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Canadian Environmental Quality Guidelines for Perfluorooctane Sulfonate (PFOS) to Protect Environmental and Human Health

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Outline

- Context
- Status
- Guideline Derivation and Values
- Monitoring Results
- Next Steps

Context for developing Canadian environmental quality guidelines for PFOS

- Assessment
- Contaminated Sites Management
- Risk Management
- Monitoring
- International- Great Lakes

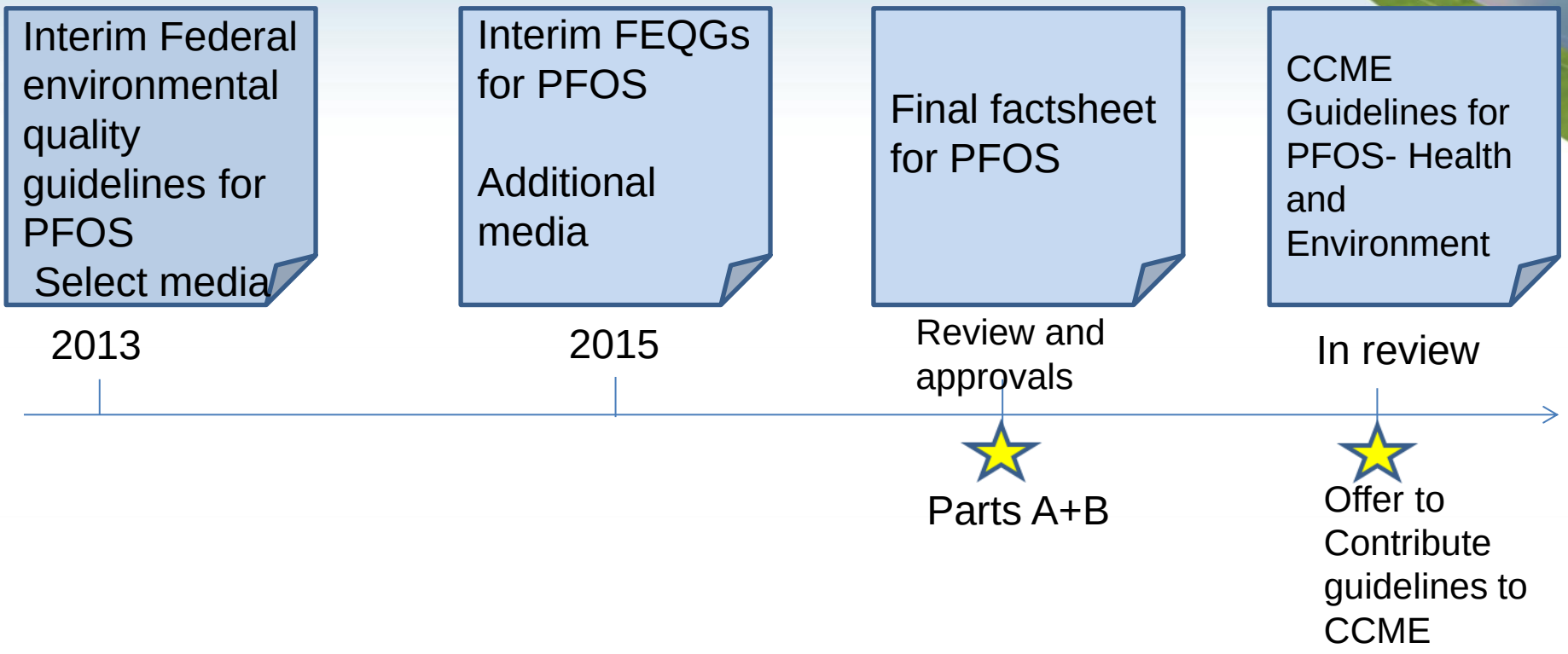
Summary of Current Risk Management Activities for PFOS

- PFOS added to the *Prohibition of Certain Toxic Substances Regulations in 2016* (Prohibition Regulations), with a limited number of exemptions.
- Previous *Perfluorooctane Sulfonate and its Salts and Certain Other Compounds Regulations (2008)* repealed.
- Prohibition Regulations prohibit the manufacture, use, sale, offer for sale and import of toxic substances and products containing them, with a limited number of exemptions.
- Other PFASs substances are also prohibited under Prohibition Regulations: PFOA, LC-PFCAs, 4 fluorotelomer-based substances
- For more information on the Prohibition Regulations,
  - Please visit: http://ec.gc.ca/lcpe-cepa/eng/regulations/DetailReg.cfm?intReg=207
  - Email: ec.interdiction-prohibition.ec@canada.ca

What are Environmental Quality Guidelines?

- Benchmarks used to assess the quality of the ambient environment
- Toxicologically-based
- Below EQG low likelihood of adverse effects of the protected use (e.g. aquatic life)
- Voluntary
- Useful for evaluating monitoring results and risk management

