



Canada's Great Lakes Strategy for PFOS, PFOA, and LC-PFCAs Risk Management

March 2022

Prepared by Environment and Climate Change Canada



Disclaimer

The purpose of this document is to present Canadian risk mitigation and management actions for: i) perfluorooctane sulfonate (PFOS); ii) perfluorooctanoic acid (PFOA); and iii) long-chain perfluorocarboxylic acids (LC-PFCAs), and the salts and precursors for these substances in accordance with Annex 3 of the Great Lakes Water Quality Agreement (GLWQA). The mention of trade names, commercial products, or organizations does not imply endorsement by the Government of Canada.

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Executive Summary

The Canada-United States Great Lakes Water Quality Agreement (GLWQA) seeks to reduce the anthropogenic release of chemicals of mutual concern (CMCs) into the air, water, land, sediment, and biota that may impair the quality of the waters of the Great Lakes. Under the GLWQA, the Parties have agreed to adopt, as appropriate, the principles of virtual elimination and zero discharge for releases and control of CMCs. This document represents Canada's Great Lakes Strategy for the risk management of three designated CMCs and their salts and precursors: (1) perfluorooctane sulfonate (PFOS); (2) perfluorooctanoic acid (PFOA); and (3) long-chain perfluorocarboxylic acids (LC-PFCAs).

PFOS, PFOA, and LC-PFCAs belong to the broader family of chemicals known as per- and polyfluoroalkyl substances (PFAS), which includes over 4,700 diverse chemicals. Note that the use of "PFAS" throughout this document refers to the broader class of chemicals; therefore, data presented in this document may or may not be applicable to all the chemicals in the family due to the lack of data on the PFAS family, specifically the lesser known chemicals in the environment. However, due to their similar chemical structures, certain PFAS may have similar chemical properties and therefore may pose similar potential adverse effects to the Great Lakes basin, that are not addressed in this document.

PFOS, PFOA, and LC-PFCAs are synthetic chemicals, and are used in a wide variety of industrial and consumer products such as adhesives, cosmetics, cleaning products, and in specialized chemical applications, such as aqueous film-forming foams (AFFF; for extinguishing hydrocarbon fuel fires). They are also used to repel water, oil, dirt, and grease from paper, packaging (especially those for food wrapping), non-stick cookware, carpets, and fabrics for outdoor clothing and upholstery. Due to their high persistence, ability to migrate long distances, and bioaccumulation potential, PFOS, PFOA, and LC-PFCAs are found in sediments, water, biological tissues, waste, and air, and can cause a variety of harmful environmental and human health effects. Exposure to PFOS and/or PFOA may result in developmental effects in children and animals, and in cancer, liver, immune, and thyroid effects (Health Canada, 2018a, 2018b). Human health effects data and environmental occurrence data, and validated analytical methods are available for PFOS, PFOA, and select LC-PFCAs.

The Government of Canada often takes a phased approach to the risk management of toxic substances. Although there are regulations in place prohibiting PFOS, PFOA and LC-PFCAs, their salts and their precursors, these regulations include a limited number of exemptions. Importing exempted products and long-range transport from other countries where PFOS, PFOA, and LC-PFCAs are not regulated may contribute to unwanted environmental exposures and subsequent ecological and human health effects in the Great Lakes basin.

In order to minimize ecological and human health effects in the Great Lakes basin, the Government of Canada has developed Canada's Great Lakes Strategy for PFOS, PFOA, and LC-PFCAs (and their salts and precursors) Risk Management, herein referred to as the "Strategy". The Strategy will focus the efforts of the Government of Canada, in cooperation and consultation with the Government of Ontario, First Nations, Métis, municipal governments, watershed management agencies, other local public agencies, and the public in implementing risk mitigation and management actions aimed at reducing three binational CMCs (PFOS, PFOA, LC-PFCAs, and their salts and precursors) in the Great Lakes basin. Current Canadian actions at the federal level to reduce the amount of PFOS, PFOA, LC-PFCAs, and their salts and precursors in the environment focus on regulations that prohibit the manufacture, use, sale, offer for

sale or import of these substances, and products that contain them, with a limited number of exemptions. The Strategy identifies opportunities for additional Canadian actions to address data gaps and better achieve key commitments under Annex 3 of the GLWQA by minimizing the release of PFOS, PFOA, LC-PFCAs, and their salts and precursors to the Great Lakes basin.

Despite ongoing risk management, three key gaps pertaining to risk mitigation and management of PFOS, PFOA, LC-PFCAs, and their salts and precursors remain for the Great Lakes region, which include a lack of (1) source information; (2) cost-effective analytical methods, routine monitoring and surveillance; and (3) data availability in a consistent, standardized format, including environmental trends and exposure data. Continued research and monitoring is needed to support coordinated efforts to identify concerns and provide a basis for actions on PFOS, PFOA, LC-PFCAs, and their salts and precursors. The Strategy identifies 16 risk mitigation and management actions for PFOS, PFOA, and LC-PFCAs as outlined in Table A for improving human and ecosystem health in the Great Lakes basin and their respective communities.

Table A. Summary of Canada's Great Lakes Strategy Actions for PFOS, PFOA, and LC-PFCAs.

Category of Action				
Regulations and Other Risk Mitigation and Management Actions	Compliance Promotion and Enforcement	Pollution Prevention	Monitoring, Surveillance, and Research Efforts	Environmental Quality Guidelines
Actions				
<p>1. Review regulations, guidelines, and advisories in other jurisdictions, and update Canadian health advisories and guidelines to match current scientific understanding</p> <p>2. Amend or develop new regulatory controls in response to human health and ecological assessments and new data</p> <p>3. Establish inventories of known sources where possible</p>	<p>4. Continue to undertake outreach activities to raise awareness of the regulations among known and potential stakeholders</p> <p>5. Continue to develop and distribute plain language guidance materials and factsheets on the regulations</p> <p>6. Continue to track reported activities allowed under specific exemptions (e.g. laboratory use)</p> <p>7. Take enforcement measures including issuing warnings, environmental protection compliance orders, or directions; and when appropriate, collect evidence for prosecution</p>	<p>8. Research and ensure safe end-of-life management practices for products containing PFOS, PFOA, LC-PFCAs, and their salts and precursors, and communicate these results</p> <p>9. Enhance support to industry associations and firms who seek to phase out or improve risk management within their sector</p>	<p>10. Continue monitoring in environmental media in the Great Lakes and publish results in a variety of publications and open access data portals</p> <p>11. Use monitoring and modelling to better characterize sources</p> <p>12. Address gaps in monitoring, toxicity, and exposure data</p> <p>13. Coordinate standardized analytical methods binationally to ensure data uniformity and comparability across jurisdictions</p> <p>14. Develop innovative, cost-effective tools and approaches for monitoring, measuring, and reducing releases from various sources</p>	<p>15. Establish and implement additional guidelines for surface waters for the protection of aquatic life</p> <p>16. Establish and implement guidelines for soil and groundwater for the protection of environmental and human health</p>

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Acronyms and Abbreviations

AFFF	Aqueous Film-Forming Foam
ATSDR	Agency for Toxic Substances and Disease Registry
CCL	Contaminant Candidate List
CCME	Canadian Council of Ministers of the Environment
CEC	Commission for Environmental Cooperation
CEPA	Canadian Environmental Protection Act, 1999
CEQG	Canadian Environmental Quality Guidelines
CESI	Canadian Environmental Sustainability Indicators
CI	Confidence Interval
CMC	Chemicals of Mutual Concern
CMP	Chemicals Management Plan
CSMI	Cooperative Science and Monitoring Initiative
ECCC	Environment and Climate Change Canada
EU	European Union
FEQG	Federal Environmental Quality Guidelines
GLNPO	Great Lakes National Program Office
GLWQA	Great Lakes Water Quality Agreement
GMP	Global Monitoring Plan
HA	Health Advisory
HUC	Hydrologic Unit Codes
IARC	International Agency for Research on Cancer
ITT	Identification Task Team
LAMP	Lakewide Action and Management Plan
LC-PFCAs	Long-Chain Perfluorocarboxylic Acids, their salts and precursors
MeFOSE	Methyl Perfluorooctane Sulfonamidoethanol
MECP	Ministry of Environment, Conservation and Parks
P2	Pollution Prevention
PFAAs	Perfluoroalkyl Acids
PFAS	Per- and - Polyfluoroalkyl Substances
PFCAs	Perfluorocarboxylic Acids
PFOA	Perfluorooctanoic Acid, its salts and precursors
PFOS	Perfluorooctane Sulfonate, its salts and precursors
PFOSF	Perfluorooctane Sulfonyl Fluoride
PFSAs	Perfluoroalkane Sulfonates
POPs	Persistent Organic Pollutants
PTFE	Polytetrafluoroethylene (Teflon)
REACH	Registration, Evaluation, Authorisation, and Restriction of Chemicals
SNUR	Significant New Use Rules
SOLEC	State of the Lakes Ecosystem Conferences
STP	Sewage Treatment Plant
TRI	Toxics Release Inventory
TSCA	Toxic Substances Control Act (United States statute)
U.S. EPA	United States Environmental Protection Agency
WHO	World Health Organization

1 Introduction

The purpose of [Annex 3](#) of the Canada-United States Great Lakes Water Quality Agreement (GLWQA) is to reduce the anthropogenic release of chemicals of mutual concern (CMCs) into the Waters of the Great Lakes, recognizing:

- (1) the importance of life cycle management;
- (2) that knowledge and information are fundamental to sound management;
- (3) that CMCs may be managed at the federal, state, provincial, Tribal, industrial, and local levels through a combination of regulatory and non-regulatory programs;
- (4) that international efforts may contribute to reductions from out-of-basin sources; and
- (5) that the public can contribute to achieving reductions.

While there is no requirement in the GLWQA to set reduction targets, consideration should be given to existing guidelines and the work of other Annexes, including Lake Ecosystem Objectives under Annex 2, Lakewide Management.

In 2016, Canada and the United States designated: (1) perfluorooctane sulfonate (PFOS); (2) perfluorooctanoic acid (PFOA); and (3) long-chain perfluorocarboxylic acids (LC-PFCAs), and their salts and precursors, as three of eight CMCs. This document represents Canada's Great Lakes Strategy for PFOS, PFOA, and LC-PFCAs Risk Management, herein referred to as the "Strategy".

PFOS, PFOA, and LC-PFCAs belong to the broader family of chemicals known as per- and polyfluoroalkyl substances (PFAS), which includes thousands of substances. Defining the scope and boundaries of the term PFAS across jurisdictions remains a challenge. PFOS, PFOA, and LC-PFCAs fall under the class of perfluoroalkyl acids (PFAAs), which includes (1) perfluorocarboxylic acids (PFCAs); and (2) perfluoroalkane sulfonates (PFSAs). There are both short-chain (C4-C7) PFCAs and PFSAs, as well as long-chain (C9-C20) PFCAs and PFSAs. PFOS and PFOA are two chemical substances that both have a total of eight carbons, and belong to the PFSA and PFCA groups, respectively (ECCC and HC, 2018).

In designating PFOS, PFOA and LC-PFCAs as CMCs, the Parties agreed that these substances are potentially harmful to human health and the environment, and pose a threat to the Great Lakes. The designation is a recognition that further action to protect the Great Lakes basin is warranted. The Strategy identifies opportunities for additional Canadian actions to address data gaps and better achieve key commitments under Annex 3 of the GLWQA. Sixteen strategy actions are documented in five categories that include: (1) Regulations and Other Risk Mitigation and Management Actions; (2) Compliance Promotion and Enforcement; (3) Pollution Prevention; (4) Monitoring, Surveillance, and Research Efforts; and (5) Environmental Quality Guidelines (**Table A**). The purpose of the Strategy is to reduce releases of PFOS, PFOA, LC-PFCAs, and their salts and precursors by focusing efforts of governments, agencies, and the public in implementing these risk mitigation and management actions. Environment and Climate Change Canada (ECCC) is responsible for the administration of the GLWQA for the Government of Canada. ECCC's Ontario Regional Director General's Office coordinates these efforts.

The U.S. Environmental Protection Agency (U.S. EPA) is responsible for the administration of the GLWQA for the Government of the United States.

Canada will use the Strategy as guidance to identify, prioritize, and implement actions to reduce PFOS, PFOA, and LC-PFCAs, their salts and precursors in the Great Lakes. Further reductions will require widespread on-the-ground action. It will take time to achieve significant reductions and for the aquatic environment to respond. Factors such as climate change, legacy sources, and changing human activities on the landscape make it difficult to predict the rate that significant changes will be seen in the Great Lakes. The ultimate success of the Strategy depends on the combined efforts of the Great Lakes community. The Strategy and its implementation will be reviewed on a regular basis and reported on through the Progress Report of the Parties.

This Strategy covers a list of 16 risk mitigation and management actions, under five categories, to address threats to water quality. These actions identified in **Table A** will be used to help identify, support, or coordinate ongoing and new projects. The Strategy contains actions that can be considered by a variety of stakeholders, including industry, academia, and non-governmental organizations. Some actions reflect ongoing efforts to address these substances in Canada.

2 Chemical Profile

An extensive summary of the environmental data and other pertinent information considered as part of the process of designating the PFOS, PFOA, LC-PFCAs, and their salts and precursors as CMCs is available in the [Binational Summary Report: Perfluorinated Chemicals \(PFOS, PFOA and LC-PFCAs\)](#) produced by the Identification Task Team (Identification Task Team [ITT], 2015). A synopsis of the various properties of PFOS, PFOA, LC-PFCAs, and their salts and precursors is presented in the subsections below.

2.1 Chemical Identity

The carbon-fluorine (C-F) bond in PFOS, PFOA, LC-PFCAs, and their salts and precursors is one of the strongest chemical bonds known in nature, which make these CMCs highly resistant to biotic and abiotic degradation and, therefore, extremely persistent in the environment.

