aforementioned internal exposure levels.

5.2.6. Human Toxicity Values

PFAS toxicity is an evolving area of research, characterized by a dynamic and rapidly growing field of scientific literature about human and animal health impacts. Sections 5.2.1 through 5.2.5 address toxicokinetic issues of absorption, distribution and elimination, which are all critical to determining daily acceptable limits of exposure to any given chemical. NHDES reviewed this toxicological literature through 2019 in its effort to establish MCLs as a part of Chapter 368 laws of 2018 (NHDES, 2019b). Using EPA risk assessment methodologies (EPA, 2000), NHDES quantified the toxicity of PFOA, PFOS, PFHxS and PFNA in terms of a chronic oral reference dose (RfD), which is a standard benchmark for developing screening levels and regulatory limits for chemicals across different environmental media.

As described by EPA (2002), a RfD is "*an estimate (with uncertainty spanning perhaps an order of magnitude) of a 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*." These are referred to as chronic oral RfDs implying chronic, or long-term, exposure throughout life via ingestion which is the primary route of exposure for PFAS. Chronic oral RfDs for certain PFAS have been previously derived in the development of drinking water standards, or maximum contaminant levels (MCLs), proposed by NHDES in June 2019 (NHDES, 2019b). The NHDES-derived RfDs for PFOA, PFOS, PFNA and PFHxS expressed as milligrams of chemical per kilogram of human body weight per day are:

- Perfluorooctanoic acid (PFOA) 6.1×10^{-6} mg/kg-d, based on hepatotoxicity
- Perfluorooctanesulfonic acid (PFOS) 3.0×10^{-6} mg/kg-d, based on immunotoxicity
- Perfluorononanoic acid (PFNA) 4.3×10^{-6} mg/kg-d, based on hepatotoxicity
- Perfluorohexanesulfonic acid (PFHxS) 4.0×10^{-6} mg/kg-d, based on reproductive toxicity

RfDs are subject to revision as the toxicological literature database for a given chemical matures. This can result in an increase or decrease of previously established RfDs based on improved understanding of the toxico-dynamics (for example, human sensitivity) and -kinetics (for example, absorption and elimination rates) of these specified PFAS. For a detailed description of the derivation of these toxicity values and supporting scientific literature, readers are referred to Technical Background Report for the June 2019 Proposed MCLs (NHDES, 2019b).

5.3. MCL - Where MCL less than Water and Fish Ingestion Criteria (Water Concentration Criteria)

The goal of this specific criteria is *to determine what concentration of PFAS in water is allowable if that waterbody is used as source of drinking water.* This approach has limited application to surface water used as a source of drinking water following adequate treatment.

5.3.1. Methodology

5.3.1.1. MCL as a Water Quality Standard for Water and Fish Ingestion Drinking Water –vs– WQSTD from 304(a)

The SWQSs allow for the adoption of an approved MCL to supersede the water and fish consumption water quality criteria to protect human health where the MCL is more protective than the fish consumption water quality criteria.

As there is no Section 304(a) guidance for any PFAS compound, a MCL at any concentration is by default, more protective. While this could be a reasonable quick (see Section 2.4) method to incorporating PFAS into the SWQS, it must be recognized that the spatial scope is limited to 20 miles upstream of any active surface water intake for a public water system. Further, as all waters are considered "…potentially acceptable for water supply uses after adequate treatment"[28] the application of an MCL based water quality criteria for human health would need to applied carefully.

5.3.1.2. Maximum Contaminant Level (MCL)

Chapter 368 laws of 2018 requiring a series of actions to be taken by NHDES. Regarding MCLs, Chapter 368:5 laws of 2018 inserted RSA 485:16-e requiring that;

> *"By January 1, 2019, the commissioner shall, in consultation with the commissioner of the department of health and human services and other interested parties, initiate rulemaking in accordance with RSA 541-A to adopt a maximum contaminant limit for perfluorooctanoic acid (PFOA), perfluoro[o]ctanesulfonic acid (PFOS), perfluorononanoic acid (PFNA), and perfluorohexanesulfonic acid (PFHxS)."*

In 2019, NHDES proposed and adopted individual MCLs and AGQS for perfluorooctanoic acid (PFOA, 12 ng/L), perfluorooctanesulfonic acid (PFOS, 15 ng/L), perfluorononanoic acid (PFNA, 11 ng/L) and perfluorohexanesulfonic acid (PFHxS, 18 ng/L). This was based on consideration of technical comments submitted by stakeholders, as well as consideration of the transfer of PFAS into breastmilk using toxicokinetic modeling described by the Minnesota Department of Health (Goeden, Greene, & Jacobus, 2019). These MCLs were implemented September 30, 2019 thereby requiring quarterly sampling by drinking water systems to determine compliance across the following year. The development of MCLs by NHDES included the identification of chemical-specific Reference Doses (RfDs) which are discussed in Section 5.2.

5.3.2. Other States

To date, only one other state has enacted a MCL for a single PFAS in addition to proposing MCLs for two additional compounds. In 2018, the New Jersey Department of Environmental Protection enacted a MCL of 13 ng/L for PFNA, and has proposed two additional MCLs of 14 and 13 ng/L for PFOA and PFOS, respectively, based on recommendations by the New Jersey Drinking Water Quality Institute (NJDWQI, 2017; NJDWQI, 2018). Other states continue to develop their limits that include enforceable MCLs along with other benchmarks such as lifetime health advisories (LHAs), health goals, health-based screening levels and others (Table 6).

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[28] RSA 485-A:8 I. regarding Class A waters, "The waters of this classification shall be considered as being potentially acceptable for water supply uses after adequate treatment."

While some states have opted to develop their own drinking water limits, several other states have not developed their own drinking water standards and instead have adopted the EPA's current LHA of 70 ng/L for the sum of PFOA and PFOS (Table 6). None of these states have promulgated the EPA LHA into a MCL. It is expected that in 2020, some other states will either propose or adopt their own MCLs. For those interested in tracking changes in drinking water thresholds across the use, readers are referred to a comprehensive list of PFAS fact sheets[29] curated by the Interstate Technology & Regulatory Council (ITRC).

Table 6. Drinking water health advisories and MCLs for a select number of U.S. States. All values are presented as ng/L or parts-per-trillion (ppt). Grey rows indicate where a state has adopted a level for the sum total of multiple PFAS equal to the center value.

<table>
<tr><th><u>Local</u></th><th>Standard Type & Status</th><th>PFBS</th><th>PFHxA</th><th>PFHxS</th><th>PFHpA</th><th>PFOA</th><th>PFOS</th><th>PFNA</th><th>PFDA</th><th>GenX</th></tr>
<tr><td>Northeast States</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Connecticut</td><td>Health Action Level</td><td></td><td></td><td colspan="5">70</td><td></td><td></td></tr>
<tr><td>Maine</td><td>EPA LHA</td><td></td><td></td><td></td><td></td><td colspan="2">70</td><td></td><td></td><td></td></tr>
<tr><td>Massachusetts</td><td>Proposed HA</td><td></td><td></td><td colspan="6">20</td><td></td></tr>
<tr><td>New Hampshire</td><td>MCL, enacted</td><td></td><td></td><td>18</td><td></td><td>12</td><td>15</td><td>11</td><td></td><td></td></tr>
<tr><td>New Jersey</td><td>MCL, mixed*</td><td></td><td></td><td></td><td></td><td>13</td><td>14</td><td>13</td><td></td><td></td></tr>
<tr><td>New York</td><td>MCL, proposed</td><td></td><td></td><td></td><td></td><td>10</td><td>10</td><td></td><td></td><td></td></tr>
<tr><td>Rhode Island</td><td>EPA LHA</td><td></td><td></td><td></td><td></td><td colspan="2">70</td><td></td><td></td><td></td></tr>
<tr><td>Vermont</td><td>Health Advisory</td><td></td><td></td><td colspan="5">20</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Other States</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Alaska</td><td>EPA LHA</td><td></td><td></td><td></td><td></td><td colspan="2">70</td><td></td><td></td><td></td></tr>
<tr><td>California</td><td>Notification Level</td><td></td><td></td><td></td><td></td><td>6.5</td><td>5.1</td><td></td><td></td><td></td></tr>
<tr><td>Colorado</td><td>EPA LHA</td><td></td><td></td><td></td><td></td><td colspan="2">70</td><td></td><td></td><td></td></tr>
<tr><td>Michigan</td><td>MCL, proposed</td><td>420</td><td>400,000</td><td>51</td><td></td><td>8</td><td>16</td><td>6</td><td></td><td>370</td></tr>
<tr><td>Minnesota</td><td>Water Guidance</td><td>2,000</td><td></td><td>47</td><td></td><td>35</td><td>15</td><td></td><td></td><td></td></tr>
<tr><td>North Carolina</td><td>DW Health Goal</td><td></td><td></td><td></td><td></td><td colspan="2">70</td><td></td><td></td><td>140</td></tr>
<tr><td colspan="11">*As of November 2019, NJ has only enacted a MCL for PFNA, but has proposed MCLs for PFOA and PFOS.</td></tr>
</table>

5.3.3. Data Needs

A clear advantage to this approach is that no additional data are required for developing MCLs that would be applied as surface water criteria at applicable waterbodies. This reduces costs associated with any risk assessment for the four PFAS in question, and reduces the time to implementation. Should additional information emerge demonstrating a need to re-evaluate the previously derived toxicity values and assumptions supporting the current MCLs, NHDES would require staff time to review the scientific literature and potentially undergo the rulemaking process for the MCLs.

Following implementation, the primary data needs are associated with surveillance and monitoring of targeted waterbodies.

5.3.4. Cost and Time Estimate to Develop

Estimated costs and time for a surface water criteria based on the existing MCLs is provided in Table 7. This includes costs and time for criteria development, as well as cost and estimated time for monitoring a water body based on said criteria. The development of the criteria (Table 7, Step A) was already

[29] https://pfas-1.itrcweb.org/fact-sheets/

completed by NHDES in 2019. If additional review is conducted to determine if different MCLs are appropriate for protection of human health, this may add an additional $25,000 to the cost of criteria development. This would include time and benefits for the NHDES toxicologist to conduct a review of relevant literature and prepare a report in a minimum three-month timeframe.

Approval by the Joint Legislative Committee on Administrative Rules (JLCAR) is required and anticipated to take four to eight months (Table 7, Step B). This will require a public comment period, response to said comments and review by interagency groups. Once approved by JLCAR, the standards would then be submitted to EPA for approval and use in any federal actions. Based on previous rule-making processes, and the unique nature of this task this is expected to take over 400 hours of NHDES staff time.

Following implementation of the surface water criteria, monitoring is required to determine compliance (Table 7, Steps C and D). Surface water sampling for PFAS uses a different analytical methodology than typical drinking water samples, and is estimated at $375 per water sample. For every waterbody, sample collection along with data entry and management will require additional NHDES staff time. Together, analysis and staff time is estimated to cost $1,300 for two-samples per waterbody. Based on sampling results NHDES would then spend time to evaluate data from waterbodies and conduct outreach to affected stakeholders.

Table 7. A) Overview of costs associated with developing a PFAS water concentration limits based on an MCL/AGQS and B) costs associated with assessing waterbodies.

	PROCESS and STEP	DATA REQUIREMENTS	ESTIMATED COSTS		ESTIMATED TIME TO COMPLETE
			Description	Item Costs*	
A) CRITERIA DEVELOPMENT COSTS	(A) Criteria Development Costs	Completed as of July 2019 in response to Chapter law 368:5 (2018)		$0 (*Completed*)	0
	(B) Adopt existing MCL/AGQS as a WCC for applicable waterbodies		NHDES staff time to conduct rulemaking process, submission to JLCAR, and submission to EPA.	$25,000	4-8 months
	Total Cost to Develop Water Concentration Criteria based on the existing MCLs			**$25,000**	4-8 months
B) WATERBODY ASSESSMENT COSTS	(C) Surface Water Testing	Measure Water Concentrations of PFAS	1 site per waterbody PFAS water concentrations Water quality parameters Staff time	$1,300 (two-samples per waterbody) × 59 surface water sources $79,000	3-4 months
	(D) Data Assessment and Notification for Waterbodies	Results from (C)	NHDES staff time to evaluate data from waterbodies and conduct outreach to affected stakeholders.	$13,000	3-4 months
	Total Costs to Assess Specified Surface Waters Annually			$92,000	3-4 months

*All costs in the table are based on 2020 prices.

5.4. *Fish Consumption Advisory – Tissue Consumption Limit*

A fish consumption advisory is not a SWQS but rather *determines how much fish can be eaten on a weekly or monthly basis from certain waterbodies.* This is achieved by estimating a daily amount of meat that can be consumed from a given waterbody, based on each PFAS concentration found in local fish and shellfish. These rates would be waterbody-specific, requiring sampling of fish and shellfish to measure tissue (for instance, muscle fillet) concentrations of specified PFAS. Consumption limits can be expressed as grams or kilograms of meat per day, or converted to four- or eight-ounce serving sizes per time period such as days, weeks or months. Additional values can be estimated for other tissues (for example, organs), but typically the highest consumption rates that result in more protective standards are those for muscle fillets.

A statewide fish consumption advisory can be developed if there is sufficient and representative data of fish tissue concentration of PFAS from across New Hampshire. A similar approach has been taken with methylmercury and statewide fish consumption advisories (NHDES, 2016b) based on extensive and ongoing tissue mercury sampling around the state. Under this advisory, the general adult population along with children seven years of age and older can eat four eight-ounce meals of freshwater fish per month. Children under the age of seven can eat one four-ounce freshwater fish meal per month, while pregnant and lactating women can have one eight-ounce freshwater fish meal per month. This applies to all freshwater fish, except for where there are certain species of stocked trout.

If NHDES conducted a representative and probabilistic sampling of New Hampshire waterbodies (approximately 50 freshwater bodies) a statewide recommendation could be made. Without representative sampling, this approach is limited to specific waterbodies where fish tissue sampling has occurred.

5.4.1. Methodology

A tissue consumption limit or maximum allowable fish tissue consumption rate (CR_{lim}) can be estimated using measured concentrations (C_m) of PFAS in fish and shellfish along with the following equation:

Equation 1. Derivation of Fish/Shellfish Consumption Advisory Values

$$CR_{lim} = \frac{RfD \times BW \times RSC}{C_m}$$

Where:

CR_{lim} – maximum allowable fish consumption rate expressed as kg of fish tissue consumed per day (kg/d)
BW – Human Body Weight (kg)
RfD – Chronic Oral Reference Dose (mg/kg-d)
RSC – Relative Source Contribution expressed as a proportion of total daily exposure
C_m – measured concentration of chemical in sampled fish tissue expressed as mg of chemical per kilogram of fish tissue (mg/kg)

This approach is arguably the easiest method to protect human health based on fish and shellfish consumption. One advantage to this method is that it does not require the development of species- or trophic-specific BAFs or BCFs, nor does it require direct measurement of surface water concentrations of PFAS. The C_m is a real-world value that measures what fish consumers are exposed to from a specific waterbody. To facilitate risk communication about consumption, advisories would be communicated as eight- or four-ounce fillet meal limits per a specified time period. As previously discussed, without broad statewide sampling, statements can only be made about that specific waterbody.

There are limitations and challenges associated with this method. The major limitation is that this approach is not informative about risks associated with surface water or sediment concentrations of PFAS and if these concentrations should trigger advisories for a waterbody. Regular resampling of fish and shellfish from target waterbodies would be required to monitor for changes in permissible consumption rates. Additionally, such resampling efforts would result in the need to communicate changes in waterbody-specific consumption rates to the affected populations.

Assumptions made in the calculation of the CR_{lim} include; 1) the reference dose (RfD) for each PFAS, 2) a consumer's body weight (BW) and 3) the relative source contribution (RSC) of PFAS from fish and seafood relative to other sources of exposure. As previously discussed under the MCLs, NHDES derived toxicity values for each of the four PFAS compounds based on a recent literature review. Reasonable estimates of BW are described in the EPA Exposure Factors Handbook (EPA, 2011), and allow for a similar basis of risk assessments by various U.S. government and nongovernment entities. To ensure appropriate protection across life stages, NHDES compares differences in exposure scenarios using BW estimates for adults, pregnant women and children as a part of its existing methodology for determining fish consumption advisories. The latter of these, the RSC, is subject to greater scientific uncertainty given the emerging nature of PFAS research.

The RSC accounts for the proportionality of a specific exposure source (for example, fish or shellfish) to the total daily exposure relative to other potential sources of exposure to a given chemical (EPA, 2000). This value is quantified as a proportion or percentage, and EPA recommends a ceiling of 80% and a floor of 20% depending on assumptions about fish and shellfish consumption and the availability of population-specific data on background exposure levels to the contaminants of concern.

As exposure to PFAS occurs from ingestion of food and liquids other than seafood, the total daily RfD is due to multiple exposure pathways including other environmental media (for example, dusts, soils, as well as personal care and consumer products reviewed by (ATSDR, 2018). A significant source of exposure other than food items is contaminated drinking water (Post, Gleason, & Cooper, 2017), which is typically driven by water intake (exposure) rates that are higher than that of food and other environmental media. In July 2019, New Hampshire adopted MCLs/AGQS for PFOA, PFOS, PFHxS and PFNA at 12 ng/L, 15 ng/L, 18 ng/L and 11 ng/L, respectively, thereby limiting the RSC of PFAS from drinking water sources. Regarding dietary exposure, EFSA recently suggested that fish and seafood may account for upwards of 80-90% of dietary exposure to PFAS (EFSA, 2018). However, the estimates by EFSA are self-described to be limited based on existing evidence and prone to bias in detection and reporting limits of PFAS in food items (EFSA, 2018). The issue of detection limits and methodologies for PFAS contamination in food is highlighted by a recent report by the US FDA (FDA, 2019). Neither NHDES or NHDHHS are equipped with staff or resources necessary to conduct a study to determine state-level RSC estimates for PFAS and it is recommended that these values are derived from existing peer-reviewed literature. Given the recent implementation of drinking water standards and evidence that fish and seafood are primary drivers of dietary exposure, historical estimates of appropriate RSC values for fish consumption may need to be re- assessed since the development of New Hampshire's PFAS MCLs.

5.4.2. Other States

A handful of other U.S. states have developed consumption advisories and surveyed for certain PFAS in their waters. The New Jersey Department of Environmental Protection surveyed 11 waterbodies for 13 PFAS, consisting of 14 water and sediment samples along with 94 fish tissue samples (NJDEP, 2019). All fish species sampled had detectable concentrations of PFAS in their muscle tissue, with the highest concentrations being long-chain sulfonic acid compounds such as PFOS and PFHxS. An interesting finding of this survey was that even fish from Echo Lake, typically a reference or control site for contaminant surveys in New Jersey, had PFAS concentrations in fish that were high enough to exceed a weekly fish consumption advisory. Based on the consumption limits developed by New Jersey Department of Environmental Protection, their preliminary findings suggest that fish consumption restrictions ranged from once per week to never across 11 waterbodies.