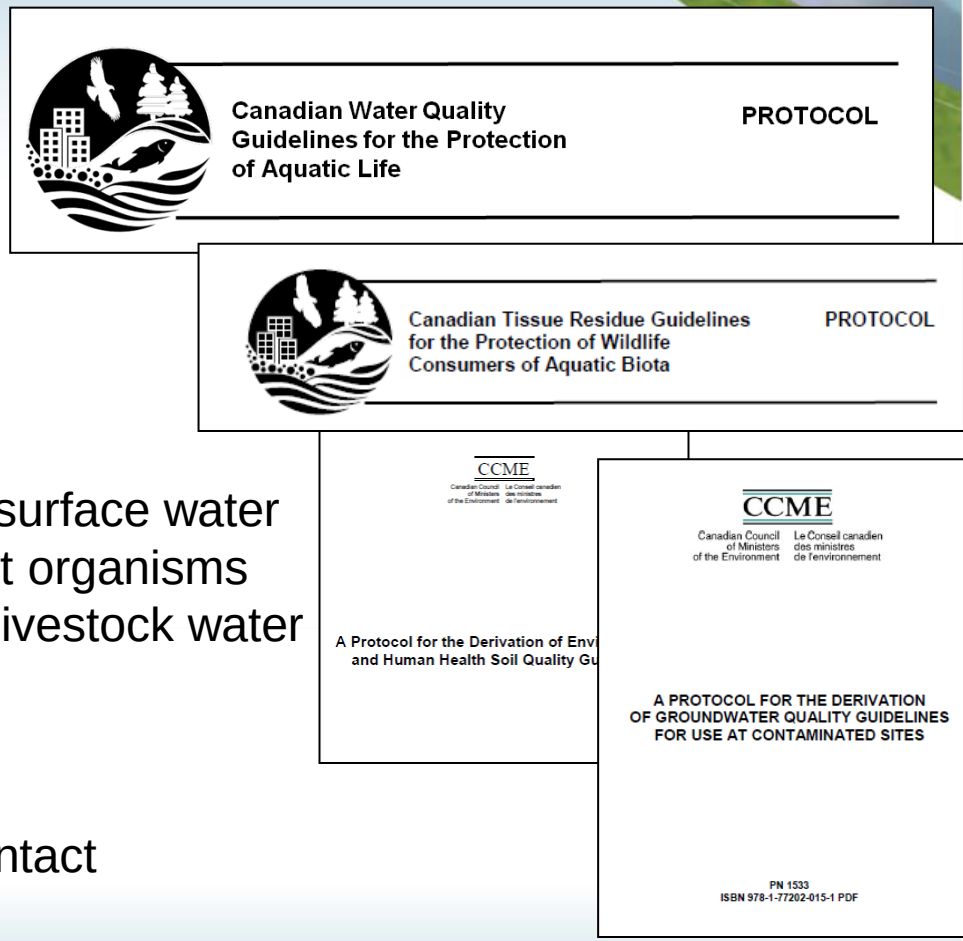
Timeline of PFOS Guideline Publication



Suite of PFOS Environmental Quality Guidelines Developed for:

Ecological

- Water
- Fish tissue
- Wildlife diet- mammals and birds
- Bird egg
- Soil contact- 4 land uses
- Soil- protect food web
- Soil- protect groundwater
- Groundwater to protect aquatic life in surface water
- Groundwater to protect soil-dependent organisms
- Groundwater to protect irrigation and livestock water
- Off-site migration



Human Health

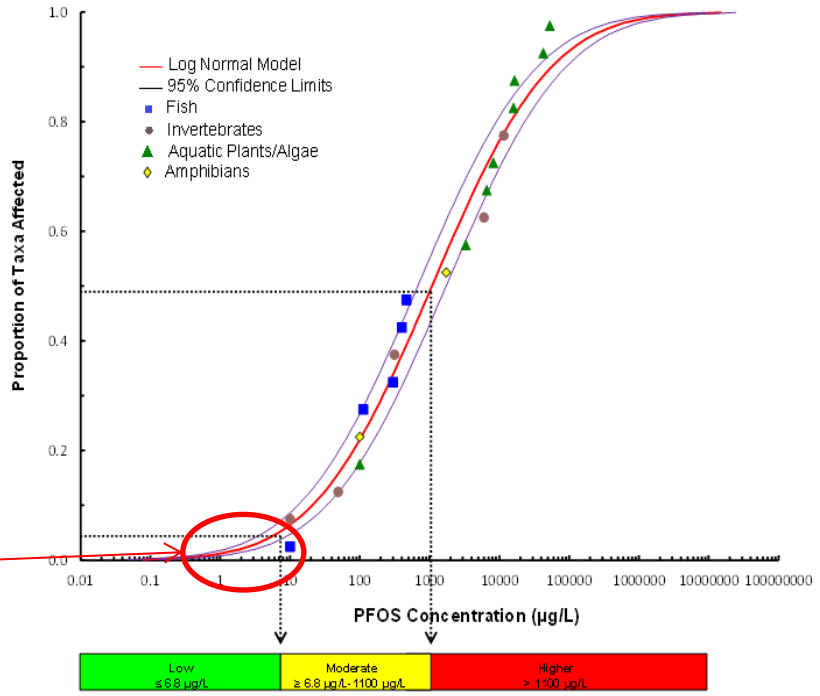
- Soil- to protect humans from direct contact
- Off-site migration

Derivation Methods

1) Water- Concentration in water with purpose to protect all forms of aquatic life for indefinite exposure

- Species sensitivity distribution
- No and low effect endpoints
- Chronic toxicity studies
- n = 20
- 5 fish
- 5 aquatic invertebrates
- 8 aquatic plants
- 2 amphibians

Hazard concentration (HC_5) = 6.8 µg/L (6800 ng/L)



Derivation Methods

2) Fish tissue - is concentration in fish tissue to protect fish themselves from direct adverse effects of bioaccumulative contaminants

= water guideline x bioaccumulation factor in fish
= 8.3 mg/kg wet weight

3) Wildlife diet- is concentration in diet to protect mammals and birds that eat aquatic biota

Tolerable daily intake ÷ (food intake: body weight)

Mammalian
= 1.1 µg/kg bw.d (rat) / 0.24 kg food/kg bw.d (mink)
= 4.6 µg/kg food

Avian
= 7.7 µg/kg bw.d (Northern bobwhite)/ 0.94 kg food/kg bw.d (Wilson's storm petrel)
= 8.2 µg/kg food

Derivation Methods

4) **Bird egg- is concentration in bird egg to protect birds themselves**

Data for 4 avian species

Lowest observed adverse effect level ÷ uncertainty factor

= 62 µg/mL yolk ÷ 10 and adjusted for % yolk in total egg

= 6.2 µg/mL yolk x 0.3

= 1.9 µg/ g whole egg

Interim Federal Environmental Quality Guidelines for PFOS

Water	Fish Tissue	Wildlife Diet		Bird Egg
		Mammalian	Avian	
6.8 µg/L (6800 ng/L)	8.3 mg/kg ww	4.6 µg/kg ww food	8.2 µg/kg ww food	1.9 µg/g ww

Ecological and Human Health Soil Quality Guidelines for PFOS (mg/kg)

	Land Use			
	Agricultural	**Residential/ Parkland**	**Commercial**	**Industrial**
Final Guideline	0.01	0.01	0.14	0.14
Human health guidelines/check values				
SSV_{HH}[b]	2.1	2.1	3.2	30.5
Direct contact guideline[d]	2.1	2.1	3.2	39.4
Inhalation of indoor air check[e]	NC	NC	NC	NC
Off-site migration check	—	—	30.5	30.5
Groundwater check (drinking water)[f]	NC	NC	NC	NC
Produce, meat, and milk check	NC	NC	—	—
Environmental health guidelines/check values				
SSV_E[c]	0.01	0.01	0.14[g], 0.21[h]	0.14[g], 0.21[h]
Soil contact guideline	11	11	61	61
Soil and food ingestion guideline	0.01	0.01	—	
Nutrient and energy cycling check	NC	NC	NC	NC
Off-site migration check	—	—	0.2	0.2
Groundwater: Livestock watering and irrigation water guideline	12[g], 9[h]	—	—	
Groundwater check (aquatic life)	0.14[g], 0.21[h]	0.14[g], 0.21[h]	0.14[g], 0.21[h]	0.14[h], 0.21[h]