2.1.1 PFOS

PFOS is an anthropogenic substance belonging to the class of PFAAs and in the sub-group of PFSAs (sulfonic acids). The PFOS molecule contains eight carbon atoms, seven of which are bonded to two fluorine atoms and one of which (the terminal carbon) is bonded to three fluorine atoms (**Figure 1**). PFOS also contains a sulfonic acid ($-\text{SO}_3\text{H}$) moiety, which is highly dissociable ($-\text{SO}_3^-\text{X}^+$) in the environment. PFOS can exist in anionic ($\text{C}_8\text{F}_{17}\text{SO}_3^- + \text{H}^+$; CAS No. 45298-90-6), acid ($\text{C}_8\text{F}_{17}\text{SO}_3\text{H}$; CAS No. 1763-23-1) and salt forms ($\text{C}_8\text{F}_{17}\text{SO}_3^-\text{X}^+$). However, under most environmental conditions, the anionic form dominates, resulting in very low volatility, high water solubility and the ability to repel both oil and water (ITT, 2015; Interstate Technology Regulatory Council [ITRC], 2017). Canada's Schedule 1 List of Toxic Substances under the *Canadian Environmental Protection Act, 1999* (CEPA) defines PFOS precursors as substances containing the perfluorooctylsulfonyl ($\text{C}_8\text{F}_{17}\text{SO}_2$, $\text{C}_8\text{F}_{17}\text{SO}_3$, or $\text{C}_8\text{F}_{17}\text{SO}_2\text{N}$) moiety that have the potential to transform or degrade to PFOS (Environment Canada [EC], 2006a).

2.1.2 PFOA and LC-PFCAs

PFOA is an anthropogenic substance belonging to the class of PFAAs and in the sub-group of PFCAs

(carboxylic acids). PFOA and other PFCAs are fluorocarbon-based chemicals (consisting of fluorine bound to carbon atoms), containing a carboxyl group (COOH). As with PFOS, it is the strength of the C-F bonds in PFOA and other PFCAs that contributes to the extreme stability and unique properties of these substances (ITT, 2015).

The PFOA molecule has a chain length of eight carbons (seven of which are perfluorinated; **Figure 1**), and LC-PFCAs contain between 9 and 20 carbon atoms (HC, 2018a). PFOA may refer to the acid (un-ionized) form (perfluorooctanoic acid; $C_7F_{15}COOH$; CAS No. 335-67-1), but some use the PFOA acronym to mean its dissociated anionic (conjugate base) form (perfluorooctanoate; $C_7F_{15}COO^- + H^+$; CAS No. 45285-51-6), or its principal salt forms ($C_7F_{15}CO_2^- X^+$) (ITT, 2015; ITRC, 2017). Canada's Schedule 1 List of Toxic Substances under CEPA defines precursors to PFOA are substances where the perfluorinated alkyl segment of the molecule (moiety) has the formula C_nF_{2n+1} (where $n = 7$ or 8) and is directly bonded to any chemical moiety other than a fluorine, chlorine or bromine atom (EC & HC, 2012b). LC-PFCAs and their salts are a homologous series of substances with the molecular formula of $C_nF_{2n+1}CO_2H$ (where $8 \leq n \leq 20$). Precursors to LC-PFCAs are any substance where the perfluorinated alkyl moiety has the formula C_nF_{2n+1} (where $8 \leq n \leq 20$) and is directly bonded to any chemical moiety other than a fluorine, chlorine or bromine atom (EC, 2012a). These substances may be formed from the degradation or transformation of their precursors, which include parent compounds and chemical products containing PFOA or PFCAs (ITT, 2015).

2.2 Physical and Chemical Properties

PFOS, PFOA, and LC-PFCAs originate from anthropogenic sources, and have been detected all over the world, even in remote locations (such as the Canadian Arctic). They share many properties including water solubility and persistence against degradation (Association of State and Territorial Solid Waste Management Officials [ASTSWMO], 2015). PFOS, PFOA, and LC-PFCAs repel oil, grease, and water, qualities which have made these substances especially useful in applications such as repellents for fabrics and carpets, clothing treatments, coatings for paper and cardboard packaging, polymerization in the manufacture of fluoropolymers (e.g. polytetrafluoroethylene, polyvinylidene fluoride), and aqueous film-forming foams (AFFF). The ecological assessments conducted under CEPA have concluded that PFOS (its salts and precursors), PFOA (its salts and precursors), and LC-PFCAs (their salts and precursors) are entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity (EC, 2006a; EC, 2012a; EC and HC, 2012b). **Table 1** lists some of the physicochemical properties of PFOS and PFOA (as free acids).

2.3 Environmental Fate and Transport

PFOS, PFOA, LC-PFCAs, and their salts and precursors are persistent, bioaccumulative, and toxic to the environment (EC, 2006a; EC, 2012a; EC and HC, 2012b). These compounds are highly soluble in water and typically present as an anion (conjugate base) in solution. They have very low volatility due to their ionic nature (Agency for Toxic Substances and Disease Registry [ATSDR], 2015). LC-PFCAs have low vapor pressure, and aquatic environments are expected to be their primary sink in the environment (EC, 2010). While precursors have the ability to transform and liberate the acids, PFOS, PFOA and LC-PFCAs themselves do not readily degrade by most natural processes. They are thermally, chemically, and

biologically stable and are resistant to biodegradation, atmospheric photo-oxidation, direct photolysis, and hydrolysis. The C-F bonds in PFOS, PFOA, and LC-PFCAs are responsible for the resistance of these substances to undergo biotic and abiotic degradation in the environment. The C-F bonds require a great amount of energy to break, and the fluorine atoms shield the carbon backbone (Organisation for Economic Co-operation and Development [OECD], 2015). PFOS, PFOA, and LC-PFCAs have been referred to as the “*forever chemicals*” in the environmental and human health context (Canadian Environmental Law Association, 2019).

PFOS, PFOA, and LC-PFCAs are environmentally persistent and mobile within the environment ([Canadian Gazette, 2021](#)). Being almost entirely in dissociated form under environmental conditions, and therefore highly water soluble, PFOS, PFOA, and LC-PFCAs tend to be found in the water column; however, they may be subject to different forms of transportation (e.g. in water, on suspended sediment, or on particles through the atmosphere), and accumulation (in soil, bioaccumulation, or deposited in sediments). PFOA does not easily adsorb to sediments or aquifer materials and, therefore, tends to stay in the water column (U.S. EPA, 2016b). Also, more volatile precursor compounds that are commonly used in consumer and industrial products may be transported for long distances to deposit and transform to compounds such as PFOS and PFOA (U.S. EPA, 2016a, 2016b). PFOS, PFOA, and LC-PFCAs in the environment transfer and cycle between air, water, animal tissues, and soil media, and, depending on the volatility, can be easily transported through the atmosphere on a global scale (ECCC, 2013). For example, PFOS, PFOA, and LC-PFCAs (PFNA, PFDA, PFUnA, PFDoA) are highly enriched in sea spray aerosols (up to ~62,000 times higher than water concentrations), which may act as a significant source of PFAAs to the atmosphere (Johansson et al., 2019). The small particle size also facilitates long-range atmospheric transport.

Within the Great Lakes, PFOS, PFOA, LC-PFCAs, and their salts and precursors enter the food chain, adhere to sediment or particles in the atmosphere, or deposit from the atmosphere after transformation of precursors. PFOS and PFOA are frequently detected in foods, water, air, precipitation, and soils in the Great Lakes ecosystem (Gewurtz et al., 2013, 2019; U.S. EPA, 2019a). Following ingestion by biota, PFOS, PFOA, LC-PFCAs, and their salts and precursors partition to proteins in tissue and blood proteins, likely driving bioaccumulation and tissue distribution patterns (Bischel et al., 2011). For LC-PFCAs, bioaccumulation (Martin et al., 2003; Dai et al. 2013) and trophic magnification factors (Müller et al., 2011) generally increase with chain length. For any given carbon chain length, PFSAs (e.g. PFOS) may have higher bioaccumulation compared to PFCAs (e.g. PFOA) of the same fluorinated carbon chain length (Conder et al., 2008) for most species. Complicating estimates of bioaccumulation in biota, evidence suggests that a significant amount of PFAA precursors may be present in tissues, and may have appreciable contributions to body burdens of PFCAs through biotransformation (Simonnet-Laprade et al., 2019).

2.4 Sources and Releases of PFOS, PFOA, and LC-PFCAs in the Great Lakes

PFOS, PFOA, LC-PFCAs, and their salts and precursors release and exposure sources within the Great Lakes are anthropogenic and may be regional or global via long-range transport.

2.4.1 Release Sources

PFOS, PFOA, LC-PFCAs, and their salts and precursors enter the Great Lakes ecosystem from Canadian and U.S. sources such as waste sites, AFFF use (e.g. military facilities, airports, firefighting training sites, AFFF storage facilities), wastewater treatment plants (WWTPs), use and disposal of consumer products containing these chemicals, degradation of precursors, long-range transport, atmospheric deposition, groundwater migration, and sediment resuspension (EC, 2006; Hu, Andrews et al., 2016; U.S. EPA, 2016a, 2016b; ASTSWMO, 2015). PFOS, PFOA, LC-PFCAs, and their salts and precursors are not manufactured in Canada; however, PFOS and PFOA were manufactured in the U.S. for several decades before production ceased in the early 2000s for PFOS, and in 2013 for PFOA. Overall, releases in Canada are decreasing due to risk management of PFOS, PFOA, LC-PFCAs, and their salts and precursors under the *Prohibition of Certain Toxic Substances Regulations, 2012*, which will be discussed in further detail in Section 3.

2.4.1.1 Industrial

Former major global manufacturers of PFOS, PFOA, and LC-PFCAs were located in the U.S., Western Europe, and Japan. While production and use of PFOS, PFOA, and LC-PFCAs in these locations has fallen sharply since 2000 due to phase-outs, new manufacturers in emerging economies (e.g. China, India, Russia, Poland) has shifted the geographical distribution of industrial production (OECD, 2015). Unintentional release of these substances from manufacturing and processing were a potential source of contamination. Although Canada did not manufacture these chemicals specifically, 600,000 kg of PFAS were imported for processing and manufacturing purposes between 1997 and 2000, of which 43% (258,000 kg) were PFOS and its precursors (EC, 2006a). Less than 1,000 kg were attributed to PFOA imports (EC and HC, 2012). The primary uses of these substances were applications involving water, oil, soil, and grease repellants for fabric, leather, packaging, rugs and carpets, as well as additives in photofinishing products, paints, and coatings. PFOS, PFOA, LC-PFCAs, and their salts and precursors are still not manufactured in Canada, but may continue to be imported in certain products. Potential ongoing uses of PFOS include photography films, papers and printing plates, and photo lithography applications (semi-conductor manufacturing). PFOA and LC-PFCAs in manufactured items may continue to be imported in Canada. It is estimated that approximately 308 tonnes of PFOA and LC-PFCAs were imported into Canada in 2010 ([Regulations Amending the Prohibition of Certain Toxic Substances Regulations, 2012](#)).

2.4.1.2 Wastewater and Landfill Leachate

Environmental releases of PFOS, PFOA, LC-PFCAs, and their salts and precursors, associated with the use of commercial and consumer products are primarily related to management of solid waste (e.g. landfills) and wastewater disposal (e.g. WWTPs and private septic systems) (ITRC, 2020).

2.4.1.2.1 Effluents

In the Great Lakes basin, studies undertaken in the late 1990s and early 2000s demonstrated PFOA concentrations in treated effluents from WWTPs in Thunder Bay and Sault Ste. Marie, Ontario at concentrations ranging from 7.9 - 24 ng/L (Scott et al., 2003). PFOA was measured in effluent at a North Toronto WWTP at 38 ng/L (Muir and Scott, 2003) and in other Ontario WWTP effluents at concentrations ranging from 7 - 55 ng/L, as well as in biosolids at concentrations ranging from 0.7 - 0.9 ng/g (Crozier et al., 2005). Crozier et al. (2005) also detected PFOS and PFOA in WWTP final effluents at concentrations of 17 - 100 ng/L and 10 - 34 ng/L, respectively. These results suggest that PFOS and PFOA

survive or are produced by transformation of their precursor chemicals in the treatment process and are subsequently discharged into receiving waters.

The International Joint Commission (IJC; 2013) summarized concentrations of select PFAS in WWTP effluent in southern Ontario. Levels of PFOA and PFOS were the highest for WWTP effluents (up to 54.7 and 208.5 ng/L, respectively) in southern Ontario (Furdui et al., 2008). PFOA and PFOS were also determined frequently in the effluents of Little River WWTP in Windsor at maximum concentrations of 141 ng/L and 82 ng/L, respectively (Tabe et al., 2009).

In 2009 and 2010, 20 Canadian municipal wastewater systems representing typical wastewater treatment processes in Canada were sampled in summer and winter for PFOS under the federal Chemicals Management Plan (EC, 2013; Guerra et al., 2014). The raw wastewater influent contained PFOS from below the method reporting limit (1.49 - 7.92 ng/L) to 1,140 ng/L (median = 4.93ng/L), and a detection frequency of 60%. PFOS concentrations in the final effluent increased, and ranged from below the method reporting limit (1.92 - 6.27 ng/L) to 1,260 ng/L (median = 5.73 ng/L), and a detection frequency of 81%. This increase may be attributed to precursors of PFOS breaking down during the treatment process to form PFOS in the effluents (EC, 2013; Guerra et al., 2014). For PFOA, raw influent concentrations across all wastewater systems ranged from <1.04 ng/L - 146 ng/L, with a median value of 5.25 ng/L. PFOA concentrations in effluent ranged from 1.86 ng/L - 142 ng/L, with a median value of 11.8 ng/L (Gewurtz et al., 2013; Guerra et al., 2014).