Following considerable sampling across multiple waterbodies, the Michigan Department of Health and Human Services listed waterbody-specific fish consumption advisories due to the presence of PFOS in a variety of freshwater fish species. These waterbody-specific advisories can be found on Michigan's PFAS response webpage[30]. This highlights the utility of this approach for use at sites with known environmental sources of PFAS.

5.4.3. Data Needs

The fundamental data need for a tissue concentration-based fish consumption advisory is fish and shellfish tissue concentrations (C_m) of PFAS from regional waterbodies. This can be achieved through a Tier 1 Screening Level Study followed by a Tier 2 Intensive Study, as described by EPA methodology for monitoring contaminants in fish (EPA, 2000). Below is the general outline of EPA's recommended approach:

1. Tier 1 Screening Level Study – Initial survey of waterbodies with conservative screening levels, which are more conservative than the standard fish consumption advisory, to determine where contamination exists. Relies on composite (pooled) sampling of a limited number of fish species and tissues. This would be conducted at a state-wide level with approximately 50 freshwater and 50 marine/estuary waterbodies.
2. Tier 2 Intensive Study (Phase I) – Based on results obtained from the Tier 1 Study, additional sampling is conducted to determine the magnitude of contamination in the edible portions of different fish and shellfish species.
3. Tier 2 Intensive Study (Phase II) – Additional sampling is conducted at various sites within the waterbody to determine geographic and size-class relationships between contaminants and fish/shellfish.
4. Follow-up Study – Intensive study of waterbodies with low to absent levels of contamination to establish where there are no restrictions on fish consumption with respect to the contaminants of concern. Consist of an additional 100 sites through probabilistic sampling.

Regardless of which studies are undertaken, it is also important to consider whether the tissue measured for C_m will focus on muscle/fillets or whole body measurements of PFAS. The use of C_m based on fillets from fish assumes that the population of recreational fishermen are not consuming the whole fish and discarding the organs. The use of whole fish for determining C_m assumes that consumers are

[30] https://www.michigan.gov/pfasresponse/0,9038,7-365-86512_88987_88989-481104--,00.html

eating most of the fish that has been caught and likely reflects subsistence fishing populations and potential certain sub-populations where cultural traditions make use of the entire fish. Because of the biochemical properties of certain long-chain PFAS, it is likely that whole body concentrations of most PFAS will be higher than concentrations found solely in fillets. Thus, use of whole body C_m would be more appropriate for the protection of certain subgroups and result in more restrictive tissue concentration-based fish and shellfish consumption advisories.

5.4.3.1. Tier 1 Screening Level Study

At a minimum, a state-wide Tier 1 Screening Level Study is required for a Fish Consumption Advisory based on Tissue Concentration, as well as Tissue Concentration Criteria (Discussed in Section 5.5). This would consist of sampling fish, shellfish and other relevant species from waterbodies where they are recreationally caught and consumed (Table 8). The costs of a state-wide Tier 1 Screening Level Study are driven by 1) the number of sites assessed and 2) the number of tissues sampled and analyzed at each site or waterbody. The sites assessed would not include waterbodies where there are preexisting prohibitions on fish/shellfish consumption due to other chemical contaminants (for example, PCBs), although for BAF purposes discussed in Section 5.6, we may want to target some areas with known contamination issues. In freshwater systems, sampling would include at least two bottom-dwelling species and two predator/gamefish species (EPA, 2000). Estuaries and marine systems require a minimum of two shellfish and two finfish species, although an additional bottom-dwelling marine species may be necessary in certain ecosystems where significant bio- or trophic magnification is suspected (EPA, 2000). Inclusion of additional species above the minimum requirements allows for more reliable estimates of the CR_{lim}, but also multiplies the costs of a statewide Tier 1 Screening Study.

Table 8 List of preferred freshwater and marine species for sampling to develop fish/shellfish consumption advisories in New Hampshire and Vermont waters. Species list based on EPA recommendations for national surveys (EPA, 2000), as well as information from NHDES and VTDEC. Most of the freshwater species listed are present in both New Hampshire and Vermont.

Family	Genus & Species	Relevant Waterbodies Habitat*
Freshwater Predator/Gamefish		
Centrarchidae	Largemouth bass (*Micropterus salmoides*)	W, S-L
	Smallmouth bass (*Micropterus dolomieu*)	C-W, R-L
	Black crappie (*Pomoxis nigromaculatus*) (New Hampshire Only)	W, S-L
	White crappie (*Pomoxis annularis*) (Primarily Vermont. New Hampshire rare.)	W, R-L
Percidae	Walleye (*Sander vitreus*)	C-W, R-L
	Yellow perch (*Perca flavescens*)	C-W, S-L
Esocidae	Northern pike (*Esox lucius*)	C-W, R-L
	Chain pickerel (*Esox niger*)	W, S-L
Salmonidae	Lake trout (*Salvelinus namaycush*)	C, L
	Brown trout (*Salmo trutta*)	C, S
	Rainbow trout (*Oncorhynchus mykiss*)	C, S
	Brook trout (*Salvelinus fontinalis*)	C, B-L
	Lake whitefish (*Coregonus clupeaformis*)	C, R-L
Freshwater Bottom-Dwellers		
Cyprinidae	Common carp (*Cyprinus carpio*)	W, R-L
Ictaluridae	Channel catfish (*Ictalurus punctatus*)	W, R-L
	Brown bullhead (*Ameiurus nebulosus*)	W, S-L
	Yellow bullhead (*Ameiurus natalis*)	W-B, S-L

Family	Genus & Species	Relevant Waterbodies Habitat*
Catostomidae	White sucker (*Catostomus commersoni*)	C-W, S-L
Estuary & Marine Predator/Gamefish		
Anguillidae	American eel (*Anguilla rostrate*)	Estuarine (to freshwater)
Percichthyidae	Striped bass (*Morone saxatilis*)	Migratory, ocean to estuarine
Pomatomidae	Bluefish (*Pomatomus saltitrix*)	Migratory, mostly ocean, occasional estuarine
Bothidae	Summer flounder (*Paralichthys dentatus*)	Ocean and Estuary nursery habitat
Pleuronectidae	Winter flounder (*Pseudopleuronectes americanus*)	Ocean and Estuarine (high salinity) nursery habitat
	Yellowtail flounder (*Limanda ferruginea*)	Ocean
	American dab (*Hippoglossoides platessoides*)	Ocean
Osmeriformes	Rainbow Smelt (*Osmerus mordax)*	Estuarine
Perciformes	White Perch (*Morone Americana*)	Estuarine
Clupeiformes	River Herring (*Alosa aestivalis*)	Natal rivers to coast, Adults come in to spawn (mostly bait use)
Estuary/Marine Shellfish		
Bivalves	Eastern oyster (*Crassostrea virginica*)	Estuarine
	Soft-shell clam (*Mya arenaria*)	Estuarine – tidal flats
	Hard clam (*Mercenaria mercenaria*)	Ocean
	Ocean quahog (*Arctica islandica*)	Ocean
	Atlantic surf clam (*Spisula solidissima*)	Ocean
	Blue mussel (*Mytilus edulis*)	Ocean to Estuarine (not head of tides)
Crustaceans	American lobster (*Homarus americanus*)	Ocean to Estuarine
	Eastern rock crab (*Cancer irroratus*)	Ocean and Estuarine (high pss)

*Relevant Waterbodies Habitat:

Freshwater Fish: B = Brooks (smaller flowing waters <5 meters wide); S = Streams (intermediate flowing waters 5-10 meters wide); R = Rivers (larger flowing waters >10 meters wide); L = Lakes (inclusive of ponds or reservoirs). C = Coldwater; C-W = Inhabits both types/coolwaters; W = Warmwater; C-B = Cold-bogs; W-B = Warm-bogs. (Simon T. P., 1999)

To manage some costs of tissue analyses in a Tier 1 Study, composite tissue (fillet) samples can be collected for the target species resulting in a single measurement of PFAS per species per waterbody. Each of these composite samples would, where possible, consists of a minimum of five individuals from a given species (EPA, 2000) (Olsen, Snyder, Stahl, & Pitt, 2009) and (Stahl, Snyder, Olsen, & Pitt, 2009). Chemical analysis of a single sample per species per waterbody drastically reduces the costs of tissue analyses, which are described below. However, for reasons detailed in Sections 5.5 to 5.7, individually-measured tissue concentrations are preferable as these will inform estimates of BAFs and BCFs, as well as provide information about how PFAS may preferentially accumulate in frequently consumed species based on size or sex. Furthermore, measurement of tissue concentrations in individual fish would be informative and likely offset some costs associated with subsequent Tier 2 Studies at a site. Additional replicate samples, ≥10% of all samples collected state-wide, would need to be collected to estimate sampling variability for each study.

The Environmental Health Program at NHDES would conduct the risk assessment of data collected from the Tier 1 Study, in consultation with NHDHHS and NHFG. The measured PFAS concentrations from across the different species and waterbodies would be compared to conservative screening levels (SLs), developed by the NHDES Environmental Health Program using existing EPA methodologies (EPA, 2000).

These SLs are derived using a similar method as that shown in Equation 1, but tend to be more conservative (≤10% the tissue concentration limit) to serve as a screening tool for site assessment and not a formal consumption advisory. Tissue concentrations of PFAS that are significantly above the SLs would trigger a Tier 2 Intensive Study of the water body, whereas those below the designated SLs would only require further investigation if the site was intended to be designated as an area of unrestricted fish consumption.

5.4.3.2. Tier 2 Intensive Study

Waterbodies with sampled tissue concentrations above the chemical-specific SLs will require a Tier 2 Study to characterize the magnitude of contamination and the associated exposure risks at that site. This differs from a Tier 1 study in that a Tier 2 Study requires individual tissue analysis, not composite sampling, and occurs in two phases (EPA, 2000). Phase I evaluates the magnitude of contamination in commonly consumed species, and increases the number of sampled fish relative to the Tier 1 Study. Phase II would assess the geographic extent of contamination in larger lakes, river systems and estuaries through multiple sampling sites within an impacted waterbody.

The costs-per-waterbody associated with Tier 2 Studies will be greater than those for Tier 1 Screening Studies. This is due to the need to assess the magnitude of contamination within fish and the addition of replicate samples to evaluate differences between size class of fish or shellfish (Tier 2, Phase I), as well as geographic distribution of contaminated fish and shellfish in a given waterbody (Tier 2, Phase II). Additional costs may occur if there is a need to evaluate other traits that may influence PFAS body burdens in target species. One example of this would be difference between sex, where existing literature suggest sex-specific difference in elimination rates of certain PFAS across vertebrates (Han, L., Russell, Kennedy, & Rickard, 2014) (Li, et al., 2018) and potential deposition of PFAS into the eggs of oviparous species (Letcher, et al., 2015) (Cui, et al., 2018). Given the current lack of information related to PFAS toxicokinetics in aquatic species (see Section 6 for additional information), there are potential unknown co-variables that influence the magnitude of contamination in fish and shellfish.

EPA recommends that the planning and design of these intensive studies consider feasibility with respect to costs and a site-specific capacity for sampling (EPA, 2016; EPA, 2000). Although some waterbodies may exceed SLs in the Tier 1 Study, local aquatic wildlife populations may not be able to sustain a higher intensity of sampling (for instance, additional replicate sampling). Where this is the case, state fisheries managers may modify the sampling plan of these intensive studies to protect the local fish and wildlife populations. Adjusted sampling plans should be reasonable and scientifically defensible, while also ensuring data collection does not compromise reliable risks assessment for the protection of public health (EPA, 2000).

Findings from the Tier 2 Studies would be compared against the SLs and consumption advisories developed by NHDES. Tissue consumption limits based on PFAS would also be compared to existing data for other chemical contaminants to determine which presents the greatest risks and therefore most restrictive consumption limit for that waterbody.

5.4.3.3. Follow-up Studies to Designate Unrestricted Consumption Areas

These studies would be similar to the Tier 2 Study design for individual sampling of organisms with the exception that this sampling would occur at sites where fish/shellfish concentrations of PFAS were below the SLs in the Tier 1 Study. This type of study is necessary if the State is to determine areas where *unrestricted consumption* may occur, and would be relevant to waterbodies used by subsistence fishing populations. However, other contaminants should be considered as a part of this step, as these other chemicals (for example, mercury, dioxins, PCBs) may already prevent unrestricted use of a waterbody. Additional information detailing this type of survey can be found in Appendix B (Screening Values for Defining Green Areas) of the EPA *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories* (EPA, 2000).

5.4.4. Cost and Time Estimate to Develop

Estimated costs and time for a surface water criteria based on limiting fish and shellfish consumption are provided in Table 9. This includes costs and time for consumption limit development, as well as cost and estimated time for monitoring waterbodies based on fish and shellfish tissue consumption limits. The development of fish and shellfish screening levels was initiated in 2019 as a result of NHDES' ongoing PFAS investigation at multiple sites across the state. If additional review is conducted to determine whether consumption limits are appropriate for a site, this may add an additional $9,000 to the cost of criteria development. This would include time and benefits for the NHDES toxicologist to conduct a review of relevant literature and prepare a report in a three-month timeframe. This work is reviewed by an NHDES risk assessor, as well as a program specialist from NHDHHS. Fish and shellfish consumption limits do not require approval by JLCAR, and therefore does not incur additional costs associated with rulemaking.

To determine which waterbodies require fish and/or shellfish consumption limits, extensive sampling and monitoring will be required. All surveys of fish and shellfish can be conducted using *optimal* or *minimal* approaches. Optimal approaches require more sampling effort, replication of tissue samples along with measurement of PFAS in water and sediment. Minimalistic approaches are based on the most basic recommendations from EPA guidance for conducting fish or shellfish tissue sampling (EPA, 2016), and may be more feasible when costs are prohibitive. Using a minimalistic approach may reduce initial cost for Tier 1 Studies, but will require more investment if high concentrations of PFAS are found in fish or shellfish following a minimalistic Tier 1 study. Thus, although more rigorous, and costly, *optimal* sampling during initial studies is more likely to reduce overall costs associated with fish or shellfish tissue sampling. Either approach will require staff support including: Chief Biologist, Field Biologist(s) and Interns to support sample collection.

For every waterbody, sample collection along with data management and notification of consumption limits will require an estimated 40 hours of NHDES staff time. Following assessment of the data collected from the various fish and shellfish sampling efforts, consumption limits would be established at tested waterbodies. Based on sampling results NHDES would then spend time communicating consumption limits and conduct outreach to affected stakeholders.

If a statewide consumption advisory is preferred, then a probabilistic sampling approach would need to be taken across 50 freshwaters systems within the state. For estuary and marine systems, an additional 50-sites would need to be sampled to provide a representative survey of estuary/marine fish and shellfish. Using the optimal approach to Tier 1 studies initially would provide sufficient data to determine adequately protective consumption limits for the majority of these waterbodies, while reducing the potential need for subsequent sampling where tissue concentrations of PFAS are found to exceed SLs. This is estimated to cost $1,647,000. Subsequent Tier 2 Studies conducted via the optimal sampling effort to determine areas with unrestricted consumption limits would add an additional $4,747,000 for a total cost if all 100 waterbodies were resampled.

Using a minimal approach to Tier 1 studies across the state, without Tier 2 follow-up, is estimated to cost $547,000. The problem with this approach is that it provides limited data for accurately determining consumption limits with subsequent analyses. Additional costs associated with subsequent sampling to investigate waterbodies with high tissue contamination would incur the cost of Tier 2 sampling that ranges from $16,000 to $47,000, for a single waterbody depending upon complexity thereby incurring up to the $4,747,000 cost if all 100 waterbodies needed resampled. Costs would be reduced if fewer sites are assessed, but this comes at a reduced certainty in data and applicability of statewide recommendations for fish and shellfish consumption.

Table 9. A) Overview of costs associated with determining safe consumption rates for a waterbody for a PFAS once fish and shellfish tissue consumption limits are established and B) cost associated with assessing waterbodies.

PROCESS and STEP		DATA REQUIREMENTS	ESTIMATED COSTS*		ESTIMATED TIME TO COMPLETE
			Description	Item Costs	
A) ADVISORY DEVELOPMENT	(A) Determine Tissue Consumption Limits	Toxicity Values (RfDs) for target PFAS, the same values used for Drinking Water Criteria or MCLs.	NHDES Staff time to evaluate data, calculate consumption limits and prepare summary report	$9,000	2-3 months includes time for interagency peer-review
	Total Cost to develop and pass tissue consumption limits for fish/shellfish consumption			**$9,000**	
B) WATERBODY ASSESSMENT COSTS	(B) Tier 1 Study	(*Optimal*) Measure Tissue Concentrations of PFAS in Fish/Shellfish Includes increased sampling to avoid future data collection if PFAS concentration exceed SLs	1 site per waterbody 4 species per site 2 predators, 2 bottom-dwellers 5 replicate tissue samples per species PFAS Water Concentrations PFAS Sediment Concentrations Water quality parameters	$16,000 <u>X100 waterbodies</u> $1,600,000	18-24 months, project planning and sample collection
		(*Minimal*) Measure Tissue Concentrations of PFAS in Fish/Shellfish	1 site per waterbody 4 species per site 2 predators, 2 bottom-dwellers 1 composite tissue sample per species PFAS Water Concentrations PFAS Sediment Concentrations Water quality parameters	$5,000 <u>X100 waterbodies</u> $500,000	18-24 months, project planning and sample collection
	(C) Tier 2 Study Only required where PFAS exceed SLs in Tier 1 Study	(*Optimal)* Measure Tissue Concentrations of PFAS in Fish/Shellfish Increased # of sampling sites per waterbody to account differences due to environmental factors (for example, spatial distributions) or within-species variability (for example, size class and/or sex)	1 site per waterbody 4 species per site 2 predators, 2 bottom-dwellers 5 replicate tissue samples per species PFAS Water Concentrations PFAS Sediment Concentrations Water quality parameters	$47,000 <u>X100 waterbodies</u> $4,700,000	12-18 months, Occurs subsequent to Tier 1 Studies use *Minimal* approach
		(*Minimal)* Measure Tissue Concentrations of PFAS in Fish/Shellfish Can be avoided if *Optimal* Data Requirements are initially met by Tier 1 Study	1 site per waterbody 4 species per site 2 predators, 2 bottom-dwellers 5 replicate tissue samples per species PFAS Water Concentrations	$16,000 <u>X100 waterbodies</u> $1,600,000	12-18 months, Occurs subsequent to Tier 1 Studies use *Minimal* approach

Table 9. A) Overview of costs associated with determining safe consumption rates for a waterbody for a PFAS once fish and shellfish tissue consumption limits are established and B) cost associated with assessing waterbodies.