Interim Federal Groundwater Quality Guidelines for PFOS

	Soil Type	
	Coarse	**Fine**
Final Groundwater Guideline ($FGWQG_F$)[1]	**6.8 µg/L**	**6.8 µg/L**
Groundwater Contact ($FGWQG_{GC}$) by soil-dependent organisms	2 mg/L	2 mg/L
Protection of freshwater life ($FGWQG_{FL}$)[2]	6.8 µg/L	6.8 µg/L
Protection of marine life ($FGWQG_{ML}$)	NC	NC
Protection of livestock watering ($FGWQG_{LW}$)	NC	NC
Protection of irrigation water ($FGWQG_{IR}$)	NC	NC
Management considerations ($FGWQG_M$)- solubility	370 mg/L	370 mg/L

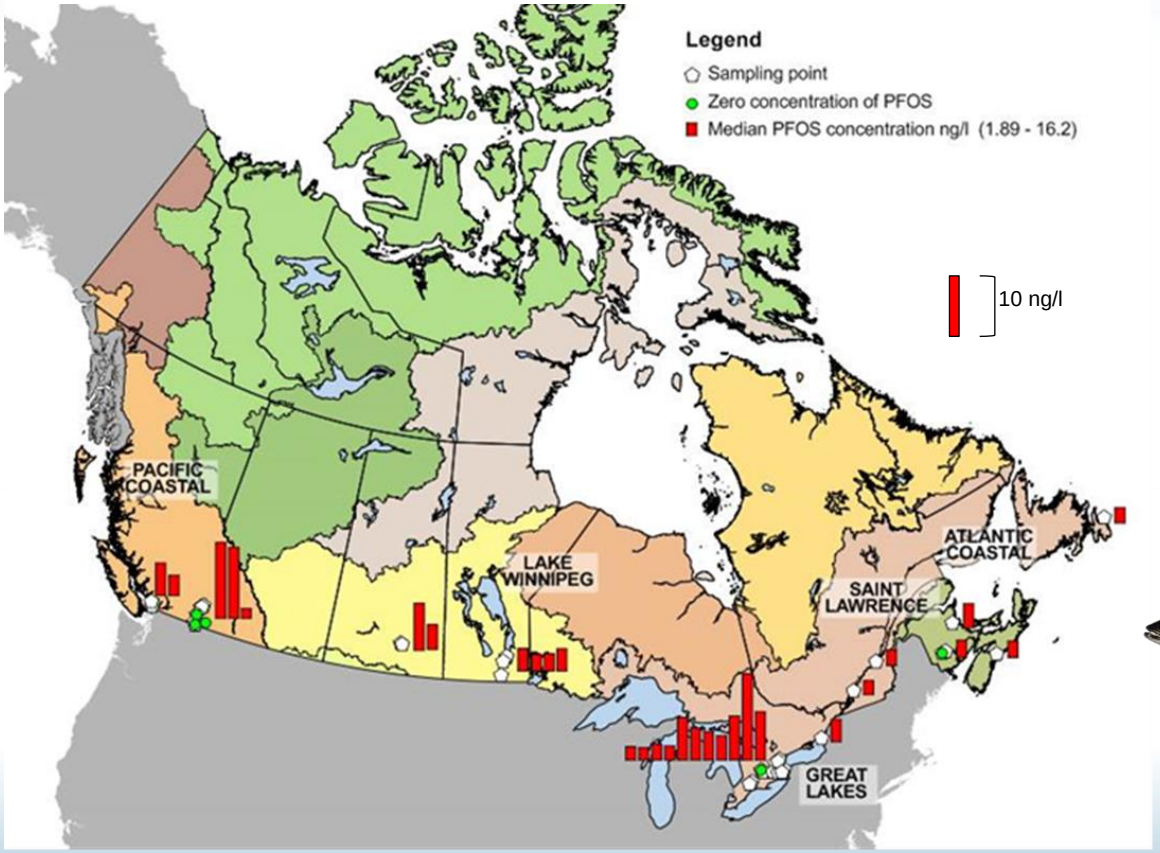
[1]The federal groundwater quality guideline-final ($FGQG_F$) is the lowest of the pathway–specific guidelines and considers other management factors such as substance solubility, analytical detection limits and background concentrations.

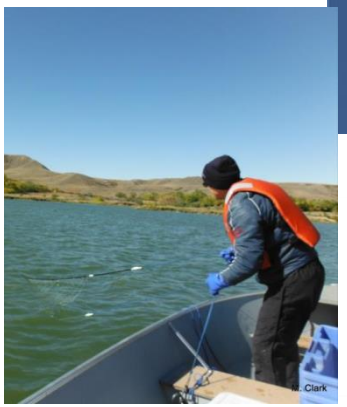
[2] $FGWQG_{FL}$ is the concentration in groundwater that is expected to protect against potential impacts on freshwater life from PFOS originating in soil that may enter groundwater and subsequently discharge to a surface water body. This pathway may be applicable under any land use category, where a surface water body sustaining aquatic life is present (i.e., within 10 kilometres of the site). Where the distance to the nearest surface water body is greater than 10 kilometres, application of the pathway should be evaluated on a case-by-case basis by considering the site-specific conditions.
NC = not calculated.