2.4.1.2.2 Biosolids

Biosolids from WWTPs can also contain PFOS, PFOA, and LC-PFCAs, and these can be released to the environment if they are applied to soils as fertilizer. Canadian wastewater treatment facilities produce more than 660,000 tonnes dry weight (dw) of biosolids each year (Canadian Council of Ministers of the Environment [CCME], 2012). For example, a study on the fate and behaviour of PFAAs in liquid and solid samples from 20 WWTPs in Canada found that PFOS was the predominant compound in biosolids, with concentrations ranging from 2.1-17,000 ng/g dw (Guerra et al., 2014). Additionally, Letcher et al. (2020) recently reported on 22 PFAS (including PFOS and PFOA) in biosolids from 20 WWTPs across Canada between 2012 and 2017. The mean of the sum concentration of the 22 PFAS in the biosolids samples ranged from 4.93-92.6 ng/g dw. PFOS and PFOA were two of the three dominant PFAS observed in samples. PFOS ranged from 0.49-50.4 ng/g dw, and PFOA ranged from <0.07-11.5 ng/g dw. These results were comparable to those reported by Guerra et al. (2014). The land application of these biosolids varies by province. Ontario has regulations on biosolids application to help minimize exposure of contaminants to humans and the environment (e.g. [Sewage Biosolids – Managing Urban Nutrients Responsibly for Crop Production, Ontario Ministry of Agriculture, Food and Rural Affairs](#); [Nutrient Management on Farms, Ontario MECP](#)). Laboratory and field studies have demonstrated the ability of some PFAS compounds, including PFOS and PFOA, to leach from biosolids into soils, while others may persist in soil surfaces (Armstrong et al., 2016). Further studies show that PFAS concentrations can be elevated in surface and groundwater in the vicinity of agricultural fields that received PFAS contaminated biosolids from an industrial source for an extended period of time (Washington et al. 2010).

2.4.1.2.3 Landfill Leachate

In order to monitor the potential release of select PFAS, including PFOS, PFOA, and LC-PFCAs (PFNA, PFDA, PFUnA, PFDoA), from a segment of the solid waste sector, landfill leachate was collected from 10 Canadian municipal solid-waste landfill sites from 2009 to 2011, including landfills near Lake Huron and Lake Superior (EC, 2013; Conestoga-Rovers & Associates [CRA], 2015). All landfill sites received municipal waste, and some also received construction waste, industrial waste, and sewage sludge. Raw leachate samples were collected at all 10 landfill sites, and treated leachate samples were collected from three landfill sites. Raw leachate (pre-treatment) samples had PFOS concentrations that ranged from 2.39 ng/L to 744 ng/L (median = 40.4 ng/L), and a detection frequency of 54%. Treated leachate samples had PFOS concentrations that ranged from 20.8 ng/L to 2,070 ng/L (median = 23.1 ng/L), and a detection frequency of 38% (**Table 2**; CRA, 2015). In some cases, PFOS concentrations increased following treatment, likely due to precursor compound breakdown (CRA, 2015). PFOA concentrations in raw leachate samples ranged from 50.3 ng/L to 2,300 ng/L (median = 500 ng/L), and a detection frequency of 100%. Concentrations in treated leachate samples ranged from 42 ng/L to 4,750 ng/L (median = 271 ng/L), and a detection frequency of 92% (**Table 2**; CRA, 2015). PFOA was also detected in landfill leachates in Waterloo, Ontario at 458 ng/L, Cambridge, Ontario at 1,144 ng/L, and Toronto, Ontario at 880 ng/L (EC and HC, 2012). Concentrations of LC-PFCAs were generally detected less frequently and at lower concentrations than PFOS and PFOA in pre- and post-treated landfill leachate, and in some cases, concentrations increased following treatment (CRA, 2015). **Table 2** presents descriptive statistics for LC-PFCAs analyzed.

2.4.1.3 Aqueous Film-Forming Foam

PFAS are used as surfactants, particularly in AFFF at airports and military facilities. Highly elevated levels of PFOS and other PFAAs were detected in biota and surface water downstream of an international airport in Hamilton, Ontario, and AFFF use at the airport may be a significant source (de Solla et al., 2012). The *Prohibition of Certain Toxic Substances Regulations, 2012* (PCTSR) prohibit the manufacture, use, sale, offer for sale or import of PFOS, PFOA, LC-PFCAs, and their salts and precursors, and products that contain them, with a limited number of exemptions. With respect to AFFF, the PCTSR does not prohibit: the use or import of AFFF that contains PFOS present in a military vessel or military fire-fighting vehicle contaminated during a foreign military operation, the use of AFFF that contains residual levels of PFOS at a maximum concentration of 10 ppm, or the use, sale, or offer for sale or import of AFFF that contains PFOA or LC-PFCAs for fire-fighting. ECCC is proposing to amend the PCTSR in winter of 2022 to further restrict activities involving PFOS, PFOA, LC-PFCAs, and their salts and precursors, in order to reduce environmental concentrations to the lowest possible levels. By comparison, in the U.S., stockpiles of PFOS-based AFFF supplies may exist and are not restricted from being used in some states (EC, 2013).

PFAAs associated with AFFF are broadly distributed in Canadian surface waters and may be found in relatively high concentrations (de Solla et al., 2012; D'Agostino and Mabury, 2017). Spatial and temporal trends of increased PFAAs in the tributaries surrounding the Toronto Pearson International Airport were presumed to be the result of AFFF discharge (Moody et al. 2002; Awad et al., 2011).

2.4.1.4 Consumer Products

In Canada, PFOA, LC-PFCAs, and their salts and precursors, may continue to be imported in manufactured items such as textiles, paper and packaging, and electrical and electronic equipment (ECCC, 2018b). However, ECCC is proposing to amend the PCTSR in the winter of 2022 to remove the exemptions for import, use, sale, and offer for sale of manufacture items containing PFOA and LC-PFCAs. Consumer products in circulation may also contain these substances, and their disposal is a concern. World-wide production of fluorotelomers (precursors to PFCAs) in 2006 was estimated at 20 million pounds, and the U.S. accounts for more than 50% of the production. Textiles and apparel accounted for approximately 50% of the volume produced, followed by carpets and carpet products, and coatings (including those for paper products; U.S. EPA, 2009b). Releases of PFOS, PFOA, and LC-PFCAs from textiles, carpets, paper products, and other consumer products during service life are direct sources. Some carpet and carpet treatment products, food contact paper and paper coatings, and home textiles had PFOA precursor levels as high as 1,400 ng/g, 160,000 ng/g, and 519 ng/g, respectively (U.S., EPA 2009). The disposal of products containing these substances into landfills can become a pathway of release to the environment (Lang et al., 2017).

2.4.1.5 Long-Range Atmospheric Deposition and Precursor Degradation

PFOS, PFOA, LC-PFCAs, and their salts and precursors have been measured in air and oceans, and can travel long distances. ECCC measured the PFOS precursor, methyl perfluorooctane sulfonamidoethanol (MeFOSE), at the High Arctic station in Alert, Nunavut between 2006 and 2010. Concentrations of MeFOSE in air oscillated from below the detection limit (0.2 pg/m^3) to 2.6 pg/m^3 (EC, 2013). The measurements demonstrate the potential for long-range transport of PFOS (e.g. via ocean currents) or volatile precursors (e.g. via atmospheric transport) to remote regions, such as the Canadian Arctic (EC and HC, 2012b). Long-term Arctic air monitoring (2006-2014) indicates that PFOA, PFOS, perfluorobutanoic acid (PFBA; short-chain PFCA), and fluorotelomer alcohols (FTOHs; PFCA precursors) are the most abundant PFAS, which all showed increasing trends at the Alert station (Wong et al., 2018; Muir et al., 2019). Model results also show that PFOA and PFOS are impacted by air masses originating from the ocean or land (Wong et al., 2018). A 2019 study by Gewurtz et al. suggests that source control of shorter-chained PFAAs may be slow to be reflected in environmental concentrations due to emissions far from the location of detection and continued volatilization from existing in-use products and waste streams.

2.4.1.6 Hexavalent Chromium Electroplating

Another significant source of PFOS was the hexavalent chromium electroplating sector, which commonly used PFOS-containing fume suppressants to control hexavalent chromium emissions. A five year limited exemption for PFOS-based fume suppressants was included in the *Perfluorooctane Sulfonate and its Salts and Certain Other Compounds Regulations*, which came into force in 2008. These Regulations were repealed in 2016 when PFOS was added to the *Prohibition of Certain Toxic Substances Regulations, 2012* with PFOA, LC-PFCAs, and their salts and precursors. The *Prohibition of Certain Toxic Substances Regulations, 2012* maintains the prohibition to use PFOS-containing fume suppressants to control hexavalent chromium emissions.

2.4.2 PFOS, PFOA, and LC-PFCAs in Environmental Media

Measurements of PFOS, PFOA, and LC-PFCAs in the Canadian environment indicate general trends that correlate to human activity. In many cases, concentrations are higher in and around cities, airports,

industrial and military facilities, as well as fields where biosolids from WWTPs are spread (**Figure 2**). PFOS has also been detected in rural and remote locations (through atmospheric transport and/or river and ocean currents from source regions), albeit at concentrations lower than in urban centres (EC, 2013). PFOS, PFOA, and LC-PFCAs have been measured throughout the Canadian environment in air, surface water, groundwater, soil, sediments, fish, and wildlife. Data are available for PFOS, PFOA, and LC-PFCAs and are discussed below.

2.4.2.1 In Air

2.4.2.1.1 Integrated Atmospheric Deposition Network

Certain precursors to PFOS and PFOA have higher volatility, resulting in concentrations in air which are subject to long range-transport, to the Arctic in particular, where they deposit. PFOS and PFOA are also present in air, but are predominantly bound to particulate matter. PFOS, PFOA and LC-PFCAs are water soluble, thus, it is appropriate to monitor them in precipitation. Under the Great Lakes Basin Monitoring and Surveillance Network, the Integrated Atmospheric Deposition Network (IADN; ECCC, 2017) measures PFOS, PFOA and LC-PFCAs in precipitation at three locations in the Great Lakes, including Point Petre (Lake Ontario), Burnt Island/Evansville (Lake Huron), and Sibley (Lake Superior). From 2006-2018, the median concentration of PFOS and PFOA in Great Lakes precipitation was 0.93 ng/L and 0.49 ng/L, respectively. Median concentrations of both substances were highest in Lake Ontario (**Table 3**; Gewurtz et al., 2019). Maximum PFOS concentrations recorded in precipitation for this time period at Point Petre were 14 ng/L. Time trends (2006-2018) for PFOA and PFOS in precipitation indicate a significant decrease over time (**Figure 3**). These overall decreasing trends were likely in response to North American phase outs and regulatory actions for PFOS, PFOA, and other LC-PFCA and their precursors, which has been ongoing since the early 2000s (Gewurtz et al., 2019).

2.4.2.1.2 Global Atmospheric Passive Sampling Network

The Global Atmospheric Passive Sampling (GAPS) Network, a program run by ECCC, has been monitoring select PFAS, including PFOS, PFOA, and LC-PFCAs (PFNA, PFDA, PFUnA, PFDoA, PFTrA, PFTeA), in the atmosphere globally at approximately 50 stations since 2009. Data provided by the GAPS program is used to assess the effectiveness of implemented control measures, temporal trends, and for investigating regional and global long-range atmospheric transport. A report on environmental monitoring and surveillance of PFOS in Canada (EC, 2013) summarized global air concentrations of PFOS collected through the GAPS program. Monitoring using passive samplers was conducted at eight locations across Canada over a three-month period in 2009. PFOS concentrations were detected in Toronto, ON (8 pg/m³), an agricultural site in Saskatchewan (5 pg/m³), Whistler, B.C. (4 pg/m³), and Alert, NU (2 pg/m³). PFOS was not detected at the other four Canadian sites. The PFOS levels measured in Canada using passive samplers were substantially lower than those measured in Paris, France (150 pg/m³), but comparable to Sydney, Florida (3.4 pg/m³), Tudor Hill, Bermuda (6.1 pg/m³), Malin Head, Ireland (3.3 pg/m³), and Hilo, Hawaii (6.6 pg/m³). In general, the results showed that although PFOS air concentrations were elevated in urban locations such as Toronto, increases were relatively minor (i.e. on the same order of magnitude) compared with more remote sites such as Lake Superior (0.43 pg/m³), demonstrating the widespread distribution of PFOS in the Canadian atmosphere (Genualdi et al., 2010; EC, 2013).

More recently, concentrations of select PFAS monitored globally at 21 GAPS stations in 2013 and 2015 were compared to those reported from 2009 to assess trends over seven years of monitoring (Rauert et al., 2018). The concentrations of PFSAs (e.g. PFOS) increased significantly from 2009 to 2015, while PFCAs (e.g. PFOA) were higher in 2015, though there was no statistically significant increase. Concentrations of both PFSAs and PFCAs were similar at all locations, illustrating the global reach of these persistent compounds. Concentrations of PFSAs at the Toronto GAPS station were 4.6 pg/m³ and 8.1 pg/m³ in 2009 and 2013, respectively. These data are in line with the significant increase in concentrations of PFSAs determined by the GAPS study (2013-2015), and suggest that PFCA concentrations may be increasing in Toronto and other urban sites (Rauert et al., 2018).

2.4.2.2 In Water

PFOS, PFOA, and LC-PFCAs are detected in tributaries and open waters across the Great Lakes basin with the highest levels generally found in areas of Lake Ontario, the western end of Lake Erie, and the Detroit River corridor (ITT, 2015). PFOS and PFOA are very soluble in water and therefore easily move through water resources, whether surface, ground, or drinking water.

2.4.2.2.1 Surface Water

From 2016 to 2017, 163 water samples were taken by the ECCC's Chemical Management Plan Monitoring and Surveillance program in eight drainage regions in Canada, including the Great Lakes, to assess PFOS concentrations in water against the Federal Environmental Quality Guidelines (FEQGs). Across Canada, PFOS was detected in 49% of samples and concentrations ranged from less than 2 ng/L to 26.1 ng/L (ECCC, 2019).