PROCESS and STEP	DATA REQUIREMENTS	ESTIMATED COSTS*		ESTIMATED TIME TO COMPLETE
		Description	**Item Costs**	
		PFAS Sediment Concentrations Water quality parameters		
(D) (*Optional*) Designate Unrestricted Consumption Sites Only performed at sites with tissue concentrations below the SLs	(*Optimal)* Measure Tissue Concentrations of PFAS in Fish/Shellfish Increased # of sampling sites per waterbody to account differences due to environmental factors (for example, spatial distributions) or within-species variability (for example, size class and/or sex)	1 site per waterbody 4 species per site 2 predators, 2 bottom-dwellers 5 replicate tissue samples per species PFAS Water Concentrations PFAS Sediment Concentrations Water quality parameters	$47,000 X100 waterbodies $4,700,000	12-18 months, Occurs the following year if Tier 1 Studies use *Minimal* approach
	(*Minimal)* Measure Tissue Concentrations of PFAS in Fish/Shellfish	1 site per waterbody 4 species per site 2 predators, 2 bottom-dwellers 5 replicate tissue samples per species PFAS Water Concentrations PFAS Sediment Concentrations Water quality parameters	$16,000 X100 waterbodies $1,600,000	12-18 months, Occurs the following year if Tier 1 Studies use *Minimal* approach
(E) Data Assessment and Consumption Limit Notifications		NHDES Staff time to analyze data, communicate consumption limits and conduct outreach to affected stakeholders	$47,000	4-6 months
Tier 1 – Total Costs for *Optimal Approach* to Assess a Waterbody based on Tissue Consumption Limits (Probabilistic Studies (B) Across 50 Freshwater & 50 Estuary/Marine Waterbodies + Assessment and Outreach (E))			**$1,647,000**	**2.5-3.5 years**
Tier 1 - Total Costs for *Minimal Approach* to Assess a Waterbody based on Tissue Consumption Limits(Probabilistic Studies (B) Across 50 Freshwater & 50 Estuary/Marine Waterbodies + Assessment and Outreach (E))			**$547,000**	**2.5-3.5 years**
Tier 2 – Total Costs for *Optimal Approach* to Assess a Waterbody based on Tissue Consumption Limits (Probabilistic Studies (C) or (D) Across 50 Freshwater & 50 Estuary/Marine Waterbodies + Assessment and Outreach (E))			**$4,747,000**	**2.5-3.5 years**

Table 9. A) Overview of costs associated with determining safe consumption rates for a waterbody for a PFAS once fish and shellfish tissue consumption limits are established and B) cost associated with assessing waterbodies.

PROCESS and STEP	DATA REQUIREMENTS	ESTIMATED COSTS*		ESTIMATED TIME TO COMPLETE
		Description	Item Costs	
Tier 2 - Total Costs for *Minimal Approach* to Assess a Waterbody based on Tissue Consumption Limits(Probabilistic Studies (C) or (D) Across 50 Freshwater & 50 Estuary/Marine Waterbodies + Assessment and Outreach (E))			**$1,647,000**	**2.5-3.5 years**

*Estimated Costs assume 10% duplication of sampling for quality assurance/quality control, as well as labor costs. All costs in the table are based on 2020 prices.

5.5. *Fish Consumption Criteria - Tissue Concentration Criteria*

The goal of the tissue concentration criteria is *to determine the protective tissue concentration limits for specified PFAS in fish and shellfish.* This is similar to the Consumption Advisory described in Section 5.4 in that both approaches address surface water contamination through measuring fish and shellfish tissue concentrations PFAS. However, a Tissue Concentration Criteria is applied uniformly to all waterbodies, whereas the previously described approach provides waterbody-specific consumptions rates. The tissue concentration criteria are determined based on the fish/shellfish consumption patterns of sensitive populations, and waterbodies where the tissue concentrations exceed the criteria are considered impaired. This does not provide a range of permissible servings over a time period like a Tissue Consumption Limit, rather, the criteria are based on the conservative estimates of general fish consumption behaviors in the population(s) of interest.

5.5.1. Methodology

The tissue concentration limit (C_{lim}) is determined as follows:

Equation 2 Tissue Concentration Criteria (Limit) for Fish and Shellfish Consumption

$$C_{lim} = \frac{RfD \times BW \times RSC}{IR}$$

Where:

C_{lim} – the fish tissue concentration limit for the chemical of concern, expressed in mg of chemical per kg of fish tissue (mg/kg)
RfD – Reference dose (mg/kg-d)
BW – Assumed human body weight (kg)
RSC – Relative Source Contribution expressed as a proportion of total daily exposure
IR - Fish or Shellfish Ingestion Rate (kg/d)

Technical issues related to the selection of RfDs, BW assumptions and the RSC are detailed in Methods for deriving a Fish Consumption Limit (Section 5.4.1). Similar considerations would be applied in the risk assessment process for deriving a tissue concentration limit, where the best available and scientifically-defensible data would be applied to protect human health.

A key and sensitive set of assumptions for determining the C_{lim} are the estimated fish tissue ingestion rates (IR) by consumers. Estimates and assumptions for fish tissue ingestion rates for the specified populations followed previously applied methods for the derivation of maximum allowable concentrations in fish. These numeric inputs rely on data from EPA Exposure Factors Handbook and updated recommendations for fish and shellfish consumption rates (EPA, 2014b; EPA, 2011). As an example, the table below summarizes the per capita fin- and shellfish consumption rates in the U.S. population expressed as grams of meat (g) consumed per kilogram of human body weight (kg) per day (d) based on national surveys conducted between 2003-2006 (EPA, 2011). These rates consumption also assumed primary consumption of fillets, and does not account for organ-meat consumption that may require additional assessment for unique sub-populations in New Hampshire. Using a broader data set (NHANES 2003-2010), EPA has also estimated some region-specific estimates of fish and shellfish consumption that are targeted at the Northeast (EPA, 2014b). Together, these consumer estimates provide a minimal basis for deriving tissue concentration limits. However, these are not specific to New

Hampshire and may over- or underestimate risk from fish and shellfish consumption for New Hampshire residents, coastal communities or subsistence fishing groups.

A key point for consideration is that larger consumption rates result in more restrictive tissue concentration limits for a chemical contaminant. Furthermore, consumption rates vary between types (for example, freshwater versus marine) of fish and shellfish, and shellfish is a broad category that includes mollusks (for example, clams and oysters) as well as crustaceans (for example, crabs and lobsters). Greater availability of this information allows for improved and more specific development of tissue concentration limits that are protective of public health, without relying on potentially highly conservative risk assessment assumptions. Thus, New Hampshire-specific fish/shellfish consumption data are preferable to national averages for determining tissue concentration limits for recreational fish and shellfish species.

Table 10. Fin- and shellfish consumption rates for the U.S. population estimated from the 2003-2006 National Health and Nutrition Examination Survey (NHANES). Table adapted from Table 10-1 of the EPA Exposure Factors Handbook, Chapter 10 (EPA 2011).

Age Group	N	% of Population Consuming	Per Capita Consumer Rate (g/kg-d)		Ounces Consumed per Week (mean)[b]	Ounces Consumed per Week (95th percentile)
			Mean	95th Percentile		
Finfish						
Birth to 1 year	865	2.6	0.03	N.R.[a]	0.04	- [c]
1 to <2 years	1,052	14	0.22	1.2	0.6	3.4
2 to <3 years	1,052	14	0.22	1.2	0.8	4.1
3 to <6 years	978	15	0.19	1.4	0.9	6.4
6 to <11 years	2,256	15	0.16	1.1	1.3	8.6
11 to <16 years	3,450	15	0.10	0.7	1.4	9.8
16 to <21 years	3,450	15	0.10	0.7	1.8	12.4
21 to <50 years	4,289	23	0.15	1.0	3.0	19.8
50+ years	3,893	29	0.20	1.2	4.0	23.7
Women of child bearing age (13-49 years)	4,103	22	0.14	0.9	2.8	17.8
Shellfish						
Birth to 1 year	865	0.66	0	N.R.	0.00	-
1 to <2 years	1,052	4.4	0.04	N.R.	0.1	-
2 to <3 years	1,052	4.4	0.04	N.R.	0.1	-
3 to <6 years	978	4.6	0.05	N.R.	0.2	-
6 to <11 years	2,256	7.0	0.05	0.20	0.4	1.6
11 to <16 years	3,450	5.1	0.03	N.R.	0.4	-
16 to <21 years	3,450	5.1	0.03	N.R.	0.5	-
21 to <50 years	4,289	13	0.08	0.50	1.6	9.9
50+ years	3,893	13	0.05	0.40	1.0	7.9
Women of child bearing age (13-49 years)	4,103	11	0.06	0.30	1.2	5.9

[a] N.R. – indicates that the available data were not reliable for estimating the 95th percentile
[b] Estimates of ounces of seafood per week are calculated based on EPA recommended body weight assumptions EPA Exposure Factors Handbook, Chapter 8 (EPA, 2011)
[c] Indicates the value was not estimated due to lack of reliable data.

5.5.2. Other States

To date, no other state has set a PFAS tissue concentration water quality criteria.

5.5.3. Data Needs

Developing a C_{lim} requires estimates of fish and shellfish consumption by the population. State agencies may default to national estimates for fish and shellfish consumption, but these values may not accurately characterize exposure risk for certain sub-groups. Coastal community, region-specific immigrant or refugee populations, as well as subsistence fishing groups like indigenous communities may have different fish consumption rates from the national average (EPA, 2014b) (EPA, 2016). If the national estimates for fish/shellfish consumption are lower than that of the target population, the resulting tissue concentration criteria will not be adequately protective. If national estimates are higher than that of the target population, this will result in overly restrictive criteria that unnecessarily limits access to viable fish and shellfish resources.

Additionally, this type of criteria would require waterbody specific measurements of PFAS in fish and/or shellfish tissues. Tissue Concentrations of PFAS in fish and shellfish would be determined following similar methods for the Tier 1 and 2 Studies (described in Section 5.4.3). The primary difference would be that instead of comparing the measured concentrations to predetermined screening levels (SLs), measured concentrations would be compared against the C_{lim} developed for fish and shellfish. For details about the methods used for these types of surveys, see section 5.4.3 (EPA, 2000; EPA, 2016). If a waterbody exceeded the C_{lim}, the 305(b) assessment process could impair the waterbody and trigger the TMDL planning process. Waterbody specific concentrations could also be used by permit writers, however, they would be faced with the challenge of determining an acceptable water concentration to maintain tissue below the C_{lim}.

5.5.3.1. New Hampshire Fish Consumption Survey

If EPA estimates of fish and shellfish consumption are not used for the development of a C_{lim}, the State will need to conduct a survey to determine population-specific fish consumption rates. There is existing guidance for the methodology to conduct a reliable survey of population-specific fish and shellfish consumption rates (EPA, 2016). An advantage to developing region-specific fish consumption rates is that this will allow for a more accurate estimate of C_{lim}, resulting in a value that minimizes the over- or underestimation of risks associated with fish and shellfish consumption.

In 2016, the Idaho Department of Environmental Quality (ID DEQ) contracted a consulting group to conduct a fish consumption study by surveying approximately 4,500 individuals from across the state (Northwest Research Group, LLC, 2016). At the time the population of Idaho was approximately 1.65 million (2015), only slightly smaller than the current combined population of New Hampshire and Vermont at approximately 1.36 million and 624,000, respectively, in 2018. Thus a similar sample size would likely provide adequate data on regional fish consumption behaviors. Using phone interviews, participants (ages 18 and older) were asked a series of fish consumption questions that were developed in collaboration with the Boise State University Public Policy Center. A similar survey could be adapted for New Hampshire and Vermont, tailoring questions around regional practices.

The major advantage to this approach is the level of accuracy and specificity it offers to the derived C_{lim} for various fish and shellfish. Additionally, this would allow for a better understanding of freshwater and marine fish consumption which are likely different values and therefore result in different regulatory standards for freshwater and marine environments. These data would also be applicable to other nonPFAS chemical contaminants, thereby providing a long-term improvement to regional risk assessment practices.

5.5.4. Cost and Time Estimate to Develop

Estimated costs and time for fish and shellfish tissue criteria are provided in Table 11. This includes costs and time for tissue concentration criteria, as well as cost and estimated time for monitoring waterbodies based on fish and shellfish tissue PFAS concentration limits.

NHDES has not developed either a fish or shellfish consumption tissue concentration criteria (Table 11). This would require determination of appropriate fish and shellfish consumption rates by New Hampshire residents (Step A) and a risk assessment to determine appropriate and scientifically-based tissue concentration limits (Step B). Use of EPA's nationally derived estimates of fish and shellfish consumption will expedite criteria development, but is prone to limitations previously discussed in this section. For an example of how much this kind of study might cost, the University of New Hampshire provided a quote of approximately $86,000 for a study of 1,000 New Hampshire residents.

Approval by JLCAR is required and anticipated to take four to eight months (Table 11, Step C). This will require a public comment period, response to said comments and review by interagency groups. Once approved by JLCAR, the standards would then be submitted to EPA for approval and use in any federal actions. Based on previous rule-making processes, and the unique nature of this task this is expected to take over 400 hours of NHDES staff time.

To determine which waterbodies exceed the fish or shellfish tissue concentration criteria will require extensive sampling and monitoring of individual waterbodies (Table 11, Steps D-E). This would follow optimal or minimal tissue sampling approaches, that are detailed in Section 5.4.4. Replicate sampling would be necessary to evaluate the magnitude and extent of contamination across species and size classes of fish that are potentially caught for consumption. Additionally, this would include data management and notification of impaired waterbodies (Table 11, Step F) based on waterbody-specific findings from Steps D and E. Based on sampling results NHDES would then spend time to evaluate data from waterbodies and conduct outreach to affected stakeholders.

Total estimated cost for developing and monitoring for fish and shellfish tissue concentration criteria an then time conducting outreach to affected stakeholders would likely range from $547,000 to $4,747,000.

Table 11. **A)** Overview of costs associated with developing a PFAS tissue concentration criteria based on fish/shellfish consumption and B) monitoring to determine compliance.

	PROCESS and STEP	DATA REQUIREMENTS	ESTIMATED COSTS*		ESTIMATED TIME TO COMPLETE
			Description	Item Costs	
A) CRITERIA DEVELOPMENT COSTS	(A) Determine Typical Fish and Shellfish Consumption Rates	(*Optimal*) Conduct a State-Wide Survey for Fish and Shellfish Consumption Patterns *Provide NH-specific information for reducing exposure to PFAS and other chemicals associated with fish and shellfish consumption	Contractor work with survey research group to conduct study of New Hampshire consumption rates.	$86,000	12-18 months, including external peer-review and preparation of final report
		(*Minimal*) Use Standard EPA Assumptions based on National Trends for Fish and Shellfish Consumption	Publically available data	$0	Immediately available
	(B) Determine Tissue Concentration Limits	Information from (A) + Toxicity Values (RfDs) for target PFAS, the same values used for Drinking Water Criteria or MCLs.	NHDES Staff time to evaluate data, calculate consumption limits and prepare summary report (see Table 9)	$9,000	2-3 months includes time for interagency peer-review
	(C)Adopt Fish/Shellfish PFAS Concentration Limits	None	NHDES Staff time to conduct rulemaking process and submission to JLCAR, and submission to EPA.	$25,000	4-8 months
	Total Cost to develop and pass Tissue Concentration Criteria based on fish/shellfish consumption			**$34,000 to $120,000**	**5-24 months**
B) WATERBODY ASSESSMENT COSTS	(D) Tier 1 Study	(*Optimal*) Measure Tissue Concentrations of PFAS in Fish/Shellfish Includes increased sampling to avoid future data collection if PFAS concentration exceed SLs	1 site per waterbody 4 species per site 2 predators, 2 bottom-dwellers 5 replicate tissue samples per species PFAS Water Concentrations PFAS Sediment Concentrations Water quality parameters	$16,000 X100 waterbodies $1,600,000	18-24 months, project planning and sample collection
		(*Minimal*) Measure Tissue Concentrations of PFAS in Fish/Shellfish	1 site per waterbody 4 species per site 2 predators, 2 bottom-dwellers	$5,000 X100 waterbodies $500,000	18-24 months, project planning and sample collection

Table 11. **A)** Overview of costs associated with developing a PFAS tissue concentration criteria based on fish/shellfish consumption and B) monitoring to determine compliance.

PROCESS and STEP	DATA REQUIREMENTS	ESTIMATED COSTS*		ESTIMATED TIME TO COMPLETE
		Description	**Item Costs**	
		1 composite tissue sample per species PFAS Water Concentrations PFAS Sediment Concentrations Water quality parameters		
(E) Tier 2 Study Only required where PFAS exceed SLs in Tier 1 Study	(*Optimal)* Measure Tissue Concentrations of PFAS in Fish/Shellfish Increased # of sampling sites per waterbody to account differences due to environmental factors (for example, spatial distributions) or within-species variability (for example, size class and/or sex)	1 site per waterbody 4 species per site 2 predators, 2 bottom-dwellers 5 replicate tissue samples per species PFAS Water Concentrations PFAS Sediment Concentrations Water quality parameters	$47,000 X100 waterbodies $4,700,000	12-18 months, Occurs subsequent to Tier 1 Studies use *Minimal* approach
	(*Minimal)* Measure Tissue Concentrations of PFAS in Fish/Shellfish Can be avoided if *Optimal* Data Requirements are initially met by Tier 1 Study	1 site per waterbody 4 species per site 2 predators, 2 bottom-dwellers 5 replicate tissue samples per species PFAS Water Concentrations PFAS Sediment Concentrations Water quality parameters	$16,000 X100 waterbodies $1,600,000	12-18 months, Occurs subsequent to Tier 1 Studies use *Minimal* approach
(F) Data Assessment and Consumption Limit Notifications		NHDES Staff time to determine which waterbodies are impaired and conduct outreach to affected stakeholders	$47,000	4-6 months
Tier 1 – Total Costs for *Optimal Approach* to Assess a Waterbody based on Tissue Consumption Limits (Studies (D) Across 100 Waterbodies + Assessment and Outreach (F))			**$1,647,000**	**2.5-3.5 years**
Tier 1 - Total Costs for *Minimal Approach* to Assess a Waterbody based on Tissue Consumption Limits (Studies (D) Across 100 Waterbodies + Assessment and Outreach (F))			**$547,000**	**2.5-3.5 years**
Tier 2 – Total Costs for *Optimal Approach* to Assess a Waterbody based on Tissue Consumption Limits (Studies (E) Across 100 Waterbodies + Assessment and Outreach (F))			**$4,747,000**	**2.5-3.5 years**

Table 11. **A)** Overview of costs associated with developing a PFAS tissue concentration criteria based on fish/shellfish consumption and B) monitoring to determine compliance.