PFOS Monitoring in the Canadian Environment

PFOS Monitoring

PFOS Concentrations in Surface Water 2012 to 2016





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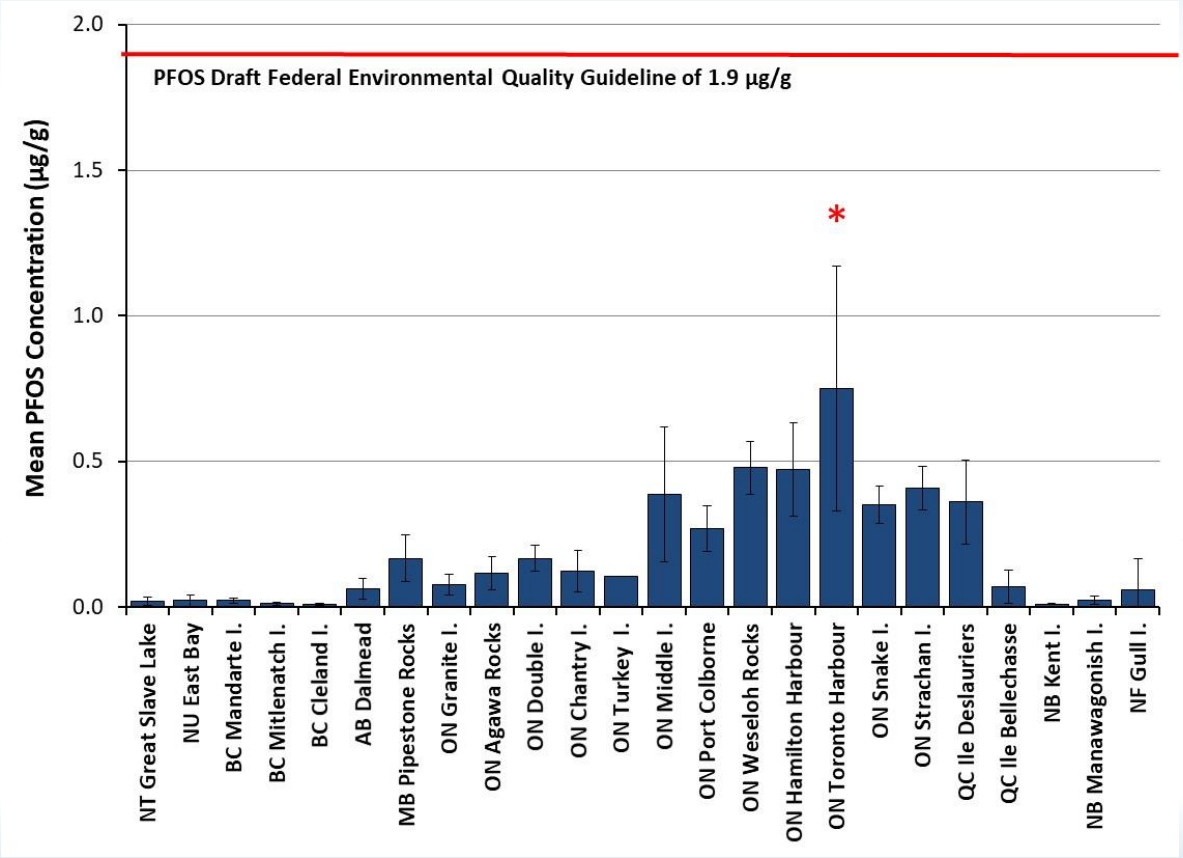
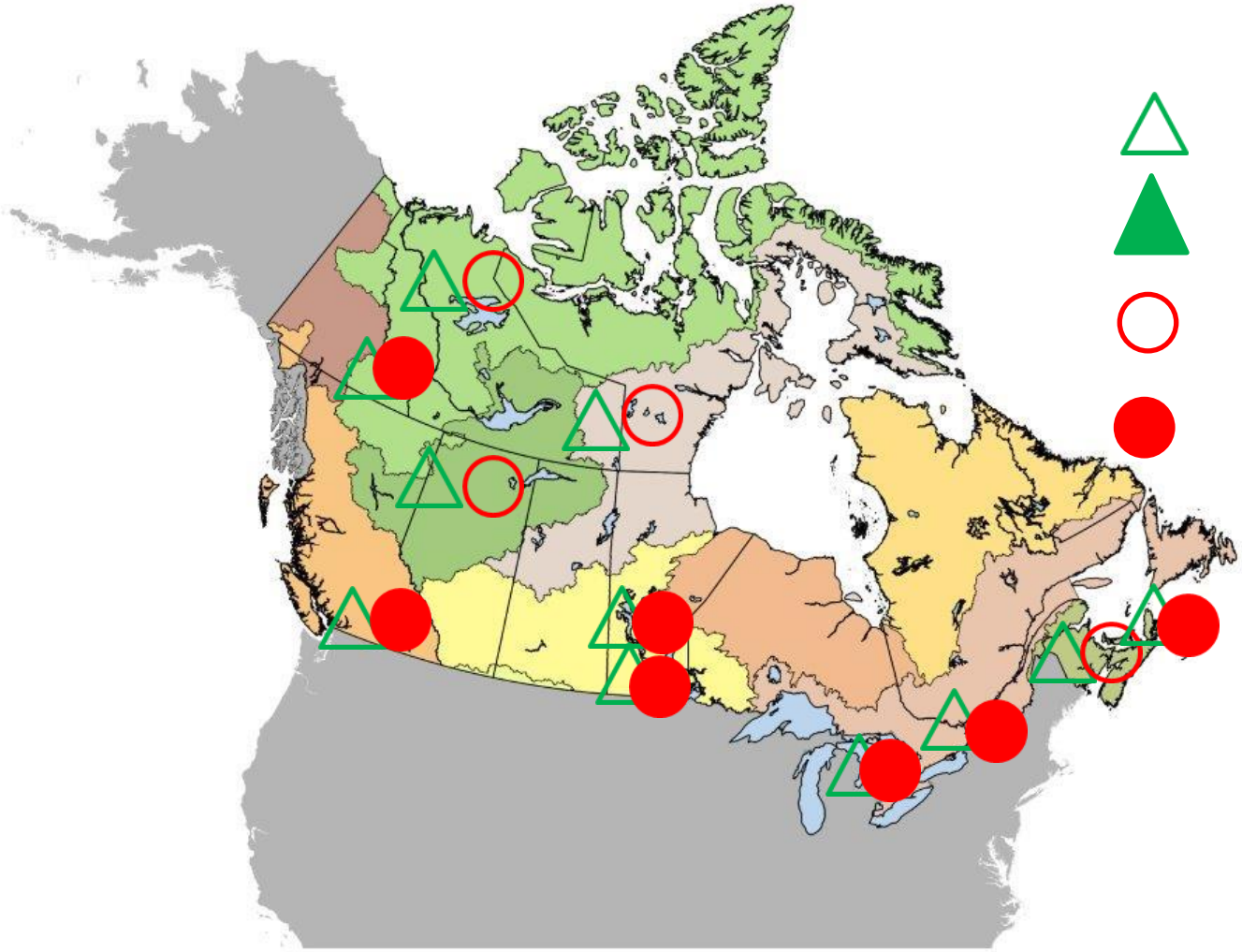
PFOS in Gull eggs across Canada 2008-2014



Gewurtz *et al.* 2016 *Sci. Total Environ.* 565: 440-450

PFOS in fish by Drainage Region (2011-14)