Median concentrations of PFOS and PFOA in Great Lakes surface water between 2006 and 2018 were 2.1 ng/L (% detection = 53%) and 1.5 ng/L (% detection = 70%), respectively (Gewurtz et al., 2019; **Table 3**). Both substances were highest in Lake Ontario. For the same time period, maximum PFOS concentrations (7.4 ng/L) in Lake Ontario measured between 2006 and 2018 were more than two order of magnitude below Canadian FEQGs for surface water (6,800 ng/L) (**Table 3**; Gewurtz et al., 2019). Time trends of PFOS and PFOA concentrations in Great Lakes surface water were not possible due to insufficient sampling events (**Figure 3**). Results from Gewurtz et al. (2019) suggest that higher surface water concentrations of PFAAs, including PFOS and PFOA, in Lake Ontario may be influenced by other sources in addition to precipitation, such as wastewater treatment effluent, street dust from traffic and subsequent urban runoff. The authors also hypothesize that given PFOS and PFOA in surface water and precipitation appear to be derived primarily from local anthropogenic sources, phase-outs and regulations will continue to be effective in reducing environmental concentrations.

2.4.2.2.2 Drinking Water

In 2012, the Ontario Ministry of Environment, Conservation and Parks (MECP; previously Ontario Ministry of Environment and Climate Change) carried out a survey of six PFAS compounds, including PFOS, PFOA, and LC-PFCAs, in raw and treated drinking water in Ontario. 113 samples (59 untreated, 54 finished) were collected from 17 drinking water systems, and maximum concentrations in 2012 were compared to those measured in 2006 (**Table 4**). The results demonstrate little difference between the maximum concentrations in the raw versus treated water samples, but show a slight decrease from 2006 to 2012 (ITT, 2015). A national survey of emerging contaminants in Canadian drinking water (including PFOA) performed by Health Canada monitored treated and raw water in winter and summer

at 35 locations in 2009, and at 30 locations in 2010. PFOA was detected (detection limit of 0.023 ng/L) in 68% of raw water samples, and 64% of treated water samples in summer 2009, with averages of 0.067 ng/L and 0.071 ng/L, respectively. PFOA concentrations were slightly lower in winter 2009, with an average of 0.057 ng/L in detected raw samples (59% detection) and 0.056 ng/L in detected treated samples (55% detection). In 2010, the detection rates for PFOA were lower, with detection rates in the summer of 18% in raw water (average of 0.066 ng/L) and 15% in treated water (average of 0.046 ng/L), and in winter of 33% in raw water (average of 0.055 ng/L) and 27% in treated water (average of 0.05 ng/L) (Health Canada, 2016). Note that these measurements were taken prior to the publication of the *Regulations Amending the Prohibition of Certain Toxic Substances Regulations, 2012*, which added controls of PFOA and LC-PFCAs prohibition regulation in 2016.

2.4.2.3 In Groundwater

A study published in 2021 examined leachate-impacted groundwater samples collected from closed landfills in Ontario (Propp et al., 2021). Several PFAS were found at elevated concentrations (0.1s – 10s of µg/L) in leachate-affected groundwater from these historic landfill sites, including PFAS such as PFBA, PFPeA, PFHxA (perfluorohexanoic acid), PFOA, and PFOS. PFOS was one of the most ubiquitous PFAS detected, which may reflect its more common use 40-70 years ago. The study highlighted the persistence of PFAS within landfills and the potential importance of historic landfills as long-term sources of PFAS to groundwater. The results also highlighted the substantial variation in PFAS composition that can occur within and between historic landfills. Older sites tended to have a higher proportion of longer-chained compounds, particularly perfluorodecanoic acid (PFDA) and PFUnDA, than younger sites.

PFOS has been detected in groundwater collected from commercial and industrial sites where AFFFs have been used in firefighting training exercises, or where spills have resulted in either contamination or suspected contamination of soil, surface water or groundwater. PFOS concentrations in groundwater at London International Airport, ON, were found to range from <5 to 130 µg/L at a former firefighting training area (Lebel 2012). In an investigation of a firefighting training site at Hamilton International Airport, PFOS concentrations in groundwater ranged from <0.02 to 560 µg/L (exp. Services Inc 2011).

2.4.2.4 In Sediment and Soil

2.4.2.4.1 Sediment

Certain PFAS are found in sediment samples from across the Great Lakes basin, with greater concentrations near population centres. Sediment cores sampled in 2006 from Lake Ontario show increasing concentrations of PFOS and PFOA over the period 1981 to 2006 (Myers et al., 2012). Open lake sampling in 2008 indicated that PFOS was the dominant PFAS observed in surface sediments, with the highest concentrations present in the depositional basins. PFOS concentrations at open lake sites ranged from 27 - 47 ng/g in the Niagara Basin, 4.4 - 19 ng/g in the Mississauga Basin, and 8.1 - 49 ng/g in Rochester Basin (Myers et al., 2012). Gewurtz et al. (2013) also found that the spatial distribution of PFOS in sediment generally related to urbanization, with higher concentrations being observed near cities, especially in southern Ontario. For example, the highest PFOS concentration in sediment sampled between 2006 and 2011 was found in Lake Ontario (10 ng/g dw), compared to lower concentrations in Lake Superior by Thunder Bay (0.5 ng/g dw) and Lake Huron (2 ng/g dw). PFOS was also detected in the

open water sediment of the other Great Lakes at concentrations of 0.89 ng/g dw (Lake Erie), 2.2 ng/g dw (Lake Huron), and 1.4 ng/g dw (Lake Superior) (ECCC, 2013).

2.4.2.4.2 Soil

PFOS levels in soils have been observed to increase with depth, suggesting migration into groundwater (Xiao et al., 2015; Weber et al., 2017). The concentrations are dependent on the soil characteristics and it has been reported that soils with high clay and organic matter content, and low pH tend to retain PFOS (Das et al., 2013; Xiao et al., 2015). In samples from the Great Lakes basin, Chu and Letcher (2017) reported 22 PFAS in sediment samples collected in 2012–2013 from western Lake Erie and Saginaw Bay (Lake Huron), and in soil samples (2015) from one biosolid applied and two non-biosolid applied farm field sites in southern Ontario. PFOS and PFOA were found at low levels (ng/g dw) in both sediment and soil samples.

PFOS concentrations in soils from suspected AFFF-impacted areas or from water-bearing zones have been investigated at the former firefighter training facility at Hamilton International Airport. PFOS concentrations in these soils ranged from <0.025 to 26 mg/kg (exp. Services Inc 2011).

2.4.2.5 In Biota

PFOS, PFOA, and LC-PFCAs are measured under various monitoring and biomonitoring programs in Canada. Through long-term monitoring programs by ECCC and MECP, these substances have been measured and are routinely monitored in top predator fish and bird eggs (herring gulls and European starlings). A geographic analysis (2006-2011) of PFOS in environmental media, including biota, has detected concentrations across Canada (ECCC, 2013; **Figure 2**).

2.4.2.5.1 Fish

Temporal Trends

In 2001, a suite of 15 PFAS were analyzed in lake trout (*Salvelinus namaycush*) collected throughout the Great Lakes. PFOS was the major substance observed, with the highest average concentrations in Lake Erie (121 ± 14 ng/g wet weight (ww)), followed by Lake Ontario (46 ± 5 ng/g ww), Huron (39 ± 10 ng/g ww), Michigan (16 ± 3 ng/g ww), and Superior (4.8 ± 0.4 ng/g ww). Different trends were observed for PFOA, with the highest average concentrations in lake trout in Lake Michigan (4.4 ± 1.6 ng/g ww), followed by Lakes Erie (1.6 ± 0.7 ng/g ww) and Huron (1.6 ± 0.3 ng/g ww), then Lake Ontario (1.5 ± 0.4 ng/g ww) and Lake Superior (1.1 ± 0.2 ng/g ww) (Furdui et al., 2007).

From 2006 to 2010, top predator fish were collected in 21 water bodies across Canada. Spatial distribution of PFOS in fish across Canada show that in many cases, higher concentrations were observed near cities, especially in southern Ontario, suggesting urban centers are major sources of PFOS in the environment (Gewurtz et al., 2013; ECCC, 2013). PFOS concentrations were highest in lake trout from Lake Erie (geometric mean = 90 ng/g ww) and Lake Ontario (geometric mean = 62 ng/g ww), and mostly low (<3 ng/g ww) in fish from Lake Superior (Gewurtz et al., 2013).

Analysis of fish tissue for PFOS in lake trout from Lake Ontario collected over the period 1979-2014 showed geometric mean tissue concentrations rising from 1979-2002, peaking at approximately 80 to 110 ng/g ww in 2002 and then decreasing to approximately 40-60 ng/g by 2013-2014 (Furdui et al. 2008; ECCC 2016). These levels are below the FEQG for fish tissue concentrations of 9.4 mg/kg ww; however, the FEQG for PFOS concentrations for the protection of mammals (4.6 µg/kg ww food) and fish-eating birds (8.2 µg/kg ww food) were exceeded in 7 of 11 drainage regions, including the Great Lakes and St. Lawrence River (ECCC, 2018a).

A review by Remucal (2019) summarized all available data on 12 commonly studied PFAS, including PFOS, PFOA, and some LC-PFCAs (PFNA, PFDA, PFUnA, PFDoA), in whole lake trout across the Great Lakes. Results show that the sum of 12 PFAS concentrations in lake trout generally increased from west to east, but is consistently highest in Lake Erie. The total average PFAS concentrations in lake trout for each of the Great Lakes from lowest to highest is 11 ng/g (Lake Superior), 24 ng/g (Lake Michigan), 46 ng/g (Lake Huron), 92 ng/g (Lake Ontario), and 136 ng/g (Lake Erie). The study found PFOS in the highest concentration and detected most frequently in the Great Lakes, and that PFOS follows the same spatial trend as the sum of 12 PFAS, with the highest average concentrations in Lake Erie. PFOA, on the other hand, appears to be constant across the Great Lakes in all available fish species and tissue types. LC-PFCAs generally increase from Lake Superior to lakes Erie and Ontario. Remucal (2019) also noted that time series data show an increase in PFOS and total PFAS in lake trout from 1979-1980 until the mid-1990s-2001; however, the trend is not linear, and more recent data show that PFOS and total PFAS concentrations have remained stable since the early 2000s.

Provincial and Federal Monitoring

Since 2007, the Ontario MECP has analyzed over 700 samples for select PFAS in tissues of 36 types of fish in the Great Lakes and connecting channels through the Fish Contaminant Monitoring Program. In addition to providing data to assess long-term environmental trends, these data provide advice for consuming Ontario fish to minimize exposure to the toxic effects of PFAS. Fish consumption advisory information can be found in the Guide to Eating Ontario Fish (available at www.ontario.ca/fishguide) which compiles information for more than 2,500 locations around the province, including many locations in the Great Lakes.

Concentrations observed for 16 PFAS compounds (**Table 5**) in edible portions of monitored fish have been assessed. The highest concentration was measured for PFOS at 68 ng/g for White Bass from the western basin of Lake Erie. Fish consumption advice is issued for both general and sensitive populations when the sum of 16 PFAS compound concentrations exceed 18 ng/g wet weight (ww), and complete fish consumption restriction is advised when levels are above 140 ng/g ww for the sensitive population (women who intend to become pregnant or are pregnant, and children younger than 15 years of age), and 560 ng/g ww for the general population. In 2020, there were four locations in the Great Lakes where PFAS concentrations resulted in consumption restrictions, which were lenient (i.e., 16 meals per month).

Science on health impacts of PFAS is still developing. Ontario continues to track scientific developments and jurisdictional approaches to better understand the effects of PFAS on human and ecological health and to develop protective benchmarks (standards, guidelines), including for new and replacement PFAS.

Ontario regularly reviews fish consumption advisory benchmarks for PFAS and updates as necessary. Revised PFAS benchmarks may result in more restrictive fish consumption advisories in the future.

From 2015 to 2017, fish sampling by the ECCC's Chemical Management Plan (CMP) Monitoring and Surveillance program was conducted in nine drainage regions in Canada, including the Great Lakes, to assess PFOS concentrations in fish tissue against the FEQGs. The analysis found that the PFOS concentrations were below the guidelines for fish health (9,400 ng/g ww) in the Great Lakes drainage regions; however, concentrations exceeded the wildlife diet guidelines (4.6 ng/g ww wildlife diet for mammals; 8.2 ng/g ww wildlife diet for birds) for fish as diet for wildlife predators (ECCC, 2019).

2.4.2.5.2 Wildlife

Monitoring and Surveillance in Support of the Chemicals Management Plan

A comprehensive dataset for certain PFAS, including PFOS, PFOA, and LC-PFCAs, in wildlife tissues has been compiled by EC (2013) under the CMP. Herring gull (*Larus argentatus*) eggs were monitored for PFOS in 1990 and 1997–2010 at seven colonies throughout the Great Lakes, including urbanized regions in southern Ontario and more remote colonies in Lake Huron and Lake Superior (Gebink et al., 2011). In the more urbanized areas, consistent with the trends observed in Lake Ontario lake trout, PFOS concentrations were variable and have not shown a consistent decline in response to the 2002 PFOS production phase out by primary suppliers. In contrast, an overall decline was evident in herring gull eggs from the more remote colonies on Lake Huron and Lake Superior (ITT, 2015).

Also under the CMP, ECCC also monitored the concentration of PFOS in herring gull and European starling (*Stumus vulgaris*) eggs over the period 2008-2011. PFOS concentrations were elevated in the Great Lakes region, with measurements greater than 0.260 µg/g ww in urban areas, and lower concentrations (0.007-0.115 µg/g ww) in non-urban areas. The results showed the highest concentrations in Lake Erie herring gull eggs at 0.676 µg/g ww. Concentrations in starling eggs were highest in a highly urbanized area of the Brantford, Ontario landfill (0.702 µg/g ww). These levels are below the FEQG for bird egg concentrations (1.9 µg/g ww; ECCC, 2018a).