PROCESS and STEP	DATA REQUIREMENTS	ESTIMATED COSTS*		ESTIMATED TIME TO COMPLETE
		Description	Item Costs	
Tier 2 - Total Costs for *Minimal Approach* to Assess a Waterbody based on Tissue Consumption Limits (Studies (E) Across 100 Waterbodies + Assessment and Outreach (F))			**$1,647,000**	**2.5-3.5 years**

* Estimated Costs assume 10% duplication of sampling for quality assurance/quality control, as well as labor costs. All costs in the table are based on 2020 prices.

5.6. *Fish/Shellfish Consumption Only (Water Concentration Criteria)*

This approach determines *water concentration limits of PFAS that will protect fish and shellfish for human consumption.* This is a modification of the Tissue Concentration Criteria (TCC) (Section 5.5) where a BAF converts the TCC into a Water Concentration Criteria (WCC). This WCC is expressed in either µg/L or ng/L and is predictive of water concentrations of PFAS that lead to unacceptable tissue concentrations in consumed fish or shellfish. A major advantage to a WCC is that it allows for monitoring of surface water concentrations instead of fish/shellfish tissue concentrations of PFAS, which significantly reduces the complexity and costs of long-term sampling efforts. That is to say, measuring PFAS in water is significantly less expensive than monitoring fish and shellfish tissues. A distinct limitation to this approach is the considerable upfront costs for biological and environmental sampling needed to estimate representative BAFs. This will require intensive data collection and is likely the most expensive approach to developing water quality criteria protective of human health, although that dataset is also required for the development of a Fish/Shellfish and Water Consumption, Water Concentration Criteria (see Section 5.7).

5.6.1. Methodology

A WCC based on fish and shellfish consumption can be estimated using the equation below. Separate values would likely need to be derived for freshwater fish, marine fish and shellfish that are caught in New Hampshire's surface waters.

Equation 3 Water Concentration Criteria for Fish and Shellfish Consumption

$$WCC = \frac{BW \times RfD \times RSC \times CF}{IR \times BAF}$$

Where:

WCC – Water Concentration Criteria (µg/L)
BW – Human Body Weight (kg)
IR – Fish or Shellfish Ingestion Rate (kg/d)
BAF – Bioaccumulation Factor (L/kg)
RfD – Chronic Oral Reference Dose (mg/kg-d)
RSC – Relative Source Contribution
CF – Units Correction Factor (1,000 µg/mg)

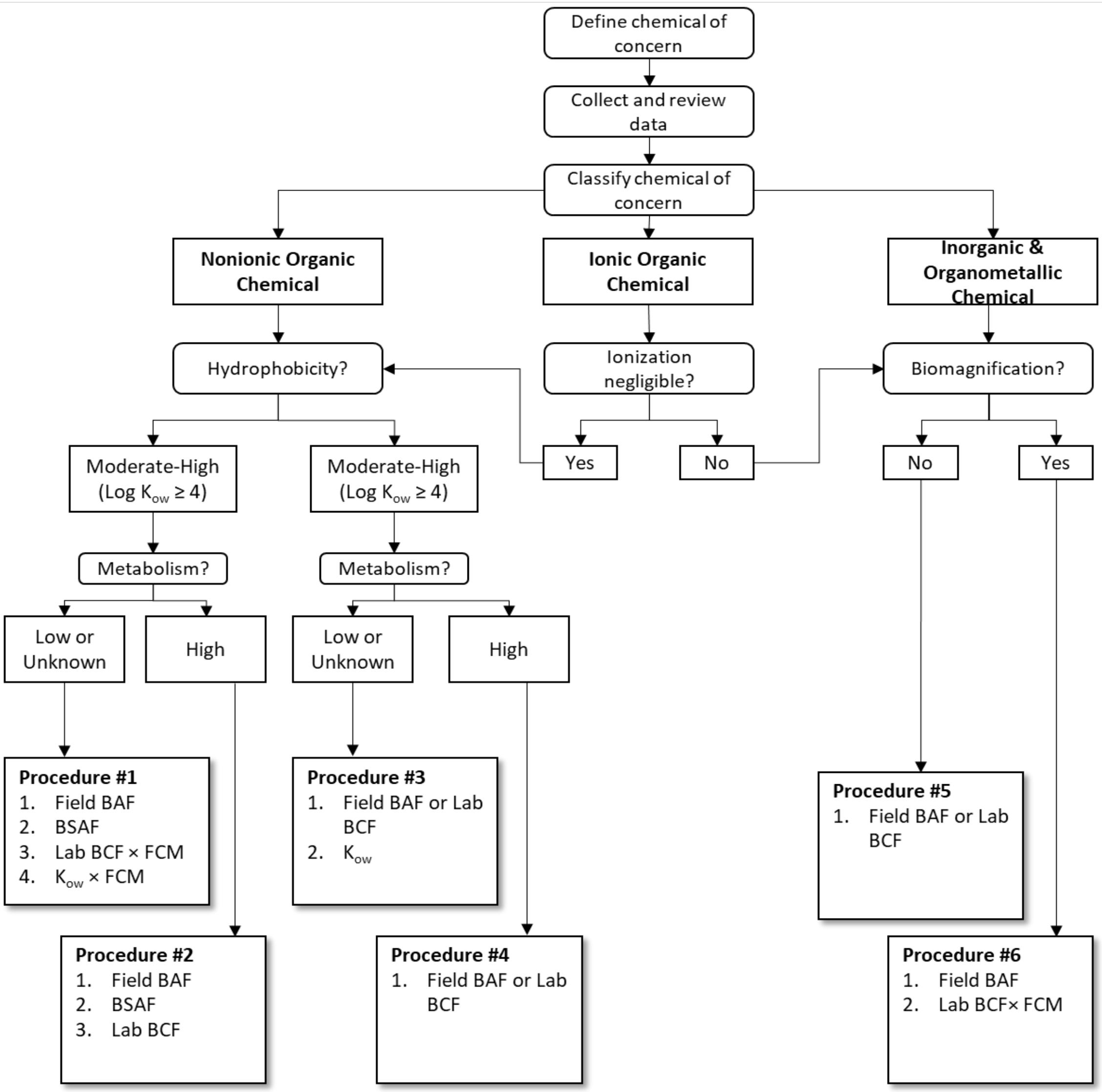
The critical component that is unique to Equation 3 is the BAF. This term translates the environmental (for instance, water) concentration of PFAS into a tissue concentration found in fish and shellfish. This is a data-driven measure of bioaccumulation, and necessary to estimate the water concentration that will result in unacceptable tissue concentration in fish and shellfish.

As defined by EPA, *bioaccumulation* describes an organism's uptake and retention of a chemical from all of its surrounding environmental media (for example, water, food, sediment) (EPA, 2003). When bioaccumulation occurs, the tissue concentrations of a chemical in an organism exceed those in the external environmental media. This can include uptake and retention of PFAS from ingested sediments, dermal exposure and the ingestion of contaminated prey species. BAFs quantify this phenomenon, where BAFs ≤ 1 indicate the chemical does not readily bioaccumulate into an organism while BAFs > 1 indicate that bioaccumulation occurs. As with other persistent chemical contaminants, the BAFs of PFAS can range from single digit values into the thousands because of their ability to partition into certain organs and tissues. For example, Michigan Department of Environmental Quality reported BAFs that ranged from 231 to 240,938 L/kg for a variety of game fish caught in regional waterbodies (MDEQ, 2018). Given the role of BAFs as a multiplier to the denominator in Equation 3, estimation and selection of the BAF can have a significant impact on the final WCC protective of human health and fish consumption.

Based on current EPA guidance documents, BAFs from field-collected fish and shellfish are the preferred estimate of accumulation of PFAS from water into biota. As a part of this same guidance, EPA provides a decision tree (Figure 4) for selecting appropriate measures of chemical accumulation in fish and shellfish tissues where Procedure 6 is deemed most appropriate for bioaccumulative compounds such as PFAS (EPA, 2003). Alternative methods for estimating chemical accumulation in fish and shellfish include: biota-sediment accumulation factors (BSAFs), BCFs, and n-octanol-water partition coefficients (K_{ow}). BSAFs estimate bioaccumulation into biota relative to sediment PFAS concentrations instead of the water column. Due to the highly-ionized behavior of PFAS in most aquatic environments, sediment accumulation may not be crucial for estimating a WCC protective of human health (EPA, 2003). However, due to the lack of fundamental research on fate ad transport of PFAS in the environment, the role of sediment should not be discounted and surveys of PFAS in the water column would benefit from matched sampling of sediments.

BCFs are typically derived for chemicals when the primary source of exposure to an organism is from ventilation or ingestion of contaminated water, not food, sediments or other environmental media. Several studies have demonstrated that ingestion of contaminated prey is a significant source of exposure for aquatic organisms (Fair, et al., 2019; Stuchal & Roberts, 2019), and therefore BAFs are more appropriate than BCFs. Furthermore, K_{ow} is not a reliable estimator of the bioaccumulative properties of PFAS. This is because several PFAS behave as surfactants capable of both hydrophobic and hydrophilic interactions despite existing in an anionic state under natural conditions. From a logistical standpoint, BCFs require laboratory facilities capable of supporting controlled exposure at various environmentally-relevant concentrations of the chemical(s) in question. Given the potential for laboratory contamination with PFAS, this type of research should be left to either academic, federal or private research institutions capable of appropriate QA/QC of exposure studies.

Figure 4. Copy of EPA Decision Tree for use of BAFs to estimate between water and tissue concentrations of PFAS in fish and shellfish (EPA, 2003).



Adaptation of EPA Exposure Decision Tree for Selecting methods for Deriving National BAFs.

US EPA. 2003. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000) Documents. Technical Support Document Volume 2: Development of National Bioaccumulation Factors

5.6.2. Other States

Outside of New England, other state agencies have investigated and in some cases developed BAFs for estimating acceptable surface water concentrations of PFAS. This includes: Florida, Michigan, Minnesota and New Jersey. As a part of its 2019 PFAS Action plan, the EPA has begun the process of problem formulation and literature review necessary for developing BAFs for PFOA and PFOS. Outside of state and federal agencies, several academic research groups have published data on BAFs from site-specific studies within the U.S., with additional ongoing studies that may be useful to New Hampshire's surface waters.

A white paper developed by the University of Florida for the Florida Department of Environmental Protection (FDEP) described potential screening levels (SLs) for PFOS and PFOA in freshwater and marine (estuary) fish (Stuchal & Roberts, 2019). Based on their review of scientific literature related to finfish and shellfish the BAFs for PFOA and PFOS were estimated to be 68 and 2,358 L/kg, respectively. When these BAFs were applied to regionally-relevant exposure assumptions for fish and shellfish consumption, the resulting SLs were 150 ng/L for PFOA and 4 ng/L for PFOS. As described by the authors of the report, this nearly two-order of magnitude difference between the SLs for PFOA and PFOS reflects differences in bioaccumulation between the two PFAS. This results in a situation where assuming equivalency between PFOA and PFOS, and other PFAS, may dramatically over- or underestimate risks associated with fish consumption and surface water concentrations.

Michigan Department of Environmental Quality characterized BAFs in carp, bluegill, rock bass and smallmouth and largemouth bass collected from various sites between 2011 and 2013 (MDEQ, 2018). Similar to the previously described observations by the University of Florida, long-chain perfluorosulfonic acids were highly bioaccumulative when compared to short chain compounds and perfluorocarboxylic acids. Across all of the sampled species, BAFs for PFOS ranged from >231 to 240,938 L/kg with the highest BAF occurring in bluegill sampled from the Au Sable River. From this, they determined that surface water concentration exceeding 12 ng/L of PFOS may warrant fish consumption advisories, based on a BAF of 2,329 L/kg observed across trophic level (TL) 3 fish. It is worth noting that the PFOS BAF identified by both the University of Florida and MDEQ are essential identical at approximately 2,300 L/kg, and may reflect a central tendency amongst certain species. Per EPA guidance, at least 3 TLs should be included for deriving a reliable BAF, and the inclusion of other TLs would better characterize variability and reduce uncertainty associated with the resulting WCC.

The Minnesota Pollution Control Agency (MPCA) estimated a site-specific BAF of 6,087 L/kg for PFOS (MPCA, 2010) for Lake Calhoun by taking the geometric mean from the fillets of four species including: blue gill (4,516 L/kg), black crappie (5,552 L/kg), Northern pike (4,908 L/kg) and Largemouth bass (10,418 L/kg), all species present in New Hampshire waters. In an earlier report, the same agency noted several differences in the bioaccumulation of PFOS between species and tissue types (MPCA, 2007). This points to the need to consider tissue differences in accumulation that might affect people consuming whole fish, as well as the potential impact of species variability of estimating a valid BAF.

More recently, fish tissue survey results from New Jersey (2015-2016) highlight a significant technical issue of analytical detection limits associated with field-derived BAFs. At a reference site called Echo Lake, surface water and sediment concentrations of PFOS were below detection limits of 1-2 ng/L and 0.1-0.2 ng/g, respectively; yet the average concentrations of PFOS in largemouth bass (4.63 mg/g) were high enough to restrict fish consumption to one meal per month (Goodrow, Ruppel, Lippincott, & Post, 2018 (updated 4/8/2019)). Thus, designating a surface water concentration based on fish consumption may be technically infeasible if field-derived BAFs indicate a WCC below current detection limits. Additionally, these findings suggest that field-derived BAFs may need to be compared to laboratory measured BCFs to reliably understand how PFAS accumulate at extremely low water concentrations.

5.6.3. Data needs

The data needs for this type of WCC include the same data needs described in Sections 5.4 and 5.5, along with the development of regional BAFs. Any investigation that measures PFAS concentrations in fish tissue, shellfish tissue, water and sediments will provide NHDES with a preliminary assessment of the occurrence, magnitude, and potential for bioaccumulation and biomagnification in New Hampshire's waters. By itself, measuring PFAS concentrations in fish and shellfish tissue will provide NHDES with preliminary species-specific data that can be used to evaluate the necessity of developing fish consumption advisories described in Sections 5.4 and 5.5. These consumption advisories would allow for an immediate exposure reduction while NHDES continues to derive BAFs for broader application at appropriate waterbodies. If these surveys are supplemented with surface water sampling and additional species across a minimum of three trophic levels it is would be feasible to determine field-measured BAFs for designating WCC. For the later objective, the target species should be those of game fish that are commonly consumed by New Hampshire residents.

5.6.3.1. Development of Bioaccumulation Factors

The current approach for deriving BAFs protective for fish and shellfish is detailed in the *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health* (EPA, 2003). BAFs for chemical contaminants can vary widely based on differences in inter- and intraspecies differences in physiology and their position in the food chain. Where possible, EPA recommends such a BAF is determined using BAFs from three trophic levels (EPA, 2015). Additionally, this will require consideration of whether the final WCC is intended to be protective of fillet or whole-fish consumption by populations of concern. Whole body BAFs will likely be more protective than fillet-derived BAFs as various internal organs (for example, liver) have been shown to typically possess higher PFAS concentrations than fillets. EPA guidance outlines how, ideally, a BAF is developed for national, regional or site-specific use (EPA, 2003).

The BAF used for derivation of a regional WCC protective of fish or shellfish for human consumption is expressed as follows:

Equation 4 Regional/National BAF Derivation

$$\text{Regional/National BAF}_{\text{TL n}} = \left[(\text{Final Baseline BAF})_{\text{TL n}} \times (f_l)_{\text{TL n}} + 1\right] \times (f_{fd})$$

Where:

Regional/National $\text{BAF}_{\text{TL n}}$ – national or broadly applicable BAF (L/kg-tissue)
Final Baseline $\text{BAF}_{\text{TL n}}$ – geometric mean BAF of field samples for a given trophic level (TL n) (L/kg-lipid), or calculated from laboratory derived BCFs (see below)
f_l – fraction of lipid content in fish tissue for given trophic level (TL n)
f_{fd} – fraction of the total concentration of chemical freely dissolved in water

This regional value accounts for BAF differences across trophic levels, the potential influence of lipid content in each species (f_l) and availability of the chemical (for instance, PFAS) in the aqueous environment. The Final Baseline BAF is a geometric mean of Baseline BAFs within a certain TL to estimate bioaccumulation between predator and prey species. Baseline BAFs can be estimated from either 1) field-collected tissue and water samples to estimate BAFs or 2) laboratory-measured BCFs which are adjusted to approximate a BAF. Using field-collected tissue and water samples, the Baseline BAF for given TL or species can be calculated as follows (EPA, 2003):

Equation 5 Estimated BAF from Field-Collected Samples

$$\text{Baseline BAF}_i = \left[\frac{\text{BAF}_T^t}{f_{fd}} - 1\right] \times \frac{1}{f_l}$$

Where:

Baseline BAF_i – baseline BAF of field sample i (L/kg-lipid)
BAF_T^t – total BAF from field sample ($\text{mg}_{\text{chemical}}$ in tissues / $\text{mg}_{\text{chemical}}$ in water)

f_{fd} – fraction of the total concentration of chemical freely dissolved in water
f_l – fraction of lipid content in fish tissue

Estimating Baseline BAFs requires the collection of fish/shellfish tissue samples paired with water samples. This would require similar sample replications described in Sections 5.4.3 and 5.5.3, namely for the Tier 2 assessments. The sampling strategy would also require species from multiple trophic levels, preferably TLs 2, 3 and 4 as described by EPA methodology (EPA, 2003). This will allow for assessment of biomagnification of PFAS in typically consumed species, and the identification of the most appropriately protective BAF.

As summarized by the EPA (2003; Table 3-1 therein), the advantage to using field-collected BAFs is that this measure incorporates the effects of biomagnification through the food chain and integrate the wide range of environmental factors that influence exposure (for example, bioavailability, prey availability, seasonality), uptake and elimination of a chemical in a given site. Additionally, this approach can also measure the target PFAS following environmental or physiological metabolism of precursor compounds, such as fluorotelomer alcohols that are metabolized to release other PFAS (Butt, Muir, & Mabury, 2014; Brandsma, et al., 2011). However, this information can be highly site-specific and require additional representative sampling across a region or the state to accurately estimate BAFs. Another limitation is that seen with sampling efforts by New Jersey where water concentrations of PFAS were below detection limits but fish tissue concentration indicate some source of exposure (NJDEP, 2019). Surface water concentrations of most chemical contaminants fluctuate significantly based on precipitation patterns and sampling events may overlap with periods of relatively low or undetectable PFAS concentrations.