= no exceedance for fish health

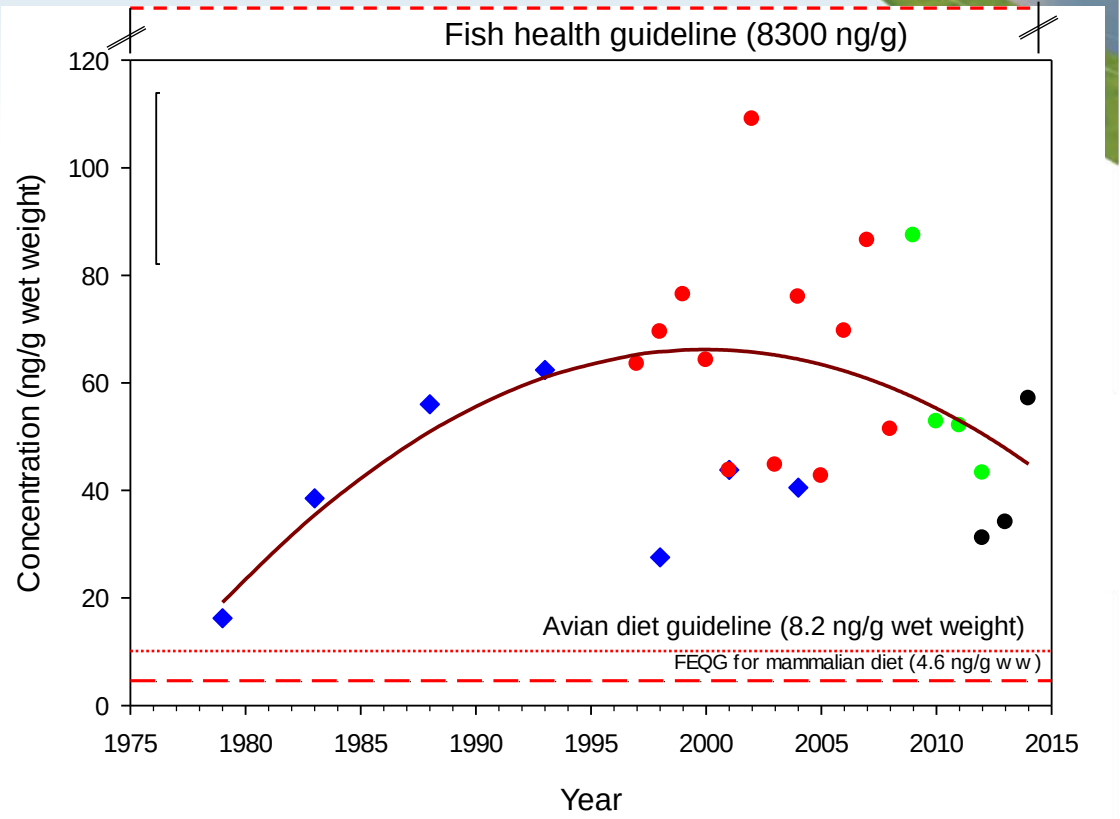
= exceedance for fish health

= no exceedance for fish as wildlife food

= exceedance for fish as wildlife food

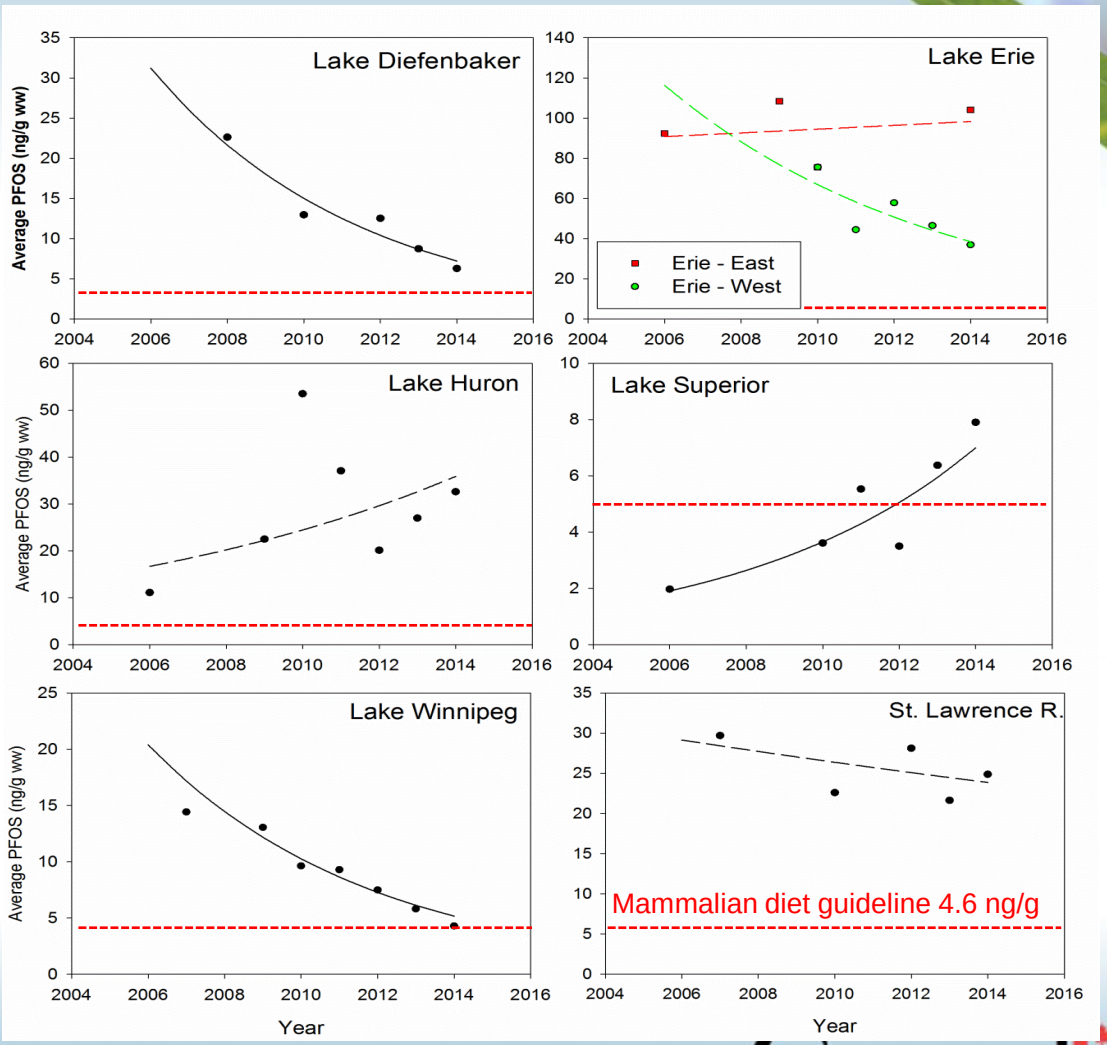
PFOS in lake trout: Trend in Lake Ontario

- Combined recent data and published literature data
- Concentrations in fish appear to have stabilized
- Slope of fitted model changes from positive to negative in 2002 – which coincides with the year 3M phased out production of PFOS



Trend 2006-2014 for PFOS in Fish in Great Lakes

- Significant decreases in western lakes Diefenbaker (SK) and Lake Winnipeg (Manitoba)
- No change in some Great Lakes
- Increasing in some Great Lakes (Lake Huron and eastern Lake Erie) that also had the highest concentrations.