Additional monitoring supported by the CMP was conducted between 2009 and 2014 in European starling eggs across Canada, including Hamilton ON. PFAAs, including PFOS, PFOA and some LC-PFCAs (PFNA, PFDoDA) were analyzed. In 2014, the median concentration of PFOS and PFOA in starling eggs in Hamilton, ON was 42 ng/g ww (range: 15-61 ng/g ww) and 0.83 ng/g ww (range: <0.75-0.90 ng/g ww), respectively (Gewurtz et al., 2018). Results revealed that within urban centres, PFSA concentrations were generally greater in urban and industrial locations, and both PFSA and PFCAs were generally greater in landfills compared to rural and remote locations. Results also suggested that PFOS leaching from consumer products in landfills is likely a major source to the environment. Furthermore, concentrations of PFCAs in eggs were not related to population, and suggests that atmospheric transport and degradation of precursors are influencing spatial trends (Gewurtz et al., 2018).

The Great Lakes Herring Gull Monitoring Program

As part of the Great Lakes Herring Gull Monitoring Program, ECCC collected 114 herring gull egg samples in 2012-2013 from 19 Canadian and U.S. colony sites across the Great Lakes and analyzed for several

PFAS (Letcher et al., 2015). PFOS was the dominant PFSA with mean concentrations ranging from 43 ng/g ww (Gull Island in Lake Superior, 2012) to 720 ng/g ww (Toronto Harbour in Lake Ontario, 2012), depending on the colony and year, and comprising between 92-99% of the total PFSA concentration. PFOS was detected in 100% of egg samples, and PFOA was detected in 70% of egg samples. Also, PFOS concentrations in some egg samples were greater than some of the known lowest observed effect concentrations (LOECs) measured and reported in captive bird model studies (Letcher et al., 2015).

2.5 High Level Summary of Adverse Effects to Human Health and the Environment

PFAAs are recognized as chemicals of concern and are considered ubiquitous in the environment because they have been detected near and far from their emission sources (Gewurtz et al., 2017). Select PFAS, PFOS, PFOA, and perfluorohexane sulfonate (PFHxS) were detected in over 98% of human blood serum samples from non-occupationally exposed adult Canadians (Canadian Health Measures Survey [CHMS], 2021). A review of select PFAS environmental monitoring data found that human exposure can be via indoor and ambient air, house dust, direct contact with consumer products containing these substances, and drinking water, although the majority of exposure can be attributed to diet (human consumption of fish, wildlife and vegetation) (Fromme et al., 2009; Health Canada, 2018a, 2018b).

Besides this background exposure of the general population, additional exposure in the Great Lakes region outside of Canada has been observed related to occupational exposure for workers at facilities that produce select PFAS (ATSDR, 2015), in populations living near these facilities, and in areas with environmental contamination of select PFAS.

The half-life of PFOS and PFOA in humans is years, as opposed to weeks or months in laboratory animals. The estimated half-life was 5.3 years (95% CI 4.6 to 6.0) for PFHxS, 3.4 years (95% CI 3.1 to 3.7) for PFOS and 2.7 years (95% CI 2.5 to 2.9) for PFOA in a study published in 2017 (Li et al.). The estimated half-life for PFHxS was considerably longer than for PFOS and PFOA. The average half-life for PFOS is considerably shorter than previously published estimates, whereas the half-life for PFOA is inline with the range of published estimates. In general, the shorter the carbon chain length, the shorter the half-life (ATSDR, 2015); however, there are some exceptions. Bioaccumulation of these substances is due to their affinity for protein-rich body compartments, such as blood serum albumin and liver (U.S. EPA, 2009b), in addition to resistance to elimination and metabolism. Therefore, low-level exposures can eventually result in high body burden for some PFAS, increasing the risk of adverse health effects.

Adverse health effects of certain PFAS have been demonstrated in animal studies, but these occurred at exposure levels higher than those found in the general human population. The main health effects observed were enlargement and changes in the function of the liver, changes in hormone levels (e.g. reduced testosterone synthesis), and adverse developmental outcomes (ATSDR, 2019). Developmental and reproductive effects, including reduced birth weight, decreased gestational length, structural defects, delays in postnatal growth and development, increased neonatal mortality, and pregnancy loss have all been associated with prenatal rodent exposure to PFOS and PFOA (ATSDR, 2019).

Some epidemiological studies in humans have demonstrated statistically significant associations between serum PFOA and PFOS levels and total cholesterol, and significant associations have been found between serum PFOA and uric acid levels at all evaluated exposure levels (ATSDR, 2019). Epidemiological studies of highly exposed occupational and general populations demonstrated that a

probable link existed between PFOA exposure and ulcerative colitis, thyroid disease, pregnancy-induced hypertension, and kidney and testicular cancer (U.S. EPA, 2016b). There is also evidence of reduced immune response in children (Grandjean et al., 2012; Abraham et al., 2020), as well as childhood obesity (Braun et al., 2016). A recent study also showed that higher baseline plasma concentrations of select PFAS, especially PFOS and PFNA, were significantly associated with a greater decline in resting metabolic rate and greater weight regain, especially in women (Liu et al., 2018). The authors concluded that the study provided initial evidence suggesting that these substances may interfere with human body weight regulation and counteract efforts to maintain weight loss in adults.

In 2006, Health Canada (HC) completed a State of the Science report (HC, 2006) and ECCC published an ecological screening assessment (EC, 2006) for PFOS, its salts and its precursors. The HC State of Science report found that PFOS and its precursors were not harmful to human health at the levels of exposure that were assessed. ECCC concluded that PFOS and its salts were harmful to the environment. In 2012, HC and ECCC completed a screening assessment to address the potential for harm to Canadians and to the environment from PFOA, its salts and precursors (EC and HC, 2012b). Based upon a comparison of levels to which Canadians may be exposed to PFOA and its salts and precursors, and the levels associated with health effects, the risk to human health from these substances was considered to be low. ECCC concluded that PFOA and its salts and precursors were harmful to the environment. In 2012, ECCC completed an ecological screening assessment for long-chain (C9 – C20) PFCAs (EC, 2012a) and concluded that LC-PFCAs and their salts and precursors were also harmful to the environment. As the ecological assessments concluded that PFOS, PFOA, LC PFCAs, and their salts and precursors are harmful to the environment, PFOS, PFOA, LC-PFCAs, and their salts and their precursors were placed on Canada's List of Toxic Substances under CEPA.

The ecological assessment for PFOS showed that estimated no effect levels of PFOS for fish, birds (liver), birds (serum), and wildlife were 0.491 µg/L, 0.609 µg/g, 0.873 µg/mL, and 0.408 µg/g, respectively. Environmental concentrations demonstrated that some wildlife organisms in Canada (e.g. polar bear, bird species) could be near or at effect levels and could be harmed by exposures to PFOS (EC, 2006). The ecological assessment for PFOA showed that PFOA exhibits moderate to low acute toxicities in pelagic organisms, including fish (70-2,470 mg/L), and exhibits low chronic toxicities in benthic organisms (>100 mg/L; EC and HC, 2012b). The ecological assessment for LC-PFCAs showed that LC-PFCAs were of low to moderate toxicity to aquatic organisms, with acute toxicity values ranging from 8.8-285 mg/L. LC-PFCAs have also been shown to cause oxidative stress to Great Lakes species such as the common cormorant. PFOS, PFOA, LC-PFCAs, and their salts and precursors are extremely persistent and meet the criteria for persistence under the *Persistence and Bioaccumulation Regulation*; though, they do not meet the criteria for bioaccumulation (EC, 2012a). The numeric criteria for bioaccumulation, as outlined in the *Persistence and Bioaccumulation Regulations*, are based on bioaccumulation data for freshwater aquatic species (fish) only, and for substances that preferentially partition to lipids. Thus, the criteria may not completely reflect the bioaccumulation potential for PFOS, PFOA and the LC-PFCAs that preferentially partition to the liver, blood and kidneys in terrestrial and marine mammals. As such, PFOS, PFOA and LC-PFCAs did not meet the numeric criteria for bioaccumulation as outlined in the *Persistence and Bioaccumulation Regulations*. Therefore, the ecological screening assessment conclusions for PFOS, PFOA, LC-PFCAs, and their salts and precursors were based on a weight of evidence approach that considered persistence, bioaccumulation, temporal trends in some species (e.g., the polar bear), long-range transport, and the widespread presence of these substances in the Canadian environment (including the Great Lakes and the Arctic) and in wildlife.

The Government of Canada announced, in April 2021, its intent to move toward addressing [PFAS as a class](#); evidence to date indicates that the PFAS used to replace regulated PFOS, PFOA, and LC-PFCAs may also be associated with environmental and/or human health effects. A class-based approach will address situations where exposure occurs to multiple PFAS at the same time, consider cumulative effects, and prevent regrettable substitutions. Canada will continue to invest in PFAS research and monitoring, and it will publish a State-of-PFAS report within 2 years to summarize relevant information on the class of PFAS.

3 Existing Management/Control Policies, Regulations, and Programs

3.1 National

PFOS was never manufactured in Canada. Prior to the announcement of a global voluntary phase out of the production of PFOS by the major manufacturer beginning in 2000, PFOS was imported into Canada and used primarily in water, oil, soil and grease repellents for paper and packaging, carpets and fabrics, and in fire-fighting foams used to fight fuel-based fires. Based on a 2004 survey of remaining PFOS uses, only 3,000 kg of PFOS was imported into Canada for use as a surfactant in the chromium electroplating sector.

The Government of Canada has conducted science-based evaluations of PFOS, PFOA, LC-PFCAs, and their salts, and their precursors to address the potential for harm to the general population of Canada and the environment. The Ministers of the Environment and Health published their final decision on the screening assessment of PFOS, its salts and precursors on July 1, 2006, concluding that PFOS, its salts, and its precursors are entering the environment at levels that constitute a danger to the environment. The final screening assessments of both PFOA, its salts and precursors and LC-PFCAs, their salts and precursors were published in August 2012, and both concluded that these substances were entering the environment at levels that constitute a danger to the environment.

A summary of the Canadian regulations, pollution prevention actions, and the monitoring and surveillance and other research efforts taken to eliminate PFOS, PFOA, LC-PFCAs, and their salts and precursors from the environment and to protect human health are presented in the following subsections.

3.1.1 Existing Statutes and Regulations

Under the *Canadian Environmental Protection Act, 1999* (CEPA), PFOS (its salts and compounds that contain one of the following groups: $C_8F_{17}SO_2$, $C_8F_{17}SO_3$ or $C_8F_{17}SO_2N$) was initially regulated through the *Perfluorooctane Sulfonate and Its Salts and Certain Other Compounds Regulations*, which came into force in 2008 (ECCC, 2008). These regulations prohibited the manufacture, use, sale, offer for sale or import of PFOS, and products containing PFOS, with a limited number of exemptions, such as the use of AFFF containing PFOS. In 2009, PFOS was added to the Virtual Elimination List with the goal of reducing the quantity or concentration in the environment to non-detectable levels (*Regulations Adding Perfluorooctane Sulfonate and Its Salts to the Virtual Elimination List; SOR/2009-15*). In 2016, the *Prohibition of Certain Toxic Substances Regulations, 2012* (PCTSR) were amended to add PFOS and the following substances to the regulations: Perfluorooctanoic acid, its salts, and its precursors (collectively referred to as PFOA); Long-chain (C9-C20) perfluorocarboxylic acids, their salts, and their precursors

(collectively referred to as LC-PFCAs; ECCC 2016). As the amended PCTSR maintained the prohibition of PFOS, the *Perfluorooctane Sulfonate and Its Salts and Certain Other Compounds Regulations* were repealed. The PCTSR prohibit the manufacture, use, sale, offer for sale or import of PFOS, PFOA, LC-PFCAs, and their salts and precursors, and products that contain them, with a limited number of exemptions.

ECCC is proposing to amend the PCTSR to further restrict activities involving PFOS, PFOA, and LC-PFCAs, their salts and precursors, and products containing them, by removing or providing time-limits for certain remaining exemptions. For example, as outlined in the 2018 [consultation document](#), the current exemption allowing the use, sale, offer for sale and import of manufactured items containing PFOA and/or LC-PFCAs would be removed. The proposed changes to the PCTSR will help to better achieve the environmental objective of reducing environmental concentrations to the lowest possible levels. The proposed regulations are expected to be published in the Canada Gazette, Part I in winter 2022.

3.1.2 Pollution Prevention Actions

In 2006, the Government of Canada initiated an [“Action Plan for the Assessment and Management of Perfluorinated Carboxylic Acids \(PFCAs\) and their Precursors”](#) to prevent the introduction of new sources of PFCAs into Canada. This Plan was developed to address confirmed sources of PFCAs from substances already in Canadian commerce, pursue further assessment of PFCAs and precursor substances already in Canadian commerce, advance scientific understanding of issues and develop solutions, particularly with regard to the contribution of fluorotelomer-based polymers degrading to PFCAs, and engage other regulatory jurisdictions in global actions to reduce the risk from LC-PFCAs.

In 2010, initial action was to establish an agreement with industry to voluntarily reduce PFCAs by 95% by 2010 and to eliminate them by 2015. This agreement, the *Environmental Performance Agreement Respecting Perfluorocarboxylic Acids (PFCAs) and their Precursors in Perfluorochemical Products Sold in Canada*, was signed on March 30, 2010 and was in effect until December 31, 2015 (ECCC, 2010). As a result of the agreement, participating companies successfully met their commitment to eliminate residual PFOA, LC-PFCAs, and their precursors.

3.1.3 Risk Management Actions

In 2012, the Government of Canada published a [Proposed Risk Management Approach for Perfluorooctanoic Acid \(PFOA\), its Salts, and its Precursors and Long-Chain \(C9-C20\) Perfluorocarboxylic Acids \(PFCAs\), their Salts, and their Precursors](#) with the objective of minimizing the release of PFOA and LC-PFCAs, their salts and precursors to the Canadian environment to the greatest extent practicable (ECCC, 2012).