An alternative to field-collected tissue and water samples to develop a Baseline BAF_i is the use of laboratory-measured BCFs that are adjusted using a food chain multiplier. The estimation of the Baseline BAF_i based on a laboratory-measured BCF is:

Equation 6 Estimated BAF from Laboratory BCFs

$$\text{Baseline BAF}_i = (FCM)_{TL\,n} \times \left[\frac{BCF_T^t}{f_{fd}} - 1\right] \times \frac{1}{f_l}$$

Where:

Baseline BAF_i – baseline BAF of field sample i (L/kg-lipid)
$(FCM)_{TL\,n}$ – Food chain multiplier for the associated trophic level (TL) of the species
BCF_T^t – total BCF from laboratory sample ($mg_{chemical}$ in tissues / $mg_{chemical}$ in water; L/kg-tissue)
f_{fd} – fraction of the total concentration of chemical freely dissolved in water
f_l – fraction of lipid content in fish tissue

This approach relies on controlled laboratory exposure studies where various fish species are exposed to known concentrations of PFAS. Following several days to weeks of exposure, animals are sampled to measure tissue concentrations of PFAS and compared to measured water concentrations. To account for bioaccumulation and biomagnification, these are adjusted by standardized reference values called food chain multipliers (FCMs) (EPA, 2003).

An advantage to this approach over field-collected BAFs is that laboratory-based BCFs allow for more control over abiotic variables such as temperature, pH and a known water concentration/exposure of PFAS. This eliminates the uncertainty of fluctuating environmental concentrations and their impact on the final BAF estimate. However, there are a limited number of fish and shellfish species that are amenable to laboratory studies, and the use of many wild-caught species would require significant investment in facility space to conduct exposure studies. Additionally, the cost associated with developing laboratory facilities capable of conducting PFAS testing would be significant for any state agency.

Aside from the Baseline BAFs, EPA recommendations include adjusting the BAF based on the lipid content (f_l) of the organism. This practice is due to the recognition that hydrophobic chemicals such as pesticides and polychlorinated biphenyl compounds (PCBs) preferentially accumulate in fatty tissues resulting in higher tissue concentrations. At a minimum, this should be accounted for in tissue analysis and any effort to develop BAFs as it would inform some understanding of variability in BAFs between and within species. However, PFAS do not display the same hydrophobic interactions seen with classical contaminants such as pesticides or PCBs, and instead preferentially interact with proteins instead of lipids (ATSDR, 2018). The implications of this are the subject of ongoing research and may play a key role in accurately estimating BAFs.

The final variable considered in Equations 4-6 is the free-dissolved fraction (f_{fd}) of PFAS in the water column which are available for exposure and uptake via ventilation or ingestion by aquatic organisms. This is estimated using Equation 7, below.

Equation 7 Estimation of Dissolved Fraction of a Chemical

$$f_{fd} = \frac{1}{1 + POC \times K_{ow} + DOC \times 0.08 \times K_{ow}}$$

Where:

f_{fd} – fraction of the total concentration of chemical freely dissolved in water
POC – concentration of particulate organic carbon (POC) (kg_{POC}/L)
DOC – concentration of dissolved organic carbon (DOC) (kg_{DOC}/L)
K_{ow} – n-octanol-water partition coefficient
0.08 – previously derived factor for estimating organic carbon partitioning in combination with K_{ow} (EPA, 2003)

It is important to note here that most PFAS are amphipathic (a molecule having both hydrophilic and hydrophobic parts) making the utility of K_{ow} values questionable in this model. Ongoing risk assessment efforts have found little to limited utility of K_{ow} for understanding the behavior of PFAS, and it has been suggested that there an alternative measured should be developed for this class of chemicals (Simon, et al., 2019) (ATSDR, 2018). This can be addressed by conducting DOC analyses with sample collected to evaluate if there is a significant effect of on the f_d of PFAS in surface waters.

5.6.4. Cost and Time Estimate to Develop

Estimated costs and time for water concentration criteria based on fish and shellfish consumption are provided below. This includes costs and time for BAF and criteria development and rulemaking, as well as cost and estimated time for monitoring waterbodies based on water concentrations of PFAS.

NHDES has not developed either BAFs or water concentration criteria for any PFAS. Using minimal data that is relevant to New Hampshire, BAFs may be estimated from other species and applied to the development of surface water criteria. However, these values would be prone to erroneously estimating bioaccumulation within NH’s waters and potential over- or underestimate reliable water criteria. Thus, it is preferable and more scientifically-defensible to estimate BAFs based on data collected from regional waterbodies.

As discussed above, developing a BAF requires representative fish tissue samples from across trophic levels and regions. NHDES could randomly sample fish, water and sediment across a large number of waterbodies in New Hampshire and where PFAS are detected in both water and fish determine local BAFs. However, as seen in New Jersey, there is significant potential that water and sediment concentrations of PFAS are below detection limits making the calculation of BAFs unfeasible. Given the currently limited known areas of PFAS contamination and inherent difficulty to fish sampling, it is likely that only sampling at this handful of sites would not result in a robust estimation of a BAF. Therefore, it is recommended that New Hampshire partner with other Northeastern States to sample impacted sites in a coordinated study design to determine BAFs for freshwater and estuary/marine species. This aggregated data from impacted sites would provide a more robust BAF while reducing the potential for lost data from sites where PFAS of interests are below detection.

For New Hampshire, there are three groupings for which BAFs would need to be developed and incur sampling costs described in the Step A of the table below. These groupings include: freshwater fish, estuary/marine fish and estuary/marine shellfish. Based on Figure 1, New Hampshire could reasonably sample at least 10 freshwater waterbodies where PFOA, PFOS, PFHxS or PFNA are found at detectable concentrations. Similarly, at least 10 coastal or estuary sites could be sampled along the Seacoast. If other Northeast states contributed data from similar species, this would result in a robust estimate of a BAF for these various groups.

In addition to the BAF, these criteria require similar knowledge about fish and shellfish consumption rates by the target population. This would require determination of appropriate fish and shellfish consumption rate by New Hampshire residents and a risk assessment to determine appropriate and scientifically-based tissue concentration limits (Table 12, Steps A and B). Use of the EPA's nationally derived estimates of fish and shellfish consumption will expedite criteria development, but is prone to limitations previously discussed in Section 5.5.3.

Approval by the Joint Legislative Committee on Administrative Rules (JLCAR) is required and anticipated to take four to eight months (Table 12, Step C). This will require a public comment period, response to said comments and review by interagency groups. Once approved by JLCAR, the standards would then be submitted to EPA for approval and use in any federal actions. Based on previous rule-making processes, and the unique nature of this task this is expected to take over 400 hours of NHDES staff time.

To determine which waterbodies exceed the fish or shellfish tissue concentration criteria will require extensive sampling and monitoring of individual waterbodies (Table 12, Steps D-E). This would follow optimal or minimal tissue sampling approaches, that are detailed in Section 5.4.4. Based on sampling results NHDES would then spend time to evaluate data from waterbodies and conduct outreach to affected stakeholders.

Table 12. A) Overview of costs associated with developing a WCC based on fish/shellfish consumption and B) costs associated with assessing waterbodies.

<table>
<tr><th colspan="2" rowspan="2">PROCESS and STEP</th><th rowspan="2">DATA REQUIREMENTS</th><th colspan="2">ESTIMATED COSTS</th><th rowspan="2">ESTIMATED TIME TO COMPLETE</th></tr>
<tr><th>Description</th><th>Item Costs</th></tr>
<tr><td rowspan="6">A) CRITERIA DEVELOPMENT COSTS</td><td rowspan="6">(A) Determine Bioaccumulation Factors (BAFs)</td><td>(Optimal) BAF for Freshwater Fish, Determine NH-specific values</td><td>1 site per waterbody
3 species per site
≥1 species per TL (TLs 2, 3 and 4)
10 replicate tissue samples per species
PFAS Water Concentrations
PFAS Sediment Concentrations
Water quality parameters</td><td>$23,000
<u>× 10 representative waterbodies</u>
$230,000</td><td>18-24 months</td></tr>
<tr><td>(Minimal) BAF for Freshwater Fish using existing data**</td><td>NHDES Staff time to evaluate available data, calculate BAFs and prepare report</td><td>$8,000</td><td>2-3 months per compound, including peer review</td></tr>
<tr><td>(Optimal) BAF for Marine/Estuary Fish, Determine NH-specific values</td><td>1 site per waterbody
3 species per site
≥1 species per TL (TLs 2, 3 and 4)
10 replicate tissue samples per species
PFAS Water Concentrations
PFAS Sediment Concentrations
Water quality parameters</td><td>$23,000
<u>× 10 representative waterbodies</u>
$230,000</td><td>18-24 months</td></tr>
<tr><td>(Minimal) BAF for Marine/Estuary Fish using existing data**</td><td>NHDES Staff time to evaluate available data, calculate BAFs and prepare report</td><td>$8,000</td><td>2-3 months per compound, including peer review</td></tr>
<tr><td>(Optimal) BAF for Marine/Estuary Shellfish, Determine NH-specific values</td><td>1 site per waterbody
3 species per site
10 replicate tissue samples per species
PFAS Water Concentrations
PFAS Sediment Concentrations
Water quality parameters</td><td>$23,000
<u>× 10 representative waterbodies</u>
$230,000</td><td>18-24 months</td></tr>
<tr><td>(Minimal) BAF for Marine/Estuary Shellfish using existing data**</td><td>NHDES Staff time to evaluate available data, calculate BAFs and prepare report</td><td>$8,000</td><td>2-3 months per compound, including peer review</td></tr>
</table>

Table 12. A) Overview of costs associated with developing a WCC based on fish/shellfish consumption and B) costs associated with assessing waterbodies.

	PROCESS and STEP	DATA REQUIREMENTS	ESTIMATED COSTS		ESTIMATED TIME TO COMPLETE
			Description	Item Costs	
	(B) Determine Water Concentration Criteria	Information from (A) + the *Criteria Developmental Requirements (i.e., fish/shellfish consumption rates) for Tissue Concentration Criteria described in Table 11.*	NHDES Staff time to evaluate data, calculate water concentration criteria and prepare summary report	$26,000	6-8 months, including external peer-review and public comment
	(C)Adopt Fish/Shellfish PFAS Concentration Limits	None	NHDES Staff time to conduct rulemaking process and submission to JLCAR, and submission to EPA.	$25,000	4-8 months
	Total Cost for *Optimal Approach* to develop and pass Water Concentration Criteria derived from Bioaccumulation Factors (BAFs), assumed 10 waterbodies per BAF group***			**$741,000**	**36 months**
	Total Cost for *Minimal Approach* to develop and pass Water Concentration Criteria derived from Bioaccumulation Factors (BAFs), BAFs developed from limited existing literature			**$75,000**	**18-20 months**
B) WATERBODY ASSESSMENT COSTS	(D) Surface Water Testing	Measure Water Concentrations of PFAS	1 site per waterbody PFAS Water Concentrations	$1,300 (two-samples per waterbody) X100 Waterbodies $130,000	1-2 months
	(E) Data Assessment and Notification for Waterbodies	Results from (D)	NHDES Staff time to determine which waterbodies are impaired and conduct outreach to affected stakeholders	$23,000	3-4 months
	Total Costs to Assess a Waterbody using BAF-derived Water Concentration Criteria (100 waterbodies)			**$153,000**	**4-6 months**

* Estimated Costs assume 10% duplication of sampling for quality assurance/quality control, as well as labor costs. All costs in the table are based on 2020 prices.
** BAFs developed from the currently available and peer-reviewed literature are limited regarding NH-relevant species, thus BAFs have limited defensibility.
*** Use of 10 sites per waterbody types also assumes collaboration and cost sharing on BAF development with other New England States.

5.7. *Water and Fish/Shellfish Consumption (Water Concentration Criteria)*

This approach determines *water concentration limits of PFAS that will protect a waterbody for 1) fish/shellfish for human consumption and 2) as a source of drinking water.* This is almost identical to the WCC described in Section 5.6, except this includes consideration of exposure to PFAS from drinking water and existing drinking water standards (for instance, MCLs or Health Advisories). The brevity of this section should not imply that this approach is the fastest or easiest criterion, rather, a WCC based on fish/shellfish and water ingestion builds on the methods and considerations previously described in Sections 5.3-5.6.

5.7.1. Methodology

A WCC based on fish/shellfish consumption and use for drinking water can be estimated using a deterministic risk assessment approach, described in the equation below. Separate values would be derived for freshwater fish, marine fish and shellfish that are caught in New Hampshire waters.

Equation 8 Water Concentration Criteria for Fish/Shellfish Consumption and Water Ingestion

$$\text{WCC} = \frac{\text{BW} \times \text{RfD} \times \text{RSC} \times \text{CF}}{\text{DI} + (\text{IR} \times \text{BAF})}$$

Where:

WCC – Water Concentration Criteria (µg/L)
BW – Human Body Weight (kg)
IR – Fish or Shellfish Ingestion Rate (kg/d)
DI – Water Ingestion rate (L/d)
BAF – Bioaccumulation Factor (L/kg)
RfD – Chronic Oral Reference Dose (mg/kg-d)
RSC – Relative Source Contribution
CF – Units Correction Factor (1,000 µg/mg)

As discussed in previous sections of this plan, where variables for this estimation are not readily references from peer-reviewed papers or methodologies they can be measured to inform the WCC based on fish/shellfish consumption and water ingestion. The variables for this type of criteria have been previously described in other sections including: Section 5.4.1 for BW, RfD and RSC, Section 5.5.1 for IR, and Section 5.6.1 for BAFs. Similar to fish and shellfish ingestion rates, the drinking water ingestion rates for various segments of the population are similarly described in the EPA Exposure Factors Handbook (EPA, 2011).

Due to the significant physiological half-lives of PFAS, exposure through drinking water as a component of this WCC requires several considerations. This includes which segment of the population is the most sensitive for the relevant exposure period. Acute or short-term exposures (for example, non-residential) are typically less conservative than chronic exposures (for example, residential), and influence the role of drinking water ingestion in a WCC. Such considerations have been discussed by multiple state and federal agency reports on the issue of guidance for PFAS in drinking water (Bartell S. J., 2018; EPA, 2016a; NHDES, 2019b; NJDWQI, 2018; NJDWQI, 2017; Goeden, Greene, & Jacobus, 2019; VDH, 2018; EPA, 2016a; NHDES, 2019b; NJDWQI, 2018).

5.7.2. Other States

To date, no other state or U.S. agency has established a surface water criterion for PFAS based on this or a similar methodology.

5.7.3. Data Needs

The data needs for this approach are identical to those described in Sections 5.3 and 5.6. Readers interested in the summarized descriptions of study needs are referred to these sections for further consideration. The advantage to this approach is that this WCC can be readily derived after obtaining sufficient data. If a waterbody exceeded the WCC, the 305(b) assessment process could impair the waterbody and trigger the TMDL planning process. Waterbody specific concentrations could also be used by permit writers and would be simpler to use than the tissue concentration WCC described in section 5.5.

5.7.4. Cost and Time Estimate to Develop

The drinking water designated use applies to all waters of the state. However, the use is described as "potentially acceptable for water supply uses after adequate treatment" (RSA 485-A:8, I). As such, the application of the Water and Fish based WCC for human health would need to be applied carefully, much like the application of the MCL based WCC (section 5.3).

Costs and time for development of criteria, implementation and monitoring are the combination of the efforts seen in Section 5.3 (MCL adoption as Water and Fish/Shellfish Consumption Criteria) (Table 7) and Section (Water Concentration Criteria to Protect Fish Consumption)(Table 12). Due to the overlap of those efforts, the Section 5.6 (Water Concentration Criteria to Protect Fish Consumption)(Table 12) describes the costs of developing this water concentration criteria and the costs to assess waterbodies for that criteria.

5.8. Recreational Contact (Water Concentration Criteria)

This approach determines *water concentration limits of PFAS that will protect human health from exposure to PFAS during recreational activities (for example, swimming and wading).* This addresses concerns for dermal exposure to PFAS and incidental ingestion of water contaminated with PFAS. However, current evidence suggest PFAS are poorly absorbed through the skin (Section 5.2.2). Conservative screening levels developed by other state agencies have found that the concentrations of PFAS that present a risk via recreational exposures such as swimming are orders of magnitude higher than concentrations that would be protective for fish/shellfish consumption, use for drinking water or some estimates of toxicity towards aquatic wildlife. New Hampshire has no other toxics that have a standard in the toxics table Env-Wq 1703-1 and a separate recreational contact concentration.

5.8.1. Methodology

Using methodology for developing screening levels for site-specific assessments (EPA, 2004), a surface water concentration criterion based on recreational contact can be derived. The estimated doses following recreational exposure (for instance, swimming) are the sum of the incidental oral dose (IID) and dermal absorbed dose (DD), which are calculated using the following equations:

Equation 9 Estimated Dose from Incidental Ingestion from Swimming.

$$IID = \frac{C_W \times IIR \times BF \times EF}{BW}$$

Where:
IID – incidental oral dose (mg/kg-d)
C_W – water concentration (µg/L)
IIR – Incidental Water Ingestion Rate (L/h)
BF – Bioavailability Factor
EF – exposure frequency in days per year (d/y)
BW – body weight (kg)

Equation 10 Estimated Dose from Dermal Absorption while Swimming.

$$DAD = \frac{K_p \times C_w \times T_e \times EF \times SA}{BW}$$

Where:
DAD – dermal absorbed dose (mg/kg-d)
K_p – skin permeability coefficient (cm/h)
C_w – surface water concentration (µg/L)
T_e – hours of direct dermal contact with surface water per day
EF – exposure frequency in days per year (d/y)
SA – surface area of skin (cm^2)
BW – body weight (kg)

These can be rearranged to solve for the maximum allowable surface water concentration, using the following formula:

Equation 11 Method to Estimate a Surface Water Criteria based on recreational Contact (for instance, Swimming).

$$WCC = \frac{RfD}{\frac{IIR \times BF \times EF}{BW} + \frac{K_p \times T_e \times EF \times SA}{BW}}$$

Thus, a surface water criterion derived by this method depends on a number of assumptions about exposure that can utilize regional data or national estimates. However, given the low rate in incidental ingestion on a scale of a few milliliters per hour and poor absorption of PFAS across the skin, most estimates of a surface water concentration protective of human health during recreational contact are several fold higher than those expected to be projected to protect fish and shellfish consumption.

A similar approach can be taken for assessment of sediments and derivation of sediment concentration criteria for PFAS. However, a very limited understanding of the fate and transport of PFAS in sediments suggest that development of such criteria would be premature.

5.8.1.1. Foam

To date, NHDES has not detected and confirmed by chemical analysis the occurrence of PFAS-derived foams on surface waters. Some anecdotal reports of concerning foam have been reported to NHDES, but in many cases this appears to be alkaline foams which are naturally occurring in New Hampshire surface waters. Using a similar approach to that described above, along with EPA guidance (EPA, 2000; EPA, 2011; USEPA, 1989), WCC can be developed for PFAS-related foams. However, these WCC would likely be far above any WCC needed to protect surface water for other uses by humans and wildlife. Other states have found it very challenging to even test the PFAS in foams as the volume of sample needed necessitates the collection of multiple large garbage bags of foam that when settled provides the sample volume needed for the analytical methods.