Next Steps

- Publish the federal and CCME environmental quality guidelines
- Continue risk management actions
- Continue monitoring PFOS in the environment
- Develop environmental quality guidelines for Perfluorooctanoic acid (PFOA)- new ecotox data underway

Thank you

Useful contacts

Federal Environmental Quality Guidelines

https://www.canada.ca/en/health-canada/services/chemical-substances/fact-sheets/federal-environmental-quality-guidelines.html#a6

PFOS Monitoring Factsheet
www.ec.gc.ca/toxiques-toxics/default.asp?lang=En&n=7331A46C-1

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Additional slides

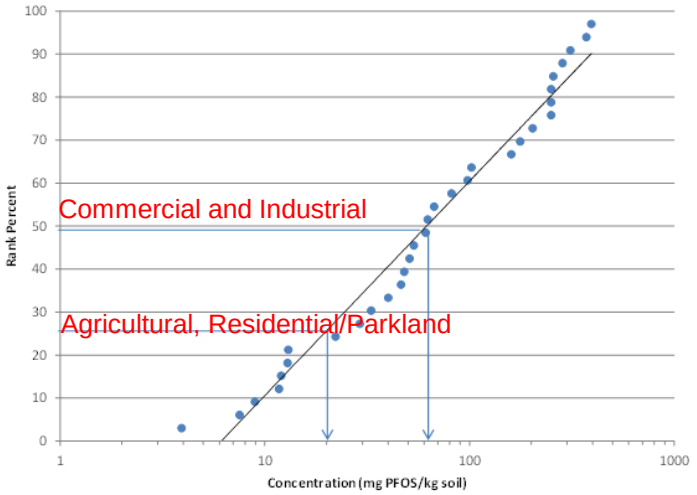
Soil Guidelines Derivation Method

5) Soil Contact –protocol for contaminated sites guidelines (level of protection is different than for ambient environment)

- 4 land uses (agricultural, residential/parkland, commercial, industrial land uses)
- Low effect concentration (EC_{25})
- 8 plant species
- 3 invertebrate species
- n = 32 endpoints

Agricultural and Residential/Parkland
= 25th percentile ÷ uncertainty factor
= 22.1 ÷ 2
= 11 mg/kg soil

Commercial and Industrial
= 50th percentile
= 61 mg/kg soil



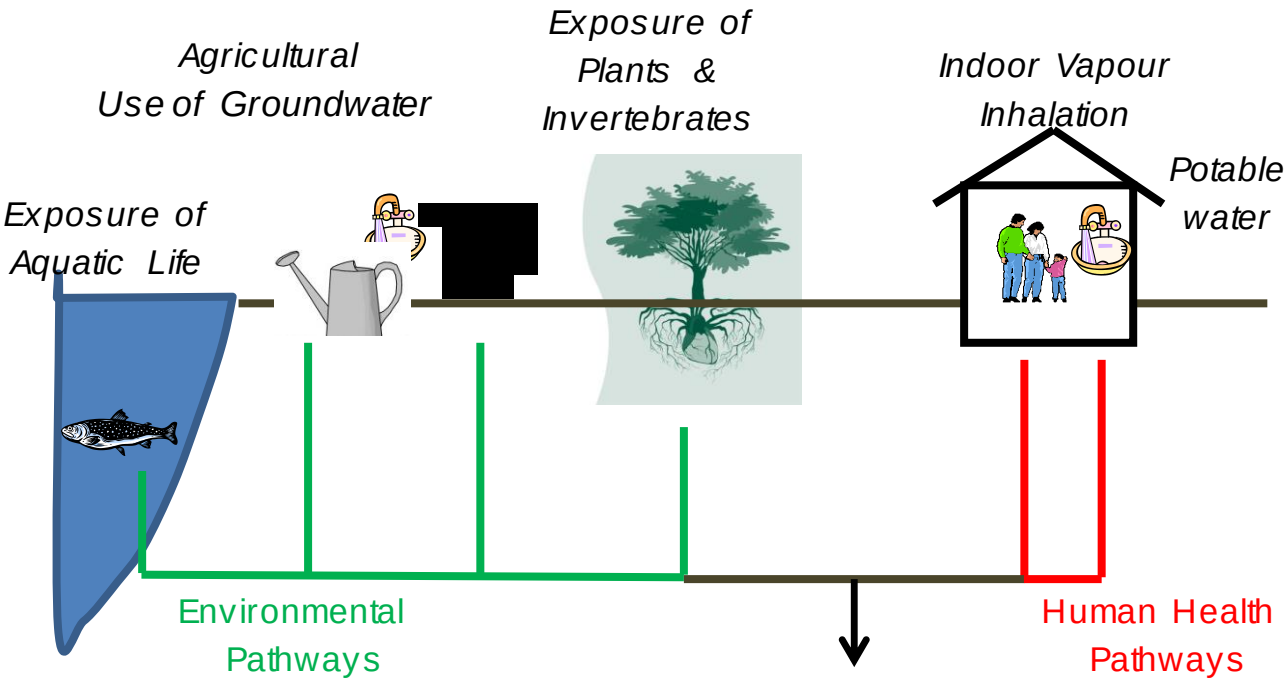
Soil- Terrestrial Food Web

Because PFOS is bioaccumulative, it triggered calculation of concentration in soil which would protect the terrestrial food chain

We looked at

- 3 trophic levels
- Animals and birds (voles, rock dove, shrew, mouse, robin, wolf and fox)
- Critical effect, total daily intake, body weight, soil ingestion, food ingestion and bioaccumulation factors

Groundwater Guideline Derivation



Lowest of the guidelines protects both environmental and human health

Final Groundwater Quality Guidelin

Human Health Soil Quality Guidelines

- Toxicolological reference values examined effects in animal model acute, subchronic and chronic studies, in vitro assays and epidemiological studies.
- Critical effect was liver cell hypertrophy in rats (0.00006 mg/kg bw/d).
- Designated critical human receptor for each land use
  - Toddler (agricultural, residential/park land)
  - Adult (commercial and industrial lands)
- Guideline = toxicity effect/ exposure

Human Health Guidelines

PFOS and PFOA

- Health effects of PFOS and Perfluorooctanoic acid (PFOA) are similar and affect the same organ in similar ways.
- Additive approach is recommended

$$\frac{[PFOS]_{medium}}{\text{Guideline PFOS}_{medium}} + \frac{[PFOA]_{medium}}{\text{Guideline PFOA}_{medium}} \leq 1$$

- If the result is below or equal to the chosen risk level (often 1), then the soil is considered acceptable for its land use.
- Currently not enough scientific justification to use additive approach for other PFAS.