Since 2016, Canada has prohibited the manufacture, use, sale, offer for sale or import of PFOS, PFOA and LC-PFCAs, their salts and their precursors and products that contain them, with a limited number of exemptions, under the *Prohibition of Certain Toxic Substances Regulations, 2012* (PCTSR, 2012; ECCC, 2016b). Canada's environmental objective for these substances is to minimize releases to the Canadian environment.

In February 2019, Health Canada's Contaminated Sites Division published a *Framework for Human Health Risk Assessment of Federal Sites Impacted with Per- and Polyfluoroalkylated Substances* to provide direction in conducting human health risk assessments at federal sites which have been impacted by past and/or current use of AFFF containing these substances, typically used during activities associated with firefighting, including training activities (HC, 2019a).

3.1.4 Monitoring, Surveillance, and Research Efforts

ECCC monitors the Great Lakes for PFOS, PFOA, and LC-PFCAs in air, precipitation, fish, herring gull eggs, sediment, and water under several different initiatives, including the national Chemicals Management Plan (CMP). In the Great Lakes, these ECCC initiatives also encompass regional programs such as the Great Lakes Herring Gull Monitoring Program (GLHGMP) and the National Fish Contaminants Monitoring and Surveillance Program, which includes analysis for PFOS and its salts and precursors, PFOA and its salts and precursors, and LC-PFCAs and their salts and their precursors. A more in-depth assessment of surface waters, surface sediments, and sediment cores is conducted on a rotational basis from one Great Lake annually. Additional water and sediment samples may also be collected from the connecting channels of the annually assessed lake. Water quality and ecosystem health data collected in the Great Lakes through these programs are used to determine baseline water quality status, long-term trends and spatial distributions, and the effectiveness of management actions. Research and analyses are reported in peer-reviewed journals and government reports.

The Canadian Environmental Sustainability Indicators (CESI) program provides data and information to track Canada's performance on key environmental sustainability issues, such as climate change and air quality, water quality and availability, and protecting nature. The environmental indicators are based on objective and comprehensive information, and convey environmental trends in a straightforward and transparent manner. CESI is the prime instrument to measure progress of the Federal Sustainable Development Strategy, and responds to ECCC's commitments under the Canadian Environmental Protection Act and the Department of the Environment Act to report to Canadians on the state of the environment. Under CESI, [PFOS in Fish and Water](#) is included as one of five water quality indicators, the report for which was most recently updated in January 2019. The CESI indicator uses Federal Environmental Quality Guidelines (FEQGs) for PFOS to provide context and help characterize potential risk. Monitoring and measurements of PFOS, PFOA, and LC-PFCAs are also published in peer-reviewed journals.

3.1.5 Canadian Environmental Quality Guidelines and Standards

Subsequent to regulatory ecological screening assessments for PFOS, ECCC initiated the development of Federal Environmental Quality Guidelines (FEQG) for PFOS, its salts and precursors. FEQGs are benchmarks for the quality of the ambient environment. These guidelines can be used to compare with monitoring data or to assist in evaluating the performance of regulatory measures. They are voluntary unless adopted into regulation. In June 2018, the [Federal Environmental Quality Guidelines for PFOS](#) were finalized by ECCC for surface waters for the protection of aquatic life, fish tissue, and wildlife diet for mammalian and avian consumers, and in bird eggs (ECCC, 2018a). Established under the CEPA, these FEQGs are intended as an adjunct to the risk assessment/risk management of priority chemicals identified in the CMP or other federal initiatives. Environmental samples collected in the Great Lakes are compared to environmental quality guidelines established for PFOS contamination in water (6.8 µg/L),

fish tissue (9.4 mg/kg whole body ww), wildlife diet (mammalian 4.6 µg/kg food; avian 8.2 µg/kg food), and bird eggs (1.9 µg/g ww) (**Table 6**; ECCC, 2018a). PFOS FEQGs were established in the absence of Canadian Council of Ministers of the Environment (CCME) guidelines, but are based on CCME methods as much as possible. FEQGs are developed where there is a federal need for a guideline, and where CCME guidelines have not been developed (ECCC, 2018a).

The CCME develops tools to assist jurisdictions with contaminated site assessment and management issues, and evaluating how to best manage priority contaminants. The CCME published [CEQGs for soil and groundwater for the protection of environmental and human health for PFOS](#) in 2021 (CCME, 2021). The CCME released draft Canadian Environmental Quality Guidelines (CEQGs) for PFOS in soil and groundwater for the assessment and remediation of contaminated sites for comment in 2018. FEQGs for PFOA are currently under development. Environmental quality guidelines are focused on protecting ecological receptors and minimizing adverse ecological effects, whereas human health guidelines are primarily concerned with protecting humans and minimizing human health risks from environmental contaminants.

Health Canada has also developed interim soil screening values for ten PFAS, including PFOA, perfluorobutanoate (PFBA), perfluorobutane sulfonate (PFBS), perfluorohexane sulfonate (PFHxS), perfluoropentanoate (PFPeA), perfluorohexanoate (PFHxA), perfluoroheptanoate (PFHpA), perfluorononanoate (PFNA), 6:2 fluorotelomer sulfonate (6:2 FTS), and 8:2 fluorotelomer sulfonate (8:2 FTS), which can be used to determine whether the concentrations detected in soil are likely to be of concern to human health as a result of direct contact with soil (**Table 6**; HC, 2019b).

In 2018, Health Canada issued Canadian drinking water guidelines for PFOS and PFOA (**Table 6**; HC, 2018a; HC, 2018b). Although there are no guidelines for other PFAS in drinking water in Canada, Health Canada has developed drinking water screening values for nine other PFAS, which can be used to determine whether the concentrations detected are likely to be of concern to human health (HC, 2019b). Drinking water screening values are provided as guidance and apply to water intended for human consumption.

3.2 Coordination with the United States

3.2.1 Lake-wide Action and Management Plans

Additional binational pollution prevention actions for PFOS, PFOA, and LC-PFCAs have been initiated through Lake-wide Action and Management Plans (LAMPs) for each Great Lake. The purpose of a LAMP is to assess the status of each Great Lake and identify the environmental stressors that are best addressed on a lake-wide scale. Each LAMP will incorporate activities identified in Canada's Great Lakes Strategy for PFOS, PFOA, and LC-PFCAs Risk Management, and any additional efforts, as appropriate.

3.2.2 The Great Lakes Water Quality Agreement

The purpose of Annex 3, Chemicals of Mutual Concern, of the GLWQA is to protect human health and the environment through cooperative and coordinated measures to reduce the anthropogenic release of CMCs to the Great Lakes. Under this Annex, Canada and the U.S. commit to develop and implement a science-based screening process to identify and designate CMCs on an ongoing basis. [Binational screening criteria, finalized in 2021](#), will be used to nominate and recommend chemical substances as CMCs. PFOS, PFOA, and LC-PFCAs are designated CMCs for which this Strategy outlines risk mitigation

and management actions to reduce their release to the Great Lakes, and improve human and ecosystem health. Annex 3 also commits to include monitoring and surveillance activities identified in the Strategy to track and assess PFOS, PFOA, and LC-PFCAs in the Great Lakes. This is done through national programs, monitoring and assessment through the CMP, and the Cooperative Science and Monitoring Initiative (CSMI).

Another aspect of the GLWQA is the establishment of a CSMI Task Team through Annex 10. The charge of the CSMI is to implement a binational effort to provide environmental and fishery managers with the science and monitoring information necessary to make management decisions for each Great Lake. Canada and the U.S. jointly assess conditions in one of the five Great Lakes each year. A five-year rotating cycle outlines which lake is scheduled for an intensive CSMI field year (**Table 7**). By studying one Great Lake per year, science and monitoring activities can focus on information needs not addressed through routine agency programs, and specific science assessments can be coordinated. Individual Lake-wide Partnership Working Groups identify science needs according to the CSMI schedule, and the Task Team implements these recommendations, as appropriate. Annex 3 contributes science priorities to Lake-wide Partnership Working Groups for the addressing CMCs in the Great Lakes under the CSMI, including actions for PFOS, PFOA, LC-PFCAs, and their salts and precursors.

3.3 International

To reduce releases of PFOS, PFOA, LC-PFCAs, and their salts and precursors, international efforts are imperative. Due to the ubiquity, persistence, bioaccumulation, and long-range transport of these substances, Canada is also engaged in global efforts concerning these compounds.

3.3.1 The Stockholm Convention on Persistent Organic Pollutants

The objective of the United Nations Environment Programme (UNEP) Stockholm Convention on Persistent Organic Pollutants (POPs) is to protect human health and the environment from POPs by severely restricting or eliminating them. POPs are organic chemicals that have a combination of harmful characteristics: they are persistent, bioaccumulative, toxic to the environment and/or human health, and are transported long distances. The Government of Canada signed and ratified the Convention in 2001, and the Convention entered into force in 2004. The Conference of the Parties (COP) to the Stockholm Convention on POPs decided to list PFOS, its salts and perfluorooctane sulfonyl fluoride (PFOSF), as well as PFOA, its salts, and PFOA-related compounds to the Convention. Therefore, Parties need to put measures in place to restrict or eliminate the production, use, import and export of these substances.

UNEP's Stockholm Convention on Persistent Organic Pollutants POPs assesses priority chemicals in the environment in time for the annual POPs Review Committee (POPRC) meetings. POPRC is reviewing, assessing and recommending to the COP on chemical listings and changes to current listings to the Convention. The COP recently amended the acceptable purposes and exemptions in the listing of PFOS, its salts, and perfluorooctane sulfonyl fluoride (PFOSF) in Annex B (for restricted uses). In the fall of 2019 at the 15th POPRC meeting, the risk management evaluation of perfluorohexanoic acid (PFHxS), its salts and PFHxS-related compounds was adopted, and PFHxS was recommended for addition to Annex A without any exemptions; the decision is anticipated in 2022.

Article 16 of the Convention requires that effectiveness of the measures adopted by the Convention be evaluated every six years. The objective of the effectiveness evaluation is to assess whether the Stockholm Convention is an effective tool to protect human health and the environment from POPs. Canada contributed to the [2017 Effectiveness Evaluation for PFOS, its salts and PFOA](#). While uncertainties remained due to limited information and data, the effectiveness evaluation committee concluded that there has been a significant drop in the production and use of PFOS, its salts and PFOA between 2003 and 2017.

Canada plays an important role under the [Global Monitoring Plan \(GMP\) on Persistent Organic Pollutants](#), which supports the implementation of Article 16 of the Stockholm Convention on Persistent Organic Pollutants. The GMP collects comparable, harmonized, and reliable information on POP levels in core environmental matrices (air, human tissues, and water) in order to identify changes in their concentrations over time, as well as on regional and global environmental transport. Canada is a key contributor to monitoring reports.

The Arctic Council's Arctic Monitoring and Assessment Programme (AMAP) monitors and assesses the status of the Arctic region with respect to pollution and climate change issues. The AMAP supports international processes that work to reduce the global threats of contaminants, such as UNEP's Stockholm Convention on Persistent Organic Pollutants.

3.3.2 The Commission for Environmental Cooperation

Established by the North American Agreement on Environmental Cooperation, the Commission for Environmental Cooperation (CEC) is an intergovernmental organization that supports cooperation among Canada, Mexico, and the United States to address environmental issues of concern in North America. The CEC's mission is to facilitate collaboration and public participation in conservation, protection, and enhancement of the North American environment in the context of increasing economic, trade, and social links among the three countries. A target list of 31 PFAS were examined as part of CEC work relating to chemicals management. The CEC released a report in 2017 on [Furthering the Understanding of the Migration of Chemicals from Consumer Products: A Study of PFAS in Clothing, Apparel, and Children's Items](#). 137 articles of clothing and apparel were examined for the presence of 31 PFAS. The study found that the degree to which these substances can migrate out of apparel and contact the skin or saliva of the wearer, or enter the environment, can be a concern.

3.3.3 The Organisation for Economic Cooperation and Development/United Nations Environment Programme Global Perfluorinated Chemicals Group

The Organisation for Economic Cooperation and Development (OECD)/United Nations Environment Programme (UNEP) Global Perfluorinated Chemicals (PFC) Group was established in response to the International Conference on Chemicals Management, and brings together experts from OECD member and non-member countries. The Group considers the development, facilitation, and promotion of international stewardship programs and regulatory approaches to reduce emissions of PFAS in products. The group works toward global elimination, where appropriate and technically feasible. Canada participated in a Steering Group on PFCs to develop the 2006 OECD survey directed at PFC producers on their production, import, and use of PFOS, PFOA, and PFCAs. The objective of the survey was to identify

knowledge gaps and assessment needs for both long- and short-chain PFCAs and their precursors (EC, 2012b).

The OECD developed a [Portal on Per- and Polyfluorinated Chemicals](#) to facilitate information exchange on PFAS and to support the global transition towards safer alternatives. Stakeholders can share information on government activities related to regulatory and stewardship efforts, updates on scientific developments, new technologies, available alternatives, and events. In 2017, the OECD developed a new list of 4,730 PFAS (non-exhaustive) as part of a new Comprehensive Global Database on PFAS. Major sources contributing to the database includes data from Canada, the U.S., and the EU. ECCC provided input on regulatory approaches to the [OECD/UNEP Synthesis Paper on Per- and Polyfluorinated Chemicals](#). Canada was also one of 15 countries that contributed to the OECD's [Risk Reduction Approaches for PFAS – A Cross-Country Analysis](#) in 2015.

4 Gap Analysis

Globally, efforts to stop manufacturing and phase out the use of PFOS, PFOA, and LC-PFCAs have had a significant positive impact on levels being monitored in environmental and biological samples (Gewurtz et al., 2019). Due to the high environmental persistence of this class of chemicals, there is a heightened need to identify the gaps in risk management, research, and monitoring to continue to address them.