5.8.2. Other States

Michigan's Department of Health and Human Services assessed exposure risk for PFOA, PFOS, PFHxS and PFNA based on draft toxicity values from the ATSDR (MDHHS, 2019). This did not establish specific recommended limits or target concentrations of these compounds in water or sediment, rather, this was a comparison of measured environmental concentrations against minimal risk levels (MRLs) drafted by the ATSDR in 2018 (ATSDR, 2018). Overall, the concentrations of the specified PFAS that would elicit concern for recreational exposure were determined to be orders of magnitude higher than concentrations described in previous section of this plan for drinking water, fish and/or shellfish consumption.

5.8.3. Data Needs

The data needs to develop this criterion are 1) estimates of recreational activity and 2) measures of dermal absorption. Similar to fish and shellfish consumption rate, New Hampshire has not quantified the time individuals spend swimming, wading and engaging in other water-related activities. A survey of New Hampshire residents would provide valuable information to inform risk assessment of PFAS and other chemicals with respect to recreational contact. Examples of this would include exposure factors such as typical time spent swimming or wading in New Hampshire surface waters and how this varies by age groups. However, basic estimates of recreational contact rates are available from the EPA who has estimated these values at a national level (EPA, 2011). These values may not accurately reflect the tendencies of New Hampshire residents or certain populations, but use of the national estimates allow for faster development of water criteria.

An area of limited information that is a critical consideration for a recreational contact standard is dermal absorption which can be measured as the skin permeability coefficient (K_p). As discussed in Section 5.2.2 of Routes of Exposure, this limited understanding is a major limitation to risk assessment for dermal contact with PFAS. Neither NHDES or NHDHHS are currently equipped to conduct these types of experiments and these efforts are more suited for academic institutions, independent laboratories or federal research agencies (for example, EPA or ATSDR). NHDES continues to monitor for new and peer-reviewed information relevant to PFAS exposure risks from non-ingestion sources, including dermal contact.

Following implementation, the primary data requirement for monitoring consists of surface water measurements of PFAS. This should occur during the spring or summer when recreational contact with surface waters is most likely to occur.

5.8.4. Cost and Time Estimate to Develop

Estimated costs and time to develop and monitor for recreational contact criteria are provided below. This includes costs and time for consumption limit development, as well as cost and estimated time for monitoring waterbodies based on fish and shellfish tissue consumption limits.

NHDES has not developed a water concentration criteria based on recreational contact. This would require determination of appropriate recreational exposure scenarios for New Hampshire residents (Step A) and a risk assessment to determine appropriate and scientifically-based tissue water concentration limits (Step B). Use of the EPA's nationally derived estimates of recreational contact will expedite criteria development, but is prone to limitations previously discussed in this and other sections as related to fish consumption rates. This information could be gathered by phone survey of New Hampshire residents to estimate reasonable and realistic exposure scenarios. For an example of how much this kind of study might cost, the University of New Hampshire provided a quote of approximately $18,000 for a study of 1,000 New Hampshire residents.

Approval by the Joint Legislative Committee on Administrative Rules (JLCAR) is required and anticipated to take four to eight months (Table 11, Step C). This will require a public comment period, response to said comments and review by interagency groups. Once approved by JLCAR, the standards would then be submitted to EPA for approval and use in any federal actions. Based on previous rule-making processes, and the unique nature of this task this is expected to take over 400 hours of NHDES staff time.

To determine which waterbodies exceed the water concentration criteria will require extensive sampling and monitoring of individual waterbodies (Steps C and D). This would follow optimal or minimal tissue sampling approaches, that are detailed in Section 5.3.4. Based on sampling results NHDES would then spend time to evaluate data from waterbodies and conduct outreach to affected stakeholders.

Total estimated cost for developing and monitoring for water concentration criteria for recreational contact would likely range from $34,000-$120,000, where subsequent assessment costs are $540,000 for two-rounds of sampling at all designated beaches, time to evaluate data from waterbodies and conduct outreach to affected stakeholders.

Table 13. A) Overview of costs associated with developing a WCC based on recreational contact and B) costs associated with assessing waterbodies..

	PROCESS and STEP	DATA REQUIREMENTS	ESTIMATED COSTS		ESTIMATED TIME TO COMPLETE
			Description	Item Costs	
A) CRITERIA DEVELOPMENT COSTS	(A) Assess Typical Recreational Contact Scenarios	(*Optimal*) Statewide/Regional Survey to Determine Population-Specific Recreational Rates	Survey contracted through external contractor	$86,000	12-18 months
		(*Minimal*) Use Estimates of Recreational Values from the EPA's Exposure Factors Handbook (Not Specific to New Hampshire Residents)	Publically available literature	$0	0
	(B) Determine Water and/or Sediment Concentration Criteria for Recreational Contact	(A) + RfDs/Toxicity Values described in Table 7 Criteria development Costs	NHDES Staff time to evaluate data, calculate consumption limits and prepare summary report	$9,000	2-3 months includes time for interagency peer-review
	(C) Adopt Recreation PFAS Concentration Limits	None	NHDES Staff time to conduct rulemaking process and submission to JLCAR, and submission to EPA.	$25,000	4-8 months
	Total Cost to Develop and Pass Water Concentration Criteria for Recreational Contact			**$34,000 to $120,000**	**6-18 months**
B) WATERBODY ASSESSMENT COSTS	(C) Surface Water Testing	Measure Water Concentrations of PFAS	1 site per waterbody PFAS Water Concentrations	$1,300 (two-samples per waterbody) <u>X381 Designated beaches</u> $495,000	1-2 months
	(D) Assessment and notification for Waterbodies	Results from (C)	NHDES Staff time to determine which waterbodies are impaired and conduct outreach to affected stakeholders	$47,000	3-4 months
	Total Costs to Assess a Waterbody using Water Concentration Criteria for Recreational Contact (× 381 Designated Beaches)			**$540,000**	**4-6 months**

*Estimated Costs assume 10% duplication of sampling for quality assurance/quality control, as well as labor costs. All costs in the table are based on 2020 prices.

6. Aquatic Life Use

6.1. *Aquatic Life Water Quality Standards Criteria*

The aquatic life designated use requires that every surface water can support aquatic life, including a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of similar natural habitats of the region.

The potential scope of an aquatic life criteria document can be seen in the recent "Final Aquatic Life Ambient Water Quality Criteria for Aluminum – 2018" (EPA, 2018). The aluminum criteria document covers just one designated use, aquatic life, and only covered freshwater aquatic life. The final dataset used 60 species tests for chronic criteria and 118 species tests for acute criteria and covered fish, invertebrates, mollusks, and an amphibian producing final criteria that vary based on changes in pH, total hardness, and DOC. Given the complex chemistry of PFAS we might expect an equally, if not more, complex effort is needed to generate a robust aquatic life PFAS criteria for fresh and marine waters of New Hampshire.

Aquatic life (or biota) criteria in water quality standards are necessary to support the designated uses of water bodies that pertain to the propagation of fish and wildlife. The aquatic life criteria of surface water quality standards for toxic chemicals represent the highest instream concentration of a pollutant or water conditions that are not expected to cause a significant risk to organisms. NHDES will rely on EPA's published methodology to establish aquatic life criteria for PFAS (Stephen, et al., 1985). This methodology relies on laboratory toxicity data from eight taxonomic groups to represent a wide distribution of species being protected by the standards. Aquatic life criteria are estimates of concentrations of pollutants in ambient water that if not exceeded are expected to protect fish, invertebrates, and other aquatic life from adverse effects associated with the exposure. The criteria are of two forms (EPA, 2017):

1) Acute aquatic life criteria, which is derived using short-term standard laboratory toxicity tests (48 to 96-hour exposure). These criteria protect against severe acute effects (for example, mortality) from short-term exposure to a toxic chemical; and
2) Chronic aquatic life criteria, which is derived using longer-term laboratory toxicity tests (7-day to over 28-day exposure). These criteria protect against longer term effects on survival, growth (for example, reduced body mass), and reproduction (for example, reduced egg production) from long-term exposure to a toxic chemical.

NHDES may also need to evaluate whether these criteria need to be differentiated by other water quality characteristics when relevant to toxicity, such as acidity (pH), total and dissolved organic carbon, temperature (cold water vs warm water surface waters), and hardness which refers to the amount of dissolved calcium and magnesium minerals or other metal ions such as iron and manganese, which can affect the toxicity of certain metals and potentially other chemical stressors.

The three components acute and chronic criteria: 1) magnitude (how much), based on toxicity testing; 2) duration (how long), and 3) frequency (how often) are provided in Table 14.

Table 14: Three Components of Acute and Chronic Aquatic Life Criteria

Components	Acute Aquatic Life Criteria	Chronic Aquatic Life Criteria
Magnitude	Criterion Maximum Concentration (CMC)	Criterion Continuous Concentration (CCC)
Duration	1-hour averaging period	4-day averaging period
Frequency (as a maximum frequency of exceedance to allow ecosystem to recover)	Once every three years	Once every three years

6.2. Steps for Deriving Aquatic Life Criteria

The first step in developing toxicity-based aquatic life criteria is to determine if there are sufficient data available from which to calculate the criteria based upon the EPA Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses (Stephen, et al., 1985). This method requires a minimum of 8-acute toxicity studies representing 8-families of aquatic biota. In addition, there is a requirement for a minimum of 3-chronic toxicity studies for the chemical, from which the Acute to Chronic Ratio (ACR) may be developed.

NHDES will undertake the following steps to establish aquatic life criteria for the four PFAS, relying on EPA Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses (Stephen, et al., 1985):

1) Determine methodology to use for deriving aquatic life criteria;
2) Collect and assess all available ecological toxicity data including bioaccumulation information, following EPA guidance. The state will rely on the EPA's curated and publically-available database called ECOTOX Knowledgebase (EPA-3, n.d.) to identify and evaluate existing peer-reviewed data and journal articles and evaluate other state data;
3) Assess any additional ecological risk assessment information expected to be released by EPA by 2021 (EPA, 2019);
4) Determine if minimum data requirements (MDRs) for acute toxicity studies are met for a minimum of eight different families according to EPA guidance (Stephen, et al., 1985). For freshwaters, these minimum data requirements include three vertebrates (a salmonid and a non-salmonid fish, and a species from a third chordate family) and five invertebrates (a planktonic crustacean, a benthic crustacean, an insect, a species from a phylum other than Chordata or Arthropoda, and a species from another order of insect or a fourth phylum). For marine waters, these minimum data requirements include two families from Chordata, a family from a phylum other than Arthrododa or Chordata, a Mysidea (shrimp-like crustacean) or Penaeidea (marine crustacean), three other families not in Chordata nor the Mysidea or Penaeidea families already used, and any other family.
5) For both fresh and marine waters, determine if MDRs for chronic toxicity studies are met for a minimum of eight different families with at least one species per family; or chronic studies from three families of aquatic animals including one fish and one invertebrate for which acceptable acute data are available and one being an acutely sensitive species (this approach utilizes acute to chronic ratios).
6) Information on applicable Food and Drug Administration restrictions.
7) Information on impacts to wildlife consumers of aquatic life.
8) For both fresh and marine waters, determine the quality and completeness of collected data, screening the data for validity based on criteria such as use of controls, use of single species and

single compound for each test, use of resident species from north America, reporting of water characteristics (for example, hardness or pH) when relevant to toxicity. Data should be rejected if it does not meet applicability criteria.

9) Evaluate the acute and chronic available data to ensure that each of the major kinds of possible adverse effects (for instance, growth, reproduction, mortality) receives adequate consideration in both fresh and marine waters. Results of acute and chronic tests with representative species of aquatic animals are necessary so that data available for tested species can be considered a useful indication of the sensitivities of appropriate untested species.
10) If chronic data are limited, an ACR will be used to estimate chronic toxicity in aquatic organisms (based on at least three different families provided that at least one is a fish, at least one is invertebrate and at least one is an acutely sensitive species). The ACR will be used when an acute toxicity profile indicates that the most sensitive surrogate aquatic species was not tested in chronic study or data gaps exist.
11) If chronic data are absent, it may not be possible to calculate a chronic criterion.
12) If enough acceptable data on acute toxicity to aquatic animals are available, the criterion maximum concentration (a.k.a. the acute criteria) that should not result in unacceptable effects on aquatic organisms will be derived following protocols established in EPA Guidelines;
13) If enough acceptable data on chronic toxicity to aquatic animals are available, the criterion continuous concentration (a.k.a. the chronic criteria) that should not cause unacceptable toxicity during a long-term exposure will be derived following protocols established in EPA Guidelines.

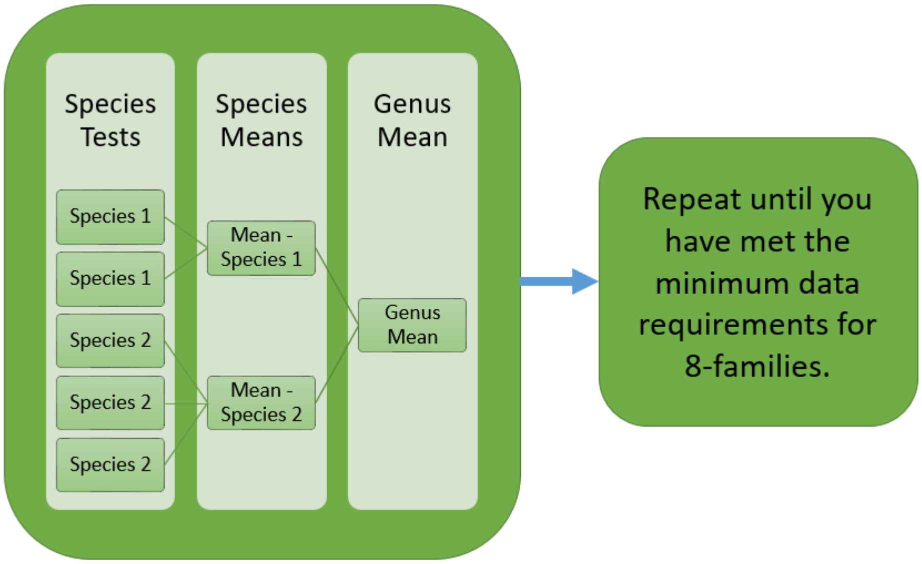
6.3. Data Needs

6.3.1. Minimum Data Requirements

To develop aquatic life criteria NHDES will need to meet the Minimum Data Requirements (MDRs) for developing toxicity-based aquatic life criteria following the EPA methodology. If a thorough review of the applicable toxicity data indicate that enough acceptable data are available, numerical water quality criteria can be derived to protect aquatic organisms and their uses from unacceptable effects due to acute (1-hour) and chronic (4-day average) exposures.

While one could conceivably meet the MDRs with merely eight acute tests and three paired chronic tests, in practice a collection of species test are used to calculate a species mean, then a collection of species within a genus are used to calculate a genus mean and when the family MDRs are met at based on the genus mean values, a criterion can be calculated (Figure 5).

Figure 5. Model of exposure pathways of PFAS relevant to surface water criteria.



The generalized process to understand potential cost is based on the following:

1) Document a summary of all useful acute and chronic toxicity studies on aquatic animals for the four PFAS.
2) Document Information on applicable Food and Drug Administration restrictions and any information on impacts to wildlife consumers of aquatic life.
3) Find usable BCF/BAF information for the four PFAS.
4) For acute criteria, achieve a minimum toxicity dataset of at least one species of freshwater animal in at least (8) different families for the four PFAS; representing possible adverse effects and sensitive aquatic organisms. For chronic criteria a minimum toxicity dataset of at least one species of freshwater animal in at least three different families for the four PFAS; for which acceptable acute data are available and one being an acutely sensitive species such that acute to chronic ratios (ACRs) can be utilized.
5) If MDRs for developing toxicity based aquatic life criteria are not met based on an ECOTOX review (below); determine specific toxicity data gaps (for example, species, endpoints) and calculate potential cost to address these data gaps. Significant resources may be needed to fund these toxicity test and complete MDRs as toxicity testing cost for these novel contaminants will be significantly higher than conventional pollutants due to much higher analytical cost and the need for PFAS-free laboratory environment. Costs could be more than 3X conventional toxicity testing cost. Estimates for single species toxicity test would be $75,000-$100,000 for acute testing and $150,000-$2,000,000 for chronic testing. Overall toxicity testing costs to address the data gaps identified could easily run into the 10's of million dollars.

ECOTOX Knowledgebase[31] is a curated and publically-available database providing chemical environmental toxicity data on aquatic life, terrestrial plants and wildlife. ECOTOX is maintained by EPA and has curated data for more than 48,000 publications. Queries are interactive by chemical, species, effect (for example, growth, mortality, reproduction) and concentration endpoints (for example, LC50, EC50). The database is being updated quarterly for PFAS. ECOTOX has been used for every National

[31] https://cfpub.epa.gov/ecotox/

Ambient Water Quality Criterion for aquatic life since 1985. For PFAS, ECOTOX has curated data from 374 publications representing 82 fluorinated chemicals, 189 species, and 879 effect measurements with a total of 12,168 records. Many of the 12,168 records represent PFAS not targeted by this plan and species that do not live in North America nor are biologically analogous to North American species. Table 15 focuses the ECOTOX data on the four PFAS covered in this plan in both their acid and conjugate base forms. Query results for all effects, endpoints, species and test conditions, as of December 11, 2019 are shown for a total of 137 distinct references:

Table 15: All ECOTOX Records for Four PFAS - Records for all Effects, Endpoints, Species, Test Conditions.

PFAS	Chemical Form	CAS Number	Records	References
PFOA	Perfluorooctanoic acid*	335-67-1	2,010	82
	Perfluorooctanoate	45285-51-6	41	4
		Total	**2051**	**86**
PFOS	Perfluorooctane sulfonic acid	1763-23-1	818	32
	Perfluorooctane sulfonate*	45298-90-6	1,031	38
		Total	**1,849**	**70**
PFHxS	Perfluorohexane sulfonic acid*	355-46-4	0	0
	Perfluorohexane sulfonate	108427-53-8	45	2
		Total	**45**	**2**
PFNA	Perfluorononanoic acid*	375-95-1	405	23
	Perfluorononanoate	72007-68-2	0	0
		Total	**405**	**23**

*Form identified in the he legislative charge (section 2.3). Second chemical form is the conjugate base except for PFOS for which the conjugate base was identified in the legislative charge.

EPA's applicability criteria are robust and require studies to be excluded when: a) taxa are not ecologically relevant, b) chemical exposure is not a single chemical, and c) exposure concentration or dose rates are not included or quantified by analytical chemistry. A preliminary review of these studies resulted in the rejection of all but 38 distinct references. Table 16 shows the number of references and the number of test animals and concentration-based endpoints (for example, LC50, EC50) for fresh and marine waters for each of the four PFAS after a preliminary review of these studies.

Table 16: ECOTOX References for four PFAS chemicals meeting applicability criteria for relevant test animals and endpoints.