Protect Soil-Groundwater-Surface Water

The soil concentration that would be protective of the aquatic life guideline:

$$CSQG_{FL} = C_W \times DF_1 \times DF_2 \times DF_3 \times DF_4 \text{ (See Figure 2)}$$

Where:

C_w = allowable chemical concentration in water at receptor (mg/L) (*i.e.* drinking water guideline, source guidance value for groundwater, guideline for protection of freshwater aquatic life, irrigation water guideline, livestock watering guideline as appropriate)

$$DF_1 = K_d + \frac{[\text{water filled porosity} + \text{air filled porosity} \times \text{Henry's law constant})]}{\text{Soil bulk density}}$$

DF_2 = 1 (assumes contamination extends right to the saturated zone)

$$DF_3 = 1 + \frac{\text{thickness of mixing zone} \times \text{saturated zone hydraulic conductivity} \times \text{saturated zone hydraulic gradient}}{\text{infiltration rate} \times \text{length of source parllel to groundwater}}$$

$$DF_4 = \frac{1}{0.25 \times \text{expF} \times \text{erfcD} \times (\text{erfB} - \text{erfC})}$$

$$= \frac{1}{0.25 \times (\text{dispersivity} \times \text{distance, dispersivity, time since release}) \times [(\text{distance, plume width, dispersivity}) - (\text{plume dimension, dispersivity})]}$$

$$= 1.0005$$

Typical values for Physiological Parameters and Intakes of Air, Water, Soil and Dust used in the Calculation of the EDIs for the Canadian General Population used to Calculate PFOS Human Health Soil Guideline

Receptor Characteristic	Breast fed Infant (0-6 m.)	Non-Breast fed Infant (0-6 m.)	Toddler (7 m.-4 yr)	Child (5-11 yr)	Teen (12-19 yr)	Adult (20+ yr)
Body weight[1] (kg)	8.2	8.2	16.5	32.9	59.7	70.7
Inhalation Rate[1,2] (m^3/d)	2.2	2.2	8.3	14.5	15.6	16.6
Water Ingestion Rate[1] (L/d)	0.3	0.3	0.6	0.8	1.0	1.5
Soil Ingestion Rate[1] (g/d)	0.02	0.02	0.08	0.02	0.02	0.02
Indoor Dust Ingestion Rate[3] (g/d)	0.036	0.036	0.041	0.032	0.0022	0.0026
Skin Surface Area[1] (cm^2)						
Hands	320	320	430	590	800	890
Arms	550	550	890	1480	2230	2510
Legs	910	910	1690	3070	4970	5720
Soil Loading to Exposed Skin[1] (kg/cm^2/event)						
Hands	1.0×10^{-7}	1.0×10^{-7}	1.0×10^{-7}	1.0×10^{-7}	1.0×10^{-7}	1.0×10^{-7}
Surfaces other than hands (arms, legs)	1.0×10^{-8}	1.0×10^{-8}	1.0×10^{-8}	1.0×10^{-8}	1.0×10^{-8}	8.0×10^{-8}

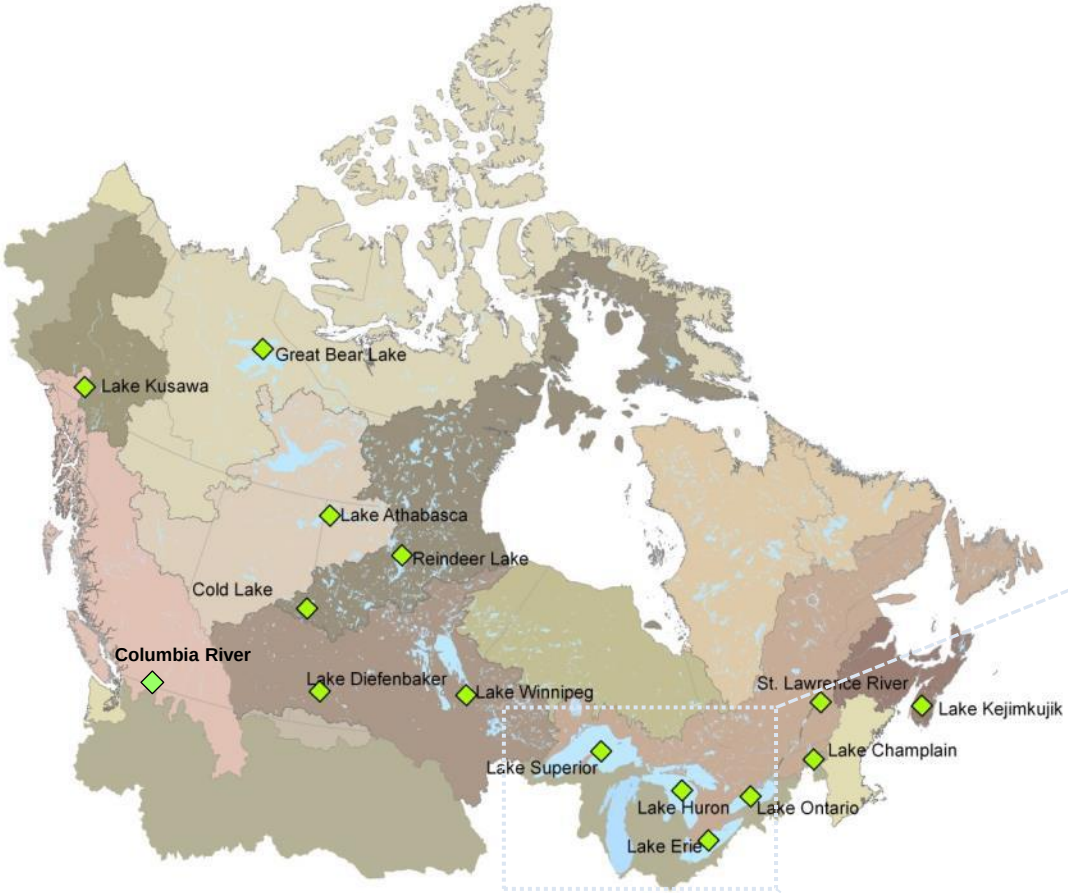
Notes:

[1] Based on Allan *et al.* (2008) inhalation rate and 7.6x10-10 concentration of airborne suspended soil particles

[2] The time spent outdoors is assumed to be 1.5 h/day for all age groups. Time spent outdoors by infant, toddler or child is assumed to be equivalent to that of an adult if child or infant is assumed to be accompanied by an adult.