There are a number of unknowns in Canada concerning unquantified sources of PFOS, PFOA, and LC-PFCAs. A potentially large number of unreported sources may have been releasing or may have the potential to release these substances into the environment, such as abandoned/closed or illegal waste sites, sites where AFFF was used, municipal wastewater effluents, and landfill leachate. In addition, the amount currently in the market, contained in consumer products or released through storm water or wastewater, is not well known. PFOS, PFOA, and LC-PFCAs in commercial and residential products are not reported or tracked; therefore, sources may go unidentified and perpetuate their distribution in the environment.

While certain sampling of PFOS, PFOA, and LC-PFCAs in Great Lakes air, precipitation, water, sediment, fish and wildlife species occurs, routine monitoring in environmental media is needed. Current monitoring in the Great Lakes may not be sufficient to detect environmental trends, and existing monitoring should be assessed to determine its adequacy to address key gaps in understanding. Scientists do not have a complete understanding of what happens to PFOS, PFOA, and LC-PFCAs in the environment, or how these substances move through the environment (e.g. sediment to fish, water to fish, sediment/water to food to fish) and at what rate (e.g. half-lives in fish by species). Additional data is needed in the Great Lakes, on time series and scales, to develop comprehensive data sets to inform further management action to reduce concentrations in the environment. While many risk mitigation and management activities and other efforts (e.g. remediation, characterization, fate-transport modelling) for certain PFOS, PFOA, and LC-PFCAs are being established, enhanced monitoring and surveillance under federal and provincial programs are necessary to inform regulatory decisions. Additional data to gain a better understanding of mammalian, avian, and aquatic life toxicity, as well as health effects data relevant to human health is needed (ITT, 2015; IARC, 2016). Wildlife predators may be at risk from eating fish in the Great Lakes that contain PFOS in their tissues at levels that exceed the FEQG for protecting predatory mammals and birds (ECCC, 2018a).

Current chemical data collected by federal, provincial, Indigenous, and other government programs are not consistent, standardized, or structured. Working to ensure better uniformity of data would be helpful to ensure that independent data collection actions can be aggregated for more rigorous analysis and to identify remaining gaps. For example, while PFOS, PFOA, and LC-PFCAs are collected in various media (e.g. air, water, land, biota), there currently is no accessible, structured repository for such data which allows government or external stakeholders to analyze the data to determine remaining concerns. PFOS and PFOA are the most researched chemicals of this large group of chemicals that are not yet well characterized. Establishing an accessible, structured database would facilitate the collection and collaboration of various research efforts to identify chemical unknowns (such as chemical properties, fate and transport characteristics), and enhance understanding of the impact of risk management activities taken thus far.

5 Risk Mitigation and Management Actions to Address Gaps

The 16 actions highlighted herein represent both new and the continuation of current risk mitigation and management actions that are needed to address the gaps outlined, and may result in measurable human health and/or environmental benefits, or enhanced understanding of PFOS, PFOA, LC-PFCAs, and their salts and precursors sources, fate, and human health/environmental effects.

5.1 Regulations and Other Risk Mitigation and Management Actions

Canada is working collaboratively with industry, other countries, and international organizations to mitigate and manage risks of PFOS, PFOA, LC-PFCAs, and their salts and precursors in the environment and in humans through regulatory approaches. As new data are collected and become available, the risk management and mitigation measures in place for these substances should be revisited and expanded to ensure they reflect the most current scientific knowledge available. Information on monitoring and exposure data is still needed. Additional data will better inform risk management and mitigation decisions. This may entail working with Canadian provinces and territories to establish enforceable drinking water standards based on the Guidelines for Canadian Drinking Water and screening values for PFOS, PFOA, LC-PFCAs, and their salts and precursors. Inventories of known sources, including use of AFFF in fire-fighting that contains residual levels of PFOS at a maximum concentrations of 10 ppm (as currently exempted under the PCTSR) should be established.

Summary of Regulations and Other Risk Mitigation and Management Strategy Actions

- Review regulations, guidelines, and advisories in other jurisdictions, and update Canadian health advisories and guidelines to match current scientific understanding
- Amend or develop new regulatory controls in response to human health and ecological assessments and new data
- Establish inventories of known sources where possible

5.2 Compliance Promotion and Enforcement

Tracking and compliance strategies are needed to ensure that regulations, such as the *Prohibition of Certain Toxic Substances Regulations, 2012*, (PCTSR) limiting or eliminating the use of PFOS, PFOA, LC-PFCAs and their salts and precursors are effective.

ECCC undertakes outreach activities to encourage the regulated community to achieve compliance with the PCTSR by raising stakeholder awareness of the prohibition and associated requirements. Compliance promotion activities include maintaining a database of stakeholders, maintaining a page on the CEPA Environmental Registry website, providing guidance materials, and responding to inquiries from stakeholders. In addition, promotional materials (such as factsheets and web materials) are developed and distributed as required.

The PCTSR includes a limited number of exemptions. Reporting requirements are associated with certain activities that are exempt from the prohibition, such as laboratory use. Information gathered through these reports provides the Government of Canada with data on the use of toxic substances and helps in determining whether additional controls are required for these uses.

ECCC is responsible for the administration and enforcement of the PCTSR. ECCC is also responsible for the administration and enforcement of the pollution prevention provisions of the *Fisheries Act*, which prohibit the deposit of deleterious substances into water frequented by fish, as well as regulations made pursuant to these provisions. These laws and regulations are enforced in accordance with publically available [Environmental Compliance and Enforcement Policies](#). When there is evidence of a contravention, officers take enforcement measures in consideration of factors set out in these policies, including issuing warnings, environmental protection compliance orders, or directions. When it is appropriate, officers conduct investigations to collect evidence for the purposes of prosecuting in court.

ECCC is also undertaking work to evaluate the risks to environmental, biodiversity, and human health objectives that stem from non-compliance, and how it prioritizes its enforcement actions.

Summary of Compliance Promotion and Enforcement Strategy Actions

- Continue to undertake outreach activities to raise awareness of the regulations among known and potential stakeholders
- Continue to develop and distribute plain language guidance materials and factsheets on the regulations
- Continue to track reported activities allowed under specific exemptions (e.g. laboratory use)
- Continue to take enforcement measures including issuing warnings, environmental protection compliance orders, or directions; and when appropriate, collect evidence for prosecution

5.3 Pollution Prevention

PFOS, PFOA, LC-PFCAs, and their salts and precursors may be found in industrial, commercial and consumer products that enter, or have the potential to enter the Canadian environment during their processing, use, and/or disposal. Risk Management Tools are needed to manage risks associated with these potential releases.

Summary of Pollution Prevention Strategy Actions

- Research and ensure safe end-of-life management practices for products containing PFOS, PFOA, LC-PFCAs, and their salts and precursors, and communicate these results
- Enhance support to industry associations and firms who seek to phase out or improve risk management within their sector

5.4 Monitoring, Surveillance, and Research Efforts

ECCC and the U.S. EPA have coordinated efforts to publish a report outlining the monitoring efforts of State of the Great Lakes (ECCC and U.S. EPA, 2019). Additional monitoring and surveillance reports have been published in peer-reviewed journals, websites, and social media. Each form of reporting is designed to target specific audiences to maximize the application of the results. Results of future monitoring efforts should continue to be published in multiple formats to effectively communicate changes observed in the Great Lakes region, inform and implement decisions, and evaluate risk management actions. Effectiveness evaluations under the Stockholm Convention for Persistent Organic Pollutants and reporting under the GMP will also help assess measures being taken at the international level for certain PFAS listed under the Convention.

The development of innovative, cost-effective tools and approaches for monitoring, measuring, and reducing releases of PFOS, PFOA, LC-PFCAs, and their salts and precursors from various sources is needed. More efficient analysis methods should be used to better understand their spatial distribution and precursor degradation. Cost-effective treatment options for removal of PFOS, PFOA, and LC-PFCAs from water and soils are also needed, to address PFAS in wastewater effluents, biosolids, landfill leachates and at sites which have been impacted by past and/or current use of AFFF.

Summary of Monitoring, Surveillance, and Research Strategy Actions

- Continue monitoring in environmental media in the Great Lakes and publish results in a variety of publications and open access data portals
- Use monitoring and modelling to better characterize sources
- Address gaps in monitoring, toxicity, and exposure data
- Coordinate standardized analytical methods binationally to encourage data uniformity and comparability across jurisdictions
- Develop innovative, cost-effective tools and approaches for monitoring, measuring, and reducing releases from various sources

5.5 Environmental Quality Guidelines

Domestic waters include all water used for indoor and outdoor household purposes. Health Canada has established drinking water guidelines for PFOS and PFOA, and [drinking water screening values](#) for nine other PFAS, one of which is a LC-PFCA (PFNA) (**Table 6**; Government of Canada, 2019).

The CCME is prioritizing the development of tools to assist the Federal Government, Provinces and Territories with contaminated site assessment, management issues, and evaluating how to best manage priority contaminants. Canada has established FEQGs for PFOS in surface water and biota tissue, and guidelines for PFOA are under development. There are no FEQGs for LC-PFCAs. The CCME has developed [CEQGs for soil and groundwater for PFOS](#); however, there are no guidelines for PFOA and LC-PFCAs in soil and groundwater (**Table 6**). In the absence of CEQGs for other PFAS, Health Canada has established human health based interim soil screening values for ten PFAS, including PFOA and one LC-PFCA (PFNA). These screening values are for use at federal contaminated sites to determine whether concentrations detected in soils at a site may be of concern to human health.

Summary of Environmental Quality Guidelines Strategy Actions

- Establish and implement additional guidelines for surface waters for the protection of aquatic life
- Establish and implement guidelines for soil and groundwater for the protection of environmental and human health

6 Conclusions

Under Annex 3 of the Canada-United States GLWQA, PFOA, PFOS, LC-PFCAs, and their salts and precursors have been identified as CMCs that originate from anthropogenic sources. While the overall concentration of these substances in the environment has decreased since 2003, concentrations of these persistent compounds remain in soils, water, air, biota tissues, wastes, and certain in-use products throughout the Great Lakes basin and globally. Significant strides have been made in reducing sources to the environment and in monitoring environmental and biological concentrations.

While measurable advancements have been made in limiting sources and collecting monitoring and surveillance data, continued binational efforts are needed to reduce the risks that PFOS, PFOA, and LC-PFCAs may pose to human health and the environment. Continued focus is needed to decide on any further actions required to protect the environment and human health; therefore, it is recommended to continue to research animal and human toxicity, precursor degradation, analytical and treatment methodologies, potential pollution prevention actions, and outreach and education activities.

A broad audience of Canadian Great Lakes stakeholders who are committed to protecting and restoring the Great Lakes ecosystem are encouraged to implement the 16 risk mitigation and management actions outlined in this document. Continued progress in seeking novel ways and/or improving upon existing ways to mitigate and manage risks of PFOS, PFOA, and LC-PFCAs will improve the health of the ecosystem and residents of the basin, and will preserve the quality of the Great Lakes for future generations.

7 Tables

Table 1. Physical and Chemical Properties of PFOS and PFOA.

Property	PFOS (Free Acid)	PFOA (Free Acid)
Chemical Abstracts Service (CAS) Registry Number	1763-23-1	335-67-1
Chemical Formula	C ₈ HF ₁₇ O ₃ S	C ₈ HF ₁₅ O ₂
Molecular Weight (g/mol)	500	414
Melting Point (°C)	No data	54
Boiling Point (°C)	258-260	192
Water Solubility (mg/L at 25°C)	680	9.5 x 10 ³
Organic Carbon Partition Coefficient (K _{oc})	2.57	2.06
Vapor pressure (mm Hg at 25°C)	0.002	0.525

Note: Physical and chemical properties differ between anion, salt, and acid forms. The properties presented above are for the free acid form of PFOS and PFOA.

Source: U.S. EPA (2017b)

Table 2. Concentration and detection frequency of PFOS, PFOA, and select LC-PFCAs in raw and treated landfill leachate from 10 Canadian municipal solid-waste landfill sites (2009-2011).

PFAS	Pre-Treatment				Post-Treatment			
	Minimum (ng/L)	Maximum (ng/L)	Median (ng/L)	Detects (%)	Minimum (ng/L)	Maximum (ng/L)	Median (ng/L)	Detects (%)
PFOS	2.39	744	40.4 U	54	20.8	2,070	23.1	38
PFOA	50.3	2,300	500	100	42	4,750	271	92
PFNA	6.22	200	34.5	67	8.17	652	32.2	54
PFDA	7.73	466	19.8	33	25.7	2,090	9.82 U	15
PFUnA	12.8	39.5	10.4 U	6	140	140	9.82 U	8
PFDoA	N/A	N/A	10.3 U	0	48	48	9.82 U	8

U indicates not detected at the associated reporting limit.

Source: CRA (2015). Data from Appendix A.

Table 3. Median and maximum PFOS and PFOA concentrations (ng/L) in precipitation and surface water samples collected in the Great Lakes basin (2006-2018).

Chemical Substance	Descriptive Statistic	Lake	Precipitation (ng/L)	Surface Water (ng/L)
PFOS	Median	Lake Ontario	1.4	5.0
	Maximum		14	7.4
	Median	Lake Erie		2.1
	Maximum			3.9
	Median	Lake Huron	0.89	<RL
	Maximum		12	3.6
	Median	Lake Superior	<RL	<RL
	Maximum		18	<RL
PFOA	Median	All Lakes	0.93	2.1
	Maximum		14	7.4
	Median	Lake Ontario	0.59	2.32
	Maximum		4.4	4.0
	Median	Lake Erie		1.6
	Maximum			5.0
	Median	Lake Huron	0.42	<RL
	Maximum		11	1.9
	Median	Lake Superior	0.48	0.61
	Maximum		9.0	1.8
Median	All Lakes	0.46	1.5	
Maximum		11	5.0	

<RL indicates that the median and/or the maximum values are below the reporting limit.