Chemical	**CAS-NO**	**References Freshwater/ Marine water**
PFOA	335-67-1/4528-55-16	23/6
PFOS	1763-23-1/45298-90-6	16/2
PFHxS	355-46-4/108427-53-8	1/0
PFNA	375-95-1/72007-68-2	5/3

The breakdown of the family level tests to understand the available tests to fulfill the MDRs for freshwaters and marine waters are provided in Table 17 and Table 18, respectively.

Table 17: Freshwater ECOTOX Studies and Relevant Test Organisms for four PFAS.

Chemical	Ref Count	Count of Tests Organisms in each Family Group										
		Vertebrates			Invertebrates			Options for 7th and 8th Families				
		Fish		3 Another Non-Salmonid family or an Amphibian	Crustacean		6 Insect	Mollusk	Rotifer	Planaria	Algae	Worm (Naididae)
		1 Salmonid	2 Non-Salmonid		4 Planktonic	5 Benthic						
PFOA	23	1	3	1	24	2	4	2	11	1	8	-
PFOS	6	1	1	1	6	-	3	2	3	-	2	1
PFHxS	1	-	-	1	-	-	-	-	-	-	-	-
PFNA	5	1	-	-	5	-	-	-	-	-	1	-

Table 18: Marine water ECOTOX Studies and Relevant Test Organisms for four PFAS and gaps.

Chemical	Ref Count	Count of Tests Organisms in each Family Group							
		Chordata		Non-Chordata Non-Arthrododa	Mysidea or Penaeidea	3 other families not in Chordata nor the Mysidea or Penaeidea family already used			Any other Family
		1 Fish	2 *Second Fish Family*	3 Mollusca	4 Mysidea	5 Penaeidea	6 Urchin	7 Algae	8 *(family gap)*
PFOA	6	1	-	5	1	-	1	1	-
PFOS	2	1	1	-	1	-	1	1	-
PFHxS	-	-	-	-	-	-	-	-	-
PFNA	3	-	-	3	-	-	-	-	-

This preliminary review of the applicable ECOTOX studies for the four PFAS indicates that there are significant toxicity data gaps for meeting EPA's MDRs for establishing criteria for freshwater aquatic organisms which includes at least one species in at least eight different families (Stephen, et al., 1985). As has been noted by some researchers, a deeper review of the ECOTOX studies may reveal that a portion of those studies measured the dose of PFAS but did not measure concentrations in the biota themselves. Failure to confirm uptake of the compound may warrant additional reference removal.

For freshwaters, the preliminary assessment of ECOTOX data (as of December 11, 2019) indicates that the EPA Minimum Data Requirements may be met for the acute but not the chronic toxicity tests for PFOA. NHDES could further evaluate toxicity data to determine if available data are acceptable for use in criteria development. PFOA studies were the most robust and include 10 families. PFOS acute studies include 9 families but appear to missing benthic crustaceans. The balance of the PFAS (PFHxS and PFNA) are not close to having the minimum data requirements. From the ECOTOX, review it appears that there is an overall lack of chronic toxicity tests for North American species.

For marine waters, the preliminary assessment of ECOTOX data, as of September 12, 2019, indicates that the EPA Minimum Data Requirements are not met for any of the four PFAS.

It is worth noting here that at the November 2019 Society of Environmental Toxicology and Chemistry (SETAC) meeting in Toronto, EPA presented a poster based on their initial review of the studies available to determine the viability of developing draft PFOA and PFOS aquatic life use criteria (Jarvis, Justice, Elias, Schnitker, & Gallagher, 2019). EPAs preliminary counts without fully evaluating the datasets based on the 1985 guidance (Stephen, et al., 1985) were slightly higher than those we found here at 62 studies for PFOA and 99 studies for PFOS that may be used in criteria development. The fundamental difference between EPAs preliminary review and that performed for this plan and perhaps some of the criteria developed in other states and countries (Section 6.4) is that this report searched for tests on the acid and conjugate base for each of the PFAS while EPA included three different compounds as PFOA and six different compounds as PFOS. For example, this plan reviewed ECOTOX data for PFOS as CAS No 1763-23-1 (Perfluorooctanesulfonic acid) and CAS No 45298-90-6 (Perfluorooctane sulfonate) while EPA included;

- 1763-23-1, Perfluorooctanesulfonic acid;
- 2795-39-3, Potassium perfluorooctanesulfonate;
- 45298-90-6, Perfluorooctanesulfonate;
- 4021-47-0, Sodium perfluorooctanesulfonate;
- 29457-72-5, Lithium perfluorooctanesulfonate; and
- 56773-42-3, Tetraethylammonium perfluorooctanesulfonate.

EPA's grouping approach is largely based on different salts of PFOS and PFOA that when added to water yield what we commonly consider PFOS and PFOA. We have not tried to resolve the different approaches in this plan except to say that it is another issue that complicates the development of aquatic life use criteria for PFAS.

The current data gaps for the four PFAS, with the exception of PFOA in freshwaters, are significant and would impede development of aquatic biota criteria, until these toxicity data gaps are addressed.

Threatened and Endangered (T&E) species will need to be considered in any criteria development. Consultation with the National Marine Fisheries Service (NMFS) would be part of criteria development to ensure T&E species and habitats are identified. The criteria derived will be evaluated to ensure that these critical T&E species are protected, following EPA guidance and as described in Section 4 of the Endangered Species Act[32].

6.3.2. Studies Needed / Costs

A minimum dataset to generate aquatic life use standards would contain eight acute toxicity tests and three chronic toxicity tests. That level of input data is estimated to produce a "Low" to "Moderate" reliable criteria depending upon the adequacy of the species sensitivity distribution (SSD) (Warne, et al., 2018). For a criteria to produce a "Moderate" to "High" reliable criteria, we would look to double the acute toxicity tests (Warne, et al., 2018). From the existing datasets, it appears that fish and invertebrates are the most sensitive species and at least one of each in required to meet the MDRs. As such those chronic toxicity tests should be focused on fish and invertebrates. The minimum datasets estimates are based on chronic tests on one vertebrate and two invertebrates while the preferred dataset estimate is based on two vertebrates and one invertebrate. For our cost estimates, test costs were derived from an understanding of the existing data from ECOTOX, the average costs for EPA Test

[32] 16 U.S.C. §§ 1533, 1536 (2012), Section 7.

Guideline series 850[33], and an understanding of differences between the analytical costs for conventional pollutants verses PFAS compounds. Table 19 contains the summarized cost estimates to perform the toxicity tests needed to produce freshwater aquatic life use criteria.

Table 19: Cost estimate for freshwater aquatic life toxicity test costs to develop "Low" to "Moderate" and "Moderate" to "High" reliability criteria.

Chemical	Minimum Dataset for "Low" to "Moderate" reliability criteria – Estimate	Minimum Dataset for "Moderate" to "high" reliability criteria – Estimate
PFOA	$2,300,000	$4,600,000
PFOS	$2,300,000	$4,800,000
PFHxS	$3,600,000	$5,700,000
PFNA	$3,600,000	$5,600,000
Total	**$ 11,800,000**	**$20,700,000**

The overall bulk of the existing aquatic life toxicity datasets are for freshwater environments. Existing marine thresholds that have been developed have typically relied upon non-native species tests and outright stated that the thresholds are higher than the freshwater environment due to the lack of data (Section 6.4). For marine estimate purposes, we followed the same procedure as was done for the freshwater environment to use as a foundation for marine criteria. Table 20 contains the summarized cost estimates to perform the toxicity tests needed to produce marine aquatic life use criteria.

Table 20: Cost estimate for marine aquatic life toxicity test costs to develop "Low" to "Moderate" and "Moderate" to "High" reliability criteria.

Chemical	Minimum Dataset for "Low" to "Moderate" reliability criteria – Estimate	Minimum Dataset for "Moderate" to "high" reliability criteria – Estimate
PFOA	$2,800,000	$5,400,000
PFOS	$2,800,000	$5,500,000
PFHxS	$3,200,000	$5,800,000
PFNA	$3,100,000	$5,700,000
Total	$11,900,000	$22,400,000

6.4. *Other Developed Aquatic Life Use Criteria*

The importance of the scientific process and desire to have large datasets to make important decisions becomes quite clear when we see the range of the few aquatic use thresholds that have been generated around the globe over the last dozen years. Whereas the drinking water MCLs are based on a fairly large and rapidly growing dataset and nationally have been honing in on similar concentrations, such

[33] See https://www.epa.gov/sites/production/files/2018-04/documents/test-cost-estimates-2018_0.pdf

convergence of a science for aquatic life is less clear (Table 21). This weaker convergence illustrates the nascent nature of the aquatic life science in the context of PFAS compounds.

Table 21: Ecological based standards, thresholds, screening values, and guidelines from different government agencies.

Location	Year	PFAS	Thresholds (ng/L)	Threshold type
Minnesota	2007[34]	PFOS	19,000 (Chronic criterion) 85,000 (Maximum criterion)	Water Quality Standards (*revisions planned*)
	2007[35]	PFOA	1,705,000 (Chronic criterion) 15,346,000 (Maximum criterion)	
Michigan	2010[36]	PFOS	140,000 (Final Chronic Value) 780,000 (Aquatic Max. Value)	Water Quality Standards
		PFOA	880,000 (Final Chronic Value) 7,000,000 (Aquatic Max. Value)	
Netherlands	2010[37]	PFOS	23 (Max. permissible conc. ecological)	Proposal for water quality standards
			2.6 (Max. permissible conc.-secondary poisoning)	
			4.6 (Max. permissible conc. ecological marine)	Proposal for water quality standards
			0.53 (Max. permissible conc.-secondary poisoning marine)	
European Union	2013[38]	PFOS	0.65 (fresh annual ave.) 36,000 (fresh-max.) 0.13 ("other surface waters" annual ave.) 7,200 ("other surface waters" -max.)	Environmental Quality Standard
Canada	2018[39]	PFOS	6,800	Fed. Env. Quality Guideline
	2012[40]	PFOA	20,000 (freshwater alga) 30,000 (minnows)	Predicted no-effect concentration
Australia	2017[41, 42]	PFOS	0.23 (fresh) 290 (marine)	Recommended Draft Default guideline values – 99% species protection[43, 44]
		PFOA	19,000 (fresh) 3,000,000 (marine)	
		PFOS	130 (fresh) 78,000 (marine)	Draft Default guideline values – 95% species protection

34 (MPCA, 2007)
35 (MPCA, 2007)
36 (DEQ, 10/21/2016)
37 (Moermond, Verbruggen, & Smit, 2010)
38 (European Parliament and the Council of the European Union, 2013)
39 (Canada, 2018)
40 (Environment Canada, Health Canada, 2012)
41 (Commonwealth Environmental Management , 2016)
42 Australia noted that these draft default guideline values were prepared for CRC CARE, version as of July 2016, that there are fewer data available for marine species than for freshwater, and that sorption to marine sediments is expected to be much stronger than for freshwater.
43 "Water/sediment quality guideline values are used as a general tool to help ensure that certain physical and chemical stressors in waterways do not exceed harmful levels. We can define a guideline value as a measurable quantity (threshold) or condition of an indicator for a specific community value below or above which we consider to be a low risk of unacceptable effects occurring." https://www.waterquality.gov.au/anz-guidelines/guideline-values
44 The draft national standards recommend that the 99 per cent level of protection be used for 'slightly to moderately disturbed systems'.

From the efforts of other countries and states within the US, two lessons come to light. First is that with the growing body of aquatic toxicity research, the draft and implemented thresholds continue to fall. The second lesson is the importance of each dataset particularly when dealing with smaller toxicity datasets. Both Australia and Canada use threshold setting approaches that are very similar to the methods prescribed by the EPA. Of note is that for PFOS, Australia (Victoria, 2017) and Canada (Canada, 2018) used nearly identical base toxicity studies except Canada omitted one chronic study of zebrafish (*Danio rerio*). From the available PFOS data, Australia calculated a species protection value of 130 ng/L while Canada derived a value of 6,800 ng/L to leave 95% of taxa unaffected. From this we see that when the available datasets for setting thresholds are small, the differences in those calculated thresholds can be large.

6.5. Cost and Time Estimates to Develop

The costs to generate the acute and chronic toxicity tests to then calculate a minimally robust aquatic life use protection criteria is estimated to be $11,800,000 for freshwaters (Table 19) and $11,900,000 for marine waters (Table 20). To generate a moderate to highly robust aquatic life use protection criteria those toxicity test costs increase to $20,700,000 for freshwaters (Table 19) and $22,400,000 for marine waters (Table 20). The funding, bidding, oversight, and implementation of these toxicity tests would be years in the making. Overall, these costs illustrate why these efforts are nearly always left to be funded and administered by the federal government. The costs outlined assume that for freshwaters, New Hampshire and Vermont are the sole funders of every needed toxicity test and New Hampshire is the sole funder for all of the needed marine toxicity tests. While this work must be done, such an assumption is unrealistic given the rate at which papers are appearing in the literature and speculation about ongoing studies. Similarly, given that few facilities are capable of conducting the needed toxicity studies, it is unrealistic to think that all of the needed studies could be conducted in a short amount of time. A more realistic funding option may be for New Hampshire and Vermont to finance a small number of toxicity studies focused on New England species expected to be particularly sensitive to PFAS contamination to ensure that when pooled with studies from other entities, New England species are well represented. Pending funding by both the New Hampshire and Vermont legislatures, Vermont DEC has discussed the pooling of resources to complete some of these toxicity tests.

Once the needed toxicity tests are completed, NHDES staff would need to analyze all of the available data in line with the EPA Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses (Stephen, et al., 1985).

Approval by the Joint Legislative Committee on Administrative Rules (JLCAR) is required and anticipated to take four to eight months (Table 22, Step C). This will require a public comment period, response to said comments and review by interagency groups. Once approved by JLCAR, the standards would then be submitted to EPA for approval and use in any federal actions. Based on previous rule-making processes, and the unique nature of this task this is expected to take over 400 hours of NHDES staff time.

To determine which waterbodies exceed the water concentration criteria will require sampling and monitoring of individual waterbodies (Table 22, Step D). Based on sampling results NHDES would then spend time to evaluate data from waterbodies and conduct outreach to affected stakeholders (Table 22, Step E).

Table 22. A) Overview of costs associated with developing a WCC to protect aquatic life and B) costs associated with assessing waterbodies.

	PROCESS and STEP	DATA REQUIREMENTS	ESTIMATED COSTS		ESTIMATED TIME TO COMPLETE
			Description	Item Costs	
A) CRITERIA DEVELOPMENT COSTS	(A) Fill toxicity testing data gaps	(*fill all data gaps*) Toxicity Tests for Freshwater Organisms	See Table 19	$11,800,000 – $20,700,000	3-6 years/compound
		(*fill all data gaps*) Toxicity Tests for Marine Organisms	See Table 20	$11,900,000 – $22,400,000	3-6 years/compound
		(*contribute New England species to data gaps*) Toxicity Tests for Freshwater Organisms	1 fish acute toxicity test 1 invertebrate acute toxicity test 1 early life stage fish chronic toxicity test	$1.,200,000	3-8 years/compound
		(*contribute New England species to data gaps*) Toxicity Tests for Marine Organisms	1 fish acute toxicity test 1 invertebrate acute toxicity test 1 early life stage fish chronic toxicity test	$1,200,000	3-8 years/compound
	(B) Determine Water Concentration Criteria	Information from (A) + the EPA Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses (Stephen, et al., 1985)	NHDES Staff time to evaluate data, calculate water concentration criteria and prepare summary report	$100,000	12 months/compound, including external peer-review/public comment
	(C)Adopt of Aquatic Life Concentration Limits	None	NHDES Staff time to complete rulemaking process and submission to JLCAR and EPA	$25,000	4-8 months
	Total Cost to develop and pass Water Concentration Criteria to protect aquatic life			**$2,525,000 – $43,225,000**	**3-8 years***
B) WATERBODY ASSESSMENT COSTS	(D) Surface Water Testing	Measure Water Concentrations of PFAS	1 site per waterbody PFAS Water Concentrations	$1,300 <u>X100 Waterbodies</u> $130,000	1-2 months
	(E) Data Assessment and Notifications	Results from (D)	NHDES Staff time to determine which waterbodies are impaired and conduct outreach to affected stakeholders	$23,000	3-4 months
	Total Costs to Assess a Waterbody based on Water Concentration Criteria (100 waterbodies)**			**$153,000**	**4-6 months**

* Estimated Costs assume 10% duplication of sampling for quality assurance/quality control, as well as labor costs. All costs in the table are based on 2020 prices.

Table 22. A) Overview of costs associated with developing a WCC to protect aquatic life and B) costs associated with assessing waterbodies.

PROCESS and STEP	DATA REQUIREMENTS	ESTIMATED COSTS		ESTIMATED TIME TO COMPLETE
		Description	Item Costs	

**There are four aquatic life criteria; freshwater acute, freshwater chronic, marine water acute, and marine water chronic.

7. Recommendations and Costs

7.1. *Capacity Building for Emerging Contaminants*

The mission of NHDES is to help sustain a high quality of life for all citizens by protecting and restoring the environment and public health in New Hampshire. As a part of that mission, it is necessary to address newly discovered chemical hazards, or "emerging" contaminants, found in the environment. While PFAS have drawn the local and national spotlight as emerging contaminants, there remain other classes of chemicals with minimal toxicity data and uncertainty regarding exposure from our environment. An example of this includes ionic liquids which are categorized as "green chemistry" but show similar chemical properties as PFAS, albeit with significantly less toxicological data available for risk assessment (Oskarsson & Wright, 2019; Egorova, Gordeev, & Ananikov, 2017). Many states respond to emerging contaminants using guidance and regulations developed at a national level by the U.S. EPA. This reliance is partially due to the EPA's considerable scientific and technical resources dedicated to emerging contaminants which exceed the resources of many states individually. However, NH's Chapter 368 laws of 2018 was clear that emerging contaminants with local impacts required a faster response at the state level than what was expected from the EPA. If NHDES is to fulfill its mission and be able to respond to other emerging contaminants, it is important to consider that capacity building within NHDES and other state agencies.

Capacity building requires expansion and staffing of existing programs. This includes having dedicated staff who work on emerging contaminant issues without sacrificing time and effort intended for on-going issues such as eutrophication of the Great Bay or arsenic in drinking water. Currently, NHDES and NHDHHS are addressing the multi-faceted issue of PFAS by stretching staff resources from existing programs. This approach of stretching existing resources will not be sustainable if these agencies are to address other emerging contaminants.

7.2. *Broad Spectrum Chemical Sampling of State-Wide Fish and Shellfish*

There are a large number of legacy and emerging chemical compounds for which we know little about their distributions in water or tissue. NHDES currently has no funding available to process samples for toxicants in fish and shellfish tissue. To NHDES' knowledge there has never been a statewide effort to test fish and shellfish for additional toxicants that present a risk to humans and wildlife. Such a comprehensive dataset that characterizes the frequency and magnitude of toxicant concentrations in fish and shellfish tissue would be used to assess consumptive risks and inform development of new, or justification of existing, water quality criteria to protect human health.