[3] Wilson *et al*. (2012)

Chemicals Management Plan
Fish Monitoring Network in Canada



Water

- 22 sampling stations
- 13 rivers and lakes
- 9 drainage basins

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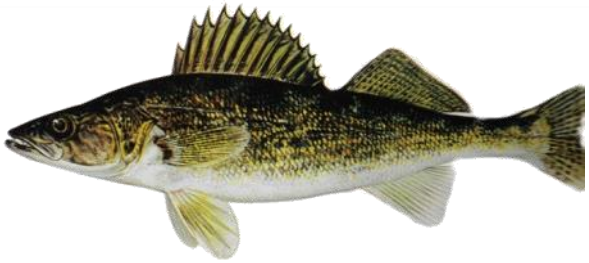
Fish Monitoring Species- Lake Trout and Walleye

- Top pelagic predators
- Well studied
- High lipid content
- Accumulate elevated contaminant levels relative to their environment and prey
- Wide ranging and long lived
  - spatial and temporal integrators of contamination
- Occur across the monitoring network (with some exceptions)

Lake Trout
(Salvelinus namaycush)



Walleye (*Sander vitreus*)

PFOS in fish by Drainage Region (2011-14)

	Tissue	As Diet item		
Drainage Region	Are concentrations above the draft FEQGs with respect to fish health?	Are concentrations above draft FEQGs with respect to fish as diet for mammalian predators?	Average value	Maximum value
Columbia	No	Yes	2	11
Yukon	No	Yes	1	7
Peace-Athabasca	No	No		
Lower Mackenzie	No	No		
Assiniboine-Red	No	Yes	11	23
Winnipeg	No	Yes	7	18
Churchill	No	No		
Great Lakes	No	Yes	29	141
St. Lawrence	No	Yes		
Saint John River	No	No		
Maritime Coastal	No	Yes	2	8

Fish Health FEQG = 8300 ng/g ww; Mammalian Diet FEQG = 4.6 ng/g ww

Aquatic & Terrestrial Avian Sentinels

24 sites 3 eggs/egg pool

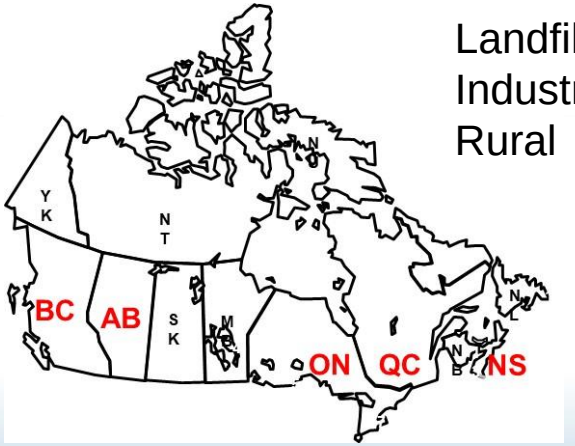
Herring Gull
(*Larus argentatus*)

Glaucous-winged Gull
(Larus glaucescens)

California Gull
(*Larus californicus)*

22 sites 10 eggs/egg pool

European Starling (*Sturnus vulgaris*)



Canadian Environmental Sustainability Index/Federal Sustainable Development Strategy Indicator: PFOS in Fish

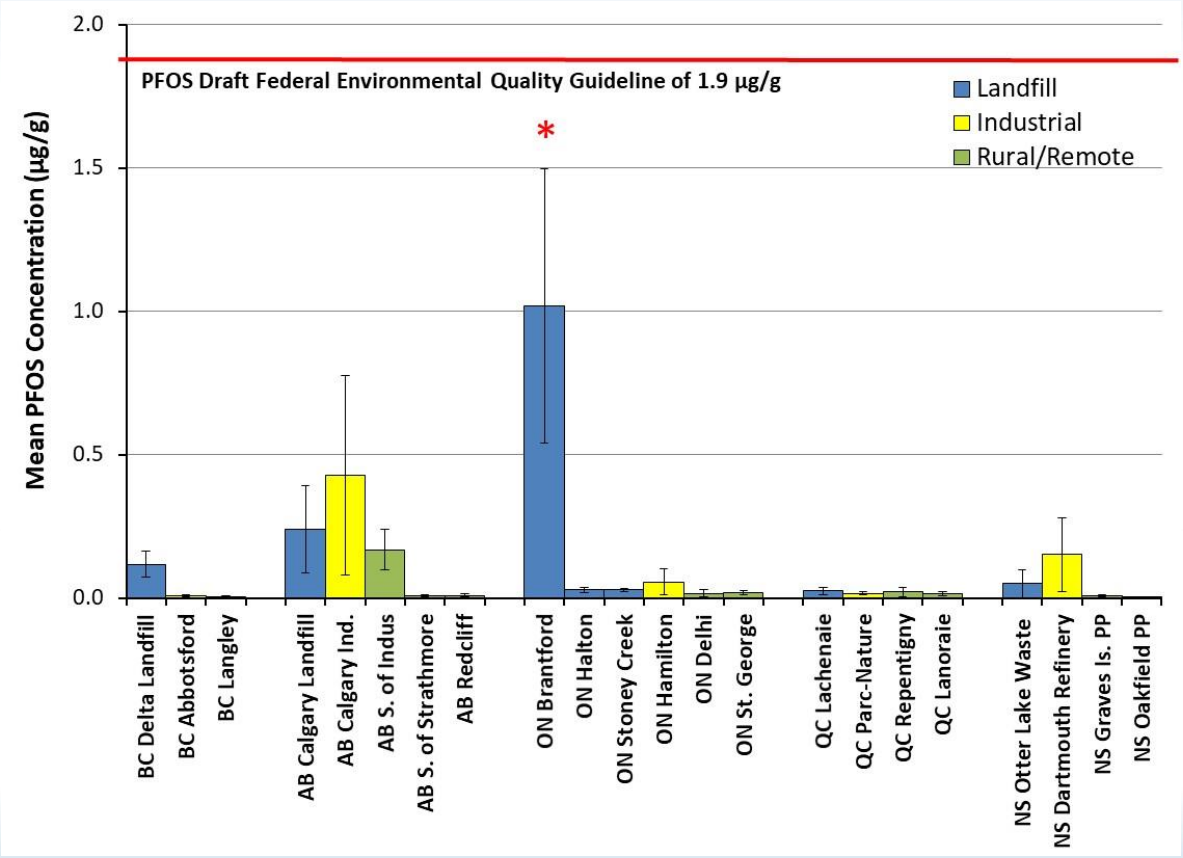
- Indicator has 2 components:

  Space and time = Exceedance of guideline by drainage region and trend over time

Federal Environmental Quality Guidelines

	PFOS (ng/g ww)
Fish Tissue	8,300
Avian Diet	8.2
Mammalian Diet	4.6

PFOS Monitoring-Starlings 2009-2014



- Of 416 egg pools analyzed between 2009-2014, one egg pool from Brantford landfill in 2010 exceeded the FEQG (2.0 µg/g); none exceeded guideline in 2016.
- Higher PFOS in landfill/industrial areas vs rural/remote locations.
- PFOS not related to quantity of waste received at individual landfills (unlike results found for PBDEs).

Gewurtz *et al.* In prep.

PFOA

- Literature review of data to develop federal environmental quality guidelines (August 2015)
- Scientific peer review of literature review (Fall-Winter 2016)
- Identified key data gaps for water and soil relative to preferred method to derive CCME guidelines
- New toxicity tests on aquatic and terrestrial organisms are underway at federal toxicology labs (2016-18) (fathead minnow, Hyalella azteca, carrot and lettuce).