Source: Gewurtz et al. (2019). Data from Table S13 (supplementary information).

Table 4. Comparison of Ontario Drinking Water 2012 Results to 2005-2006 Results.

Compound	Sample Type	% Detection		Detection Limit (ng/L)	Maximum (ng/L)	
		2006	2012	2006 & 2012	2006	2012
PFNA	Raw	31	29	0.5	1.1	0.9
	Treated	24	24		1.0	0.8
PFOA	Raw	88	71	0.5	6.0	4.5
	Treated	71	74		6.0	4.6
PFOS	Raw	81	53	0.5	6.5	4.2
	Treated	76	44		6.4	3.6

Note: In 2005/2006, 33 samples (16 untreated source water and 17 finished drinking water) were collected at 8 drinking water systems in Ontario. In 2012, 113 samples (59 untreated, 54 finished) were taken from 17 drinking water systems.

Source: Ontario MECP, unpublished data.

Table 5. Maximum concentration of various PFAS compounds in edible portions of Great Lakes fish observed in Ontario fish monitoring

PFAS	Maximum Concentration (ng/g)
PFBA	1
PFBS	2
PFDA	13
PFDOA	6.9
PFDS	5.8
PFHPA	2
PFHXA	1
PFHXS	2
PFNA	7.8
PFOA	1.9
PFOS	68
PFOSA	6.9
PFPEA	1
PFTEA	3.8
PFTRA	7.6
PFUNA	13

Source: Ontario MECP, unpublished data.

Table 6. Canadian Guidelines for PFOS and PFOA in Environmental Media

Media	Guideline	Unit	Guideline Value	
			PFOS	PFOA
Drinking water	Maximum Acceptable Concentration (MAC) [†] Health Canada (2018)	µg/L	0.6	0.2
Surface water	Federal Environmental Quality Guideline (FEQG) ECCC (2018)	µg/L	6.8	--
Fish tissue	FEQG ECCC (2018)	mg/kg ww [*]	9.4	--
Wildlife diet (Mammalian)	FEQG ECCC (2018)	µg/kg ww food ^{**}	4.6	--
Wildlife diet (Avian)	FEQG ECCC (2018)	µg/kg ww food	8.2	--
Bird egg	FEQG ECCC (2018)	µg/g ww	1.9	--
Soil [†]	Human Health Soil Screening Value Health Canada (2019)	mg/kg		0.7
Soil [†]	Canadian Environmental Quality Guideline (CEQG) Canadian Council for Ministers for the Environment (CCME; 2021)	mg/kg dw ^{***}	0.01	--
Groundwater	CEQG CCME (2021)	mg/L	0.0006	--

[†]As the toxicological effects of PFOA and PFOS are considered to be additive, a hazard index approach should be applied such that the sum of the ratios of the detected concentrations to the corresponding guideline for PFOS and PFOA should not exceed 1.

$$\text{Hazard Index} = \frac{[\text{PFOS}]}{\text{Guideline}_{\text{PFOS}}} + \frac{[\text{PFOA}]}{\text{Guideline}_{\text{PFOA}}} \leq 1$$

*ww = wet weight

**The wildlife diet guidelines are intended to protect either mammalian or avian species that consume aquatic biota. It is the concentration of PFOS in the aquatic biota food item, expressed on whole body, wet weight basis that could be eaten by terrestrial or semi-aquatic mammalian or avian wildlife.

***dw = dry weight

Table 7. Cooperative Science and Monitoring Initiative Rotational Cycle.

Great Lake	Focus Year
Huron	2002, 2007, 2012, 2017
Ontario	2003, 2008, 2013, 2018
Erie	2004, 2009, 2014, 2019
Michigan	2005, 2010, 2015, 2020*
Superior	2006, 2011, 2016, 2021

* delayed to 2021 due to Covid-19 pandemic

8 Figures

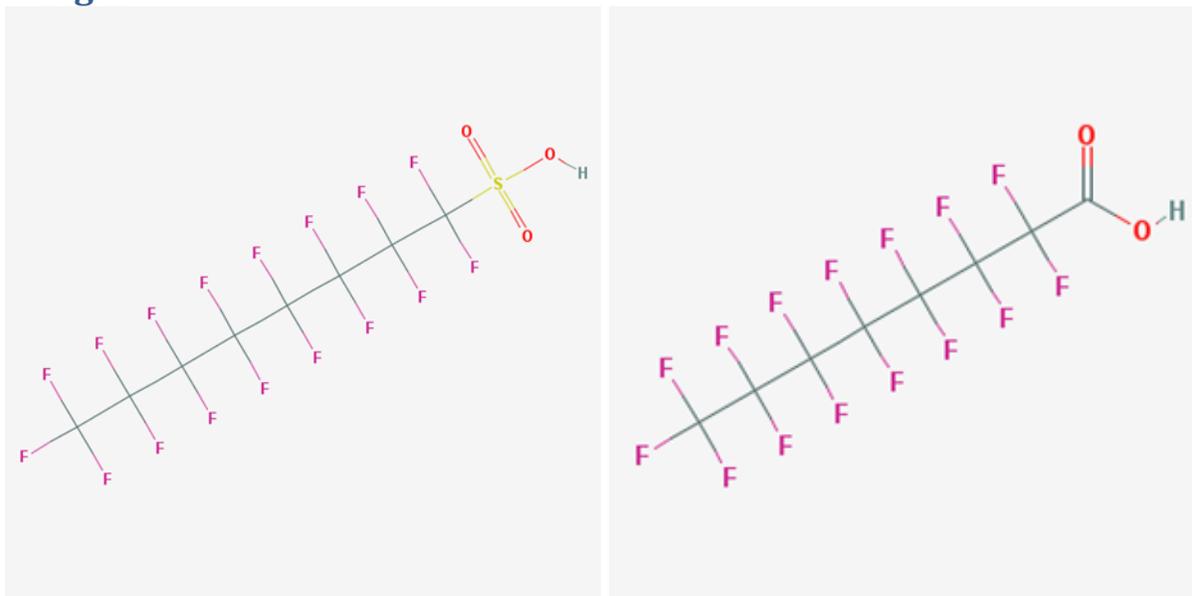


Figure 1. Structures of PFOS (left) and PFOA (right). Source: NCBI (2017)

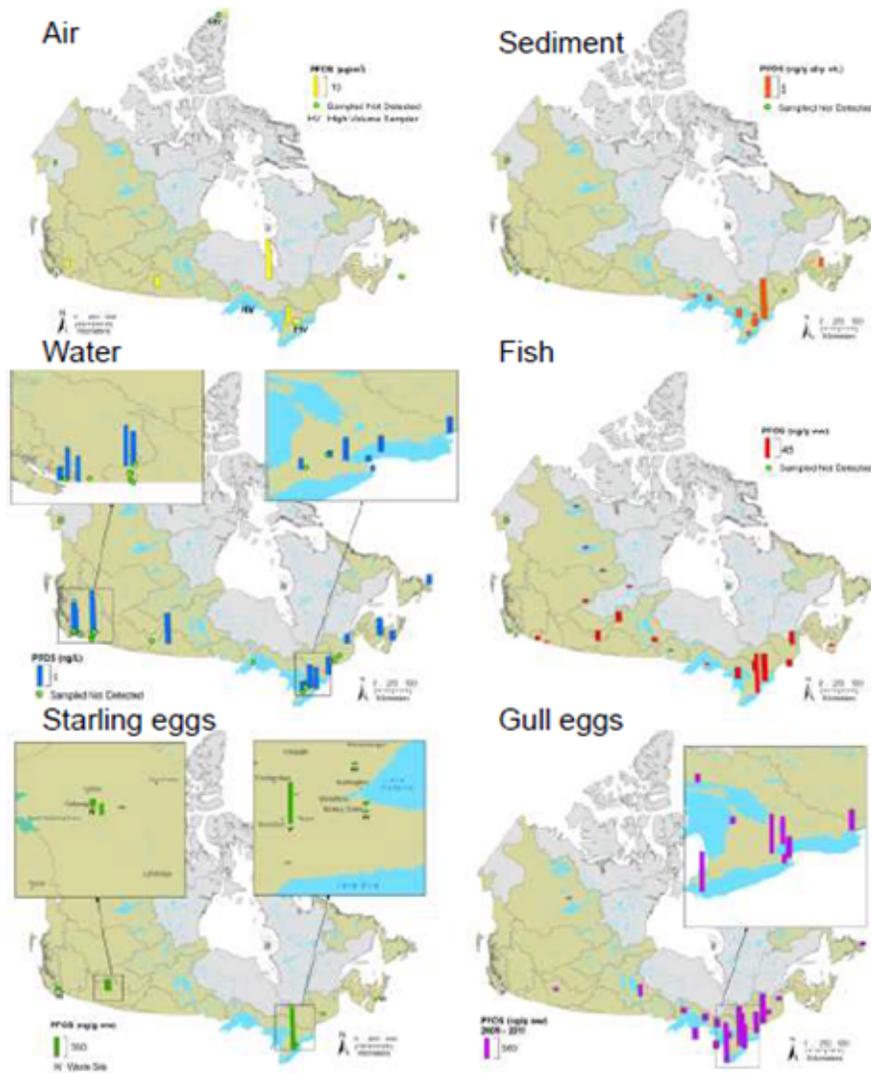
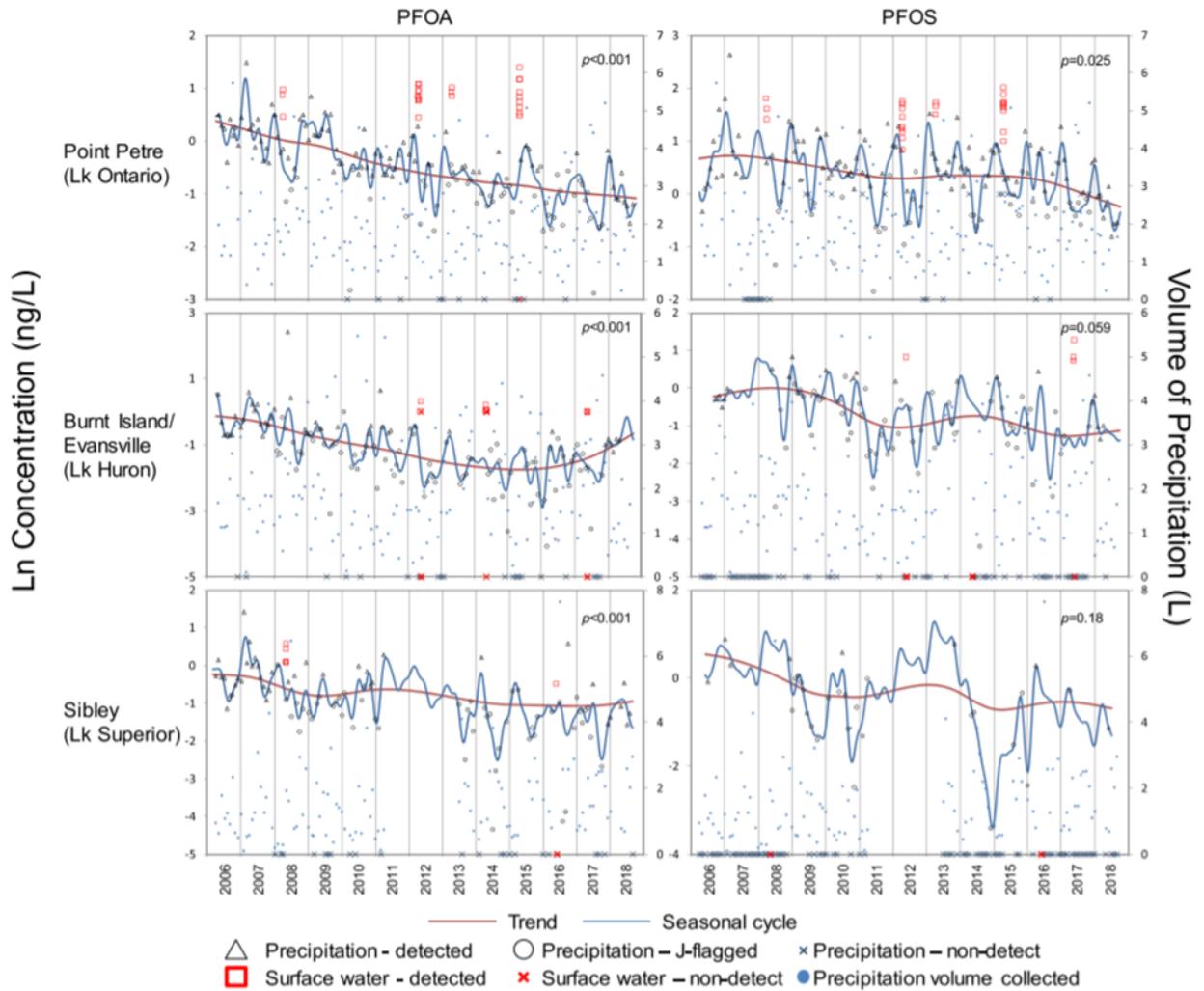


Figure 2. PFOS concentrations in air, sediment, water, fish, and wildlife (European Starling and Herring Gull eggs) across Canada, 2006-2011 (EC, 2013).
 For air, PFOS concentrations are either for passive or high-volume samplers, collected in 2009. Other collections: sediment samples (2008); water samples (2007-2010); fish samples (2006-2010); starling eggs collected as pooled samples (2009), sites denoted with a W were collected from waste sites (i.e., landfills); gull eggs collected as pooled samples (2009-2011), the spatial trends for individual gull samples collected in 2008 are similar and not shown. The green circles represent sites where PFOS concentrations were not detected. Where there was more than one data point available for a given media/location, the average (geometric mean) value was plotted on the maps.

Figure 3. Time trends of PFOA and PFOS in precipitation and surface water collected from three locations in the Great Lakes basin. **Source:** Gewurtz et al. (2019).



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