A collaborative multi-agency effort to collect, process, and analyze toxicant data from fish and shellfish tissue would inform the development of more comprehensive and updated consumption guidelines. This effort is envisioned as a collaborative effort between NHDES, NHF&G, and NHDHHS as well as the UNH Jackson Estuarine Laboratory to sample toxicants in shellfish from coastal waters. Currently, NHDHHS is not staffed to fully work with the NHDES programs to monitor and assess shellfish safety. To sample and analyze 5 fish from 50 lakes, 50 rivers, and 50 estuarine sites plus 50 shellfish samples over a two-year period for historic toxicants, such as DDT, dioxin and PCBs as well as newer toxicants such as PFAS, 1,4-dioxane and yet unidentified emerging contaminants, NHDES estimates the state would need to expend approximately $660,000 annually on analysis. Salary, benefits and expenses plus equipment to perform the sampling, food safety and regulatory consultation, education, technical assistance and food safety guidance to shellfish harvesters and dealers would require $250,000 annually. The information generated would be available to make screening level determinations on fish and shellfish consumption in specific waterbodies and for specific toxicants in order to minimize human health risks. Over time, the dataset could be used for trend analysis. The data will also be used to determine if specific toxicants are prevalent statewide. Lastly, NHDES will utilize the data, to the extent possible, to revise or implement water quality criteria.

7.3. Build Lab Capacity

It is clear that the cost of sample analysis to develop water quality standards will be substantial to say nothing of the personnel costs to collect and analyze that data nor the dollars already spent on sample analyses in the state. An estimate based on a count of PFAS samples in the EMD suggest that approximately $3,500,000 (as of August 2019) have already been spent on the analysis of samples from New Hampshire. As noted in Section 4 the volume of samples have been steadily climbing. Estimates to set-up a PFAS lab range from $560,000-$720,000 (equipment + personnel). Due to the degree of difference between the water sample and tissue sample concentrations and matrix type, two sets of equipment would be needed if both water samples and tissue samples were to be analyzed. It is anticipated that the recurring cost of personnel and materials would be balanced by the dollars that go into the general fund from sample analysis fees. Building state capacity to analyze samples within the New Hampshire state lab would likely result in substantial cost savings due to limited shipping while keeping the analysis dollars in New Hampshire.

7.4. Data Uploads to the EMD

The goal of the EMD has been to act as a single statewide repository of environmental monitoring data. However, submission of electronic datasets is not a requirement of many of the programs and as such, it becomes very difficult at times to synthesize and report on the number and nature of samples collected around the state. For a sense of scale, there are approximately 4,000 PFAS samples (predominantly groundwater) in the EMD that have been submitted by consultants associated to investigation sites, however, there are estimated to be another 4,000 PFAS samples (also predominantly groundwater) that only exist in PDFs of reports submitted to NHDES. While those reports are available on the departments OneStop system (Section 4.2.1) their absence from the EMD means that understanding the interrelated nature of nearby sites and any regional modeling efforts are severely hampered without extensive paper report review and hand data entry efforts. Templates have been built by NHDES and are used by many of the laboratories and consultants to provide direct electronic upload of datasets after they have performed their quality assurance/quality control (QA/QC). For some projects, upload is done on an ongoing process while some projects upload once a year. Such uploads should be a routine process for all programs.

7.5. Product Use/Need

Given the minute concentrations that can bioaccumulate to cause health and environmental problems and the difficulty and cost associated with treatment the call to stem the production and use of PFAS compounds as a whole has been made by multiple groups. In 2019, Cousins outlined a three category framework to aid the phase out of non-essential uses of chemicals of concern they called; 1) "non-essential", 2) "substitutable", and 3) "essential" (Cousins, et al., 2019). Even the "essential" category was qualified as, "[t]his essentiality should not be considered permanent; rather, a constant pressure is needed to search for alternatives in order to move these uses into category 2." To that end, states have already started to push for limited use. For example, in 2019 Washington state passed RCW 70.365 that they're calling Safer Products for Washington (https://ecology.wa.gov/ToxicsInProducts). The new law authorizes Washington state to regulate five priority chemical classes of chemicals in consumer products starting with PFAS compounds. San Francisco's Plastic, Litter, and Toxics Reduction Law goes into effect January 1, 2020 for all compostable foodware to be Biodegradable Products Institute (BPI) certified. BPI certification is the only North American certification that ensures items entering the compost stream are truly and fully compostable. BPI-certified products are free of noncompostable plastic and as of January 1, 2020, will be free of intentionally added toxic fluorinated chemicals (https://sfenvironment.org/reduceplastic-purchasing-guidelines). As a final example, the Maine Legislature has passed a bill aiming to prohibit the sale of food packaging with certain industrial chemicals. Maine's bill also lets state regulators decide whether to ban other chemicals found in food packaging. Of course, such legislation should be considered in a manner that avoids banning one class of chemicals in favor of regrettable substitutions with newer chemicals that have less human health or animal toxicity data than PFAS.

A second approach says that the degree of exposure should be transparent to the end user and the company's manufacturing and using the PFAS compounds should be making that information readily available so that the consumer can choose to use or not use the product. A catch with this approach is that some portion of the product will ultimately work its way into the waste streams from those end users and may require treatment. We have seen a collection of state-level consumer protection laws for 1,4-dioxane that aim to reduce the concentration in the public and the waste stream. Like the product based bans, this leads to varying exposure by state and product.

This state-by-state approach to regulating PFAS compounds in consumer products is already starting to yield a patch-work quilt of rules that is complicated for the consumer and producer alike. Absent New Hampshire's own PFAS in consumer products action or adoption of such from other states, efforts should be put in place to push for national controls. The end result would be a healthier public and environment as well as reduced treatment costs.

7.6. Risk Communication and Education

The issues of risks related to PFAS contamination, or any emerging contaminant, are complex and difficult to discuss between subject matter experts and affected communities. This means risk communication and education efforts should be given priority in any effort to develop and implement surface water quality criteria. NHDES' and NHDHHS' own experience with community outreach and education on PFAS in drinking water underscores the challenge of risk communication and need for additional expertise in identifying the concerns, needs and information gaps for affected communities. Thus, it is recommended that a Health Educator or Community Engagement Specialist is recruited to facilitate risk communication and education.

The Health Educator/Community Engagement Specialist (HE), a member of NHDHHS Division of Public Health Services (DPHS), would work closely with the public and engage with the community when surface water quality issues are identified. This HE will also work with the NHDES Environmental Health Program, NHDHHS Environmental Health Integration Team (EHIT), environmental regulators and other stakeholders to develop and implement communication and education initiatives related to PFAS and other environmental contaminants. The HE will (1) conduct a needs assessment to identify the needs and priorities of the community; (2) organize public meetings with the community; (3) assist NHDES and

NHDHHS staff in developing their technical presentations for these meetings; and (4) prepare fact sheets, media releases, and other communication products needed to reach affected communities.

Currently, NHDES and NHDHHS do not address this need with a fulltime staff member. Instead, the departments leverage limited staff time to address requests for public education and communication efforts. This position would fill a critical role for both departments, while improving the capability of NHDES and NHDHHS to pursue federal funds related to environmental health programs. This position would be an Administrator I (LG 27, Step 5) at 0.5 FTE ($55,000 annually) support work related to environmental health education including conducting education and outreach activities related to the PFAS Surface Water Quality Standards and fish/shellfish consumption advisories to affected stakeholders.

7.7. PFAS Class Grouping and Mixture Toxicity

An ongoing area of debate regarding PFAS is whether and how to regulate this large and diverse group of fluorinated chemicals as a class. Some have argued that PFAS should be regulated as a class, with a variety of proposed methods for achieving this approach. This includes the summation of multiple PFAS compounds in environmental media, as seen with the VT DOH drinking water advisory for five PFAS (∑ 20 ng/L), or the development of Toxic Equivalency Factors (RIVM, 2018). Others have argued that due to the documented toxico-kinetic and –dynamic differences between specific PFAS, such grouping approaches may inaccurately represent risks and lack a clear scientific basis (Peters & Gonzales, 2011). As a part of the 2019 PFAS Action Plan, the EPA is generating toxicity data on a larger group of PFAS aimed at informing toxicity for the large set of PFAS that lack conventional toxicity data and potentially address groups of PFAS (EPA, 2019). This is a keen area of interest amongst state agencies (ECOS, 2019), and remains an issue of public and scientific discussion.

As with existing contaminant issues, there remains concern for the risk associated with exposure to mixtures of chemicals. This includes mixtures of different PFAS, as well as PFAS with other contaminants that have been historically recognized to present significant health risks to the residents of New Hampshire (for example, radon, arsenic and air pollution). Currently, the EPA methodology for developing surface water criteria has limited information or tools for how to best address these issues, especially in environmental systems as complex as surface waters.

7.8. Regulatory Challenges for PFAS as a Class

Since PFAS are being used extensively in commercial products and industrial applications, a priority for New Hampshire has been to conduct investigations where PFAS of concern are released and the detected specified PFAS occurs above the state screening levels or MCLs where appropriate. New Hampshire has been proactive identifying potential sources of certain PFAS into the environment, working with regional and federal partners to understand the scope of this environmental and regulatory challenge. However, there are substantial technical challenges that question the efficacy of managing PFAS using current regulatory tools that merit acknowledgement. Some of these challenges include the following:

- Analytical Method Limits: Many PFAS remain undetected in the environment and human serum because analytical techniques to isolate, identify and quantify several PFAS are not yet available (Bartell S. J., 2018, p. 71);
- Uncertainty about the Number of PFAS: Since the United States began phasing out of PFOS and PFOA production, PFAS substitutes “have been rapidly introduced into the market and exposure is more difficult to assess accurately due to a lack of analytical standards.” (Birnbaum, 2019, p. 4).

Some have estimated that the number of different PFAS is nearly 5,000, or more, unique CAS numbers (Organisation for Economic Co-operation and Development, 2018), but others have questioned whether this accurately reflects the true number of PFAS in commercial and industrial use.

- Proprietary Information: Industries that hold proprietary the chemical nature of new individual PFAS or PFAS applications in the production of consumer products and industrial uses can affect the capability to monitor for PFAS in the environment and mitigate public exposure where necessary (Bartell S. J., 2018, p. 12);
- Lack of Information on Gas-Phase PFAS: EPA monitoring methods do not capture gas-phase PFAS attributed to municipal wastewater and landfill leachates (Bartell S. J., 2018, p. 74). The role of atmospheric fate and transport requires additional study to understand how it impacts surface water quality and human health.
- Precursors: "PFAS precursors" are those PFAS that can be transformed into other PFAS in the human body or from environmental degradation. For example, Perfluoroalkyl acids (PFAAs), which include PFOA and PFOS, can be formed from precursors following degradation, potentially posing additional human health risks and affecting the design and performance of remediation approaches (EPA, 2017b, p. 5).
- Time and Resources: It would take a substantial amount of time and public resources to evaluate the safety of the vast number of PFAS under the current regulatory framework. Given the current rate of EPA and the Federal Drug Administration (FDA) in evaluating the safety of individual chemicals, it will take a significant amount of public resources to fully evaluate the toxicity of PFAS and establish standards to regulate them. Moreover, while these toxicity assessments would occur, these chemicals continue to be used in the marketplace resulting in further environmental release and exposure.

While there currently are no federal standards for regulating PFAS as a class or subclasses, the EPA has acknowledged several of these challenges in their PFAS Action Plan (EPA, 2019). The issues outlined above raise the question as to whether our current regulatory approach meets the demands of growing public interests and an ever-increasing number of emerging contaminants, such as PFAS. As emphasized by multiple state agencies, it is preferable to manage PFAS as a class or subgroup given the potential for similarities amongst certain compounds. Managing chemicals as a class has been a strategy used to regulate other families of chemicals found to be toxic in the environment, such as Polychlorinated Biphenyls (PCBs), but the current debate around the science of their similarities raises concerns for the scientific defensibility of certain group approaches.

7.9. Criteria Development Costs, Assessment Costs, and Other Financial Implications

Human health has been the main focus of PFAS discussions to date in the state. To that end, the priority for the development of PFAS surface water quality standards is also focused on minimizing the risks to public health. Some of these standards could be adopted relatively quickly while others will take significant time and resources.

It is not recommended that New Hampshire embark on developing its own aquatic life use criteria at this time. The number of aquatic life toxicological data gaps for most of the PFAS compounds is extensive. Further, all indications are that the potential criteria to protect human health are likely to be significantly lower than the endpoints to protect aquatic life. While New Hampshire should make efforts to contribute to the overall body of scientific literature on the impacts to aquatic life, it is not rational to think that New Hampshire should take on the full burden of those data gaps. For acute and chronic criteria endpoints to protect aquatic life, it is recommended that New Hampshire encourages and contributes to, but waits for national efforts to buildout the full data gaps before calculating aquatic life use support criteria. New Hampshire contributions should focus on studies on sensitive and iconic New England species that may not be test organisms covered by national studies.

Table 23 below presents a summary of the costs associated with developing each of the water quality criteria and then the subsequent costs of assessing waterbodies. The costs in the table below are not additive. Each criterion is presented in the table as if it is the only criteria to be developed and then assessed. Some of the work on one criterion may also be used on other criterion. If multiple criteria were to be funded for development and implementation there would be synergies of costs that in some cases would be less than the sum of the parts. The total costs will largely be determined by two factors – 1) the type of criteria chosen, and 2) how many waterbodies are assessed. As assessment is likely to identify some waterbodies with PFAS impacts, the investigation of the sources of PFAS will become a future, unquantified cost, and is not estimated as a part of this plan. It is important to note that the development of a criteria does not ensure the criteria will be met. In order to understand whether or not a waterbody meets a new criterion, assessment sampling data would be needed. Some of the criteria have lower development costs but very high assessment costs while others have higher development costs but lower assessment costs.

Table 23. Summary of costs associated with developing and then assessing the health of waterbodies for human health and aquatic life.

Criteria	Estimated Development Costs of Approach*	Estimated Time to Initiate Rulemaking	Subsequent Assessment Costs to Determine which Waterbodies are Meeting Criteria*
MCL adoption as Water Consumption Criteria **- Applied to waters within 20 miles upstream of surface drinking water supplies**	$25,000	4-8 months	$92,000 for two-rounds of samples Covers the 59 surface water supplies and subsequent outreach.
Establish Fish Consumption Advisory **- Determines how many fish meals are safe to eat in a week or month**	$9,000	2-3 months	$547,000 - $4,747,000 Based on a 100 waterbodies probabilistic survey sampling strategy and added sampling costs based on initial sampling results and subsequent outreach.
Fish/Shellfish Tissue Criteria **- Assess tissue consumption safety based on amount of PFAS in fish/shellfish tissue**	$34,000 - $120,000 Based National or New Hampshire consumption rates.	5-24 months	$547,000 - $4,747,000 Based on a 100 waterbodies targeting at-risk and high-use waterbodies and subsequent outreach.
Fish/Shellfish Water Criteria **- Assess tissue consumption safety based on a water sample**	$75,000 - $741,000 Based on literature or New Hampshire specific bioaccumulation factors.	18-36 months	$153,000 for two-rounds of samples Covers 100 waterbodies targeting at-risk and high-use waterbodies and subsequent outreach.
Fish/Shellfish Consumption PLUS Water Consumption Criteria **- Assess water samples based on amount of fish AND water that is safe to consume**	*Combination of MCL adoption as Water and Fish/Shellfish Consumption Criteria (line 1) and Water Concentration Criteria to Protect Fish Consumption (line 4).*		
	$75,000 - $741,000 Based on literature or New Hampshire specific bioaccumulation factors.	18-36 months	$153,000 for two-rounds of samples Covers 100 waterbodies targeting at-risk and high-use waterbodies and subsequent outreach.
Recreational Contact **- Assess water samples for acceptable levels for physical contact with surface water**	$34,000 - $120,000 Based on literature or New Hampshire specific recreation rates.	6-18 months	$540,000 for two-rounds of samples Covers the 381 designated beaches and subsequent outreach.
Aquatic Life Use **- Assesses levels of PFAS that will impact fish and other aquatic life****	$2,525,000 - $43,225,000 Contributing or filling all data gaps.	3-8 years	$153,000 for two-rounds of samples Covers 100 waterbodies targeting at-risk and high-use waterbodies and subsequent outreach.

* Approximately 8,500 distinct waterbodies in the state.

**There are four aquatic life criteria; freshwater acute, freshwater chronic, marine water acute, and marine water chronic.

As discussed in section 2.4.1, the development of numeric water quality criteria must accurately reflect the latest scientific knowledge and, as such, does not consider the cost of implementation. This is true both in state law and the Clean Water Act. The process by which water quality standards are implemented is the time that costs of implementation can be taken into consideration. Permitting tools such as the anti-degradation process, compliance schedules, and use attainability analysis can allow for cost implications. There are other potential costs associated with surface water quality standards and their implementation that are described in Table 24.

Table 24**.** Summary of other financial implications associated with PFAS and emerging contaminants.

Source of Cost (Section number)	**Cost Description**	**Estimated Cost**
Work to determine the costs to the regulated entities (Section 2.5.2)	The cost of PFAS criteria to the regulated community identified will necessarily become a topic of future discussion. One approach to quantifying these costs would be to add a financial analyst to agency staff.	$100,000 (salary, benefits and expenses).
Cost to the state lab to increase sample capacity (Section 7.3)	Set-up a PFAS lab. Depending upon the range of concentrations, multiple equipment sets may be needed.	$560,000 - $720,000 (one equipment set + personnel).
Cost to build emergent contaminant sampling and staff capacity (Section 7.2)	Build emergent contaminant sampling capacity for lake, river and estuarine sampling of fish tissue and estuarine sampling of shellfish tissue. Plus staffing to perform sampling, public outreach and food safety guidance.	$660,000 (analytical costs) + $250,000 (salary, benefits and expenses plus equipment).
Cost to NHDES EHP and NHDHHS (Section 7.2 and 7.6)	Community outreach and education specialist, and a Program Specialist in the NHDHHS Food Safety program,	$55,000 (salary, benefits and expenses) $45,000 (salary, benefits and expenses).

As noted above, the development of surface water quality standards for toxic substances is complicated, expensive and time-consuming. It is further complicated by the lack of data on PFAS bioaccumulation factors and aquatic life effects. The subsequent assessment of surface waters is also an expensive proposition. Given the potential costs involved in developing, assessing and complying with surface water standards we anticipate significant debate on the best use of funds to address PFAS contamination. To further this discussion, we suggest that a comprehensive PFAS mitigation strategy be developed to minimize the further introduction of these compounds into our environment and ultimately begin to remove those currently in our waste stream.

8. References

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