A water quality snapshot of Grafton Lake, Bowen Island

By Peter S. Ross, Samantha Scott and Marie Noël

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RAINCOAST CONSERVATION FOUNDATION

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Executive summary

Water is essential for life, and steps are needed to understand, protect and restore its health throughout British Columbia (BC). The Raincoast Healthy Waters program (Raincoast Conservation Foundation) was launched in 2023 and conducts community-oriented water pollution monitoring in partnering BC watersheds.

The Healthy Waters team conducted a one-time visit to sample water at the outflow from Grafton Lake on Bowen Island (Figure 1), BC, on October 8, 2024. This 'snapshot' assessment was used to compare against the more comprehensive sampling done in other watersheds, and contributes to an understanding of threats to water quality, monitoring options and action priorities for the community.

The composite sample was analysed for coliform, nutrients (6), physical parameters, metals (37), pesticides (62), polycyclic aromatic hydrocarbons (PAHs; 76), pharmaceuticals and personal care products (PPCPs; 141), polychlorinated biphenyls (PCBs; 209), alkylphenol ethoxylates (APEs; 4), bisphenols (BPs; 6), per- and poly-fluoroalkyl substances (PFAS; 40), and sucralose. Results for the tire chemical breakdown product 6PPD-Quinone are pending. Results from Grafton Lake were compared to samples collected from source water (i.e. above built-up environments and generally an upstream reference sample for the watershed) in 12 other BC watersheds. Results were also compared to pertinent Drinking Water Quality Guidelines from Health Canada (n=35), Environmental Quality Guidelines from BC (n=56), the Canadian Council of Ministers of the Environment (n=43), and Federal Environmental Quality Guidelines (n=7).

We detected 125 contaminants out of 587 measured in Grafton Lake, excluding nutrients, fecal coliform and physical parameters. Grafton Lake ranked 8th most contaminated overall out of 21 source water samples from 12 watersheds in BC. This ranking was driven by relatively high concentrations of the human waste tracer sucralose (ranked 1 of 21), PCBs (3 of 21), PAHs (3 of 21), PPCPs (6 of 21), and PFAS (6 of 21). There were no exceedances of available Drinking Water Guidelines (for which we have Guidelines for just 6% of our analytes) or Environmental Quality Guidelines (for which we have Guidelines for just 10% of our analytes).

This lake is an important source of drinking water for Bowen island, as well as habitat for coho salmon and cutthroat trout. A combination of human waste and atmospheric deposition of pollutants into a relatively shallow lake (average depth 8.8 m; maximum depth 16 m; perimeter 14.7 km^2) appear to be driving water quality profiles in Grafton Lake.

These initial findings point to the value of monitoring and enhanced protection measures for this important water body on Bowen Island, which serves people, fish and wildlife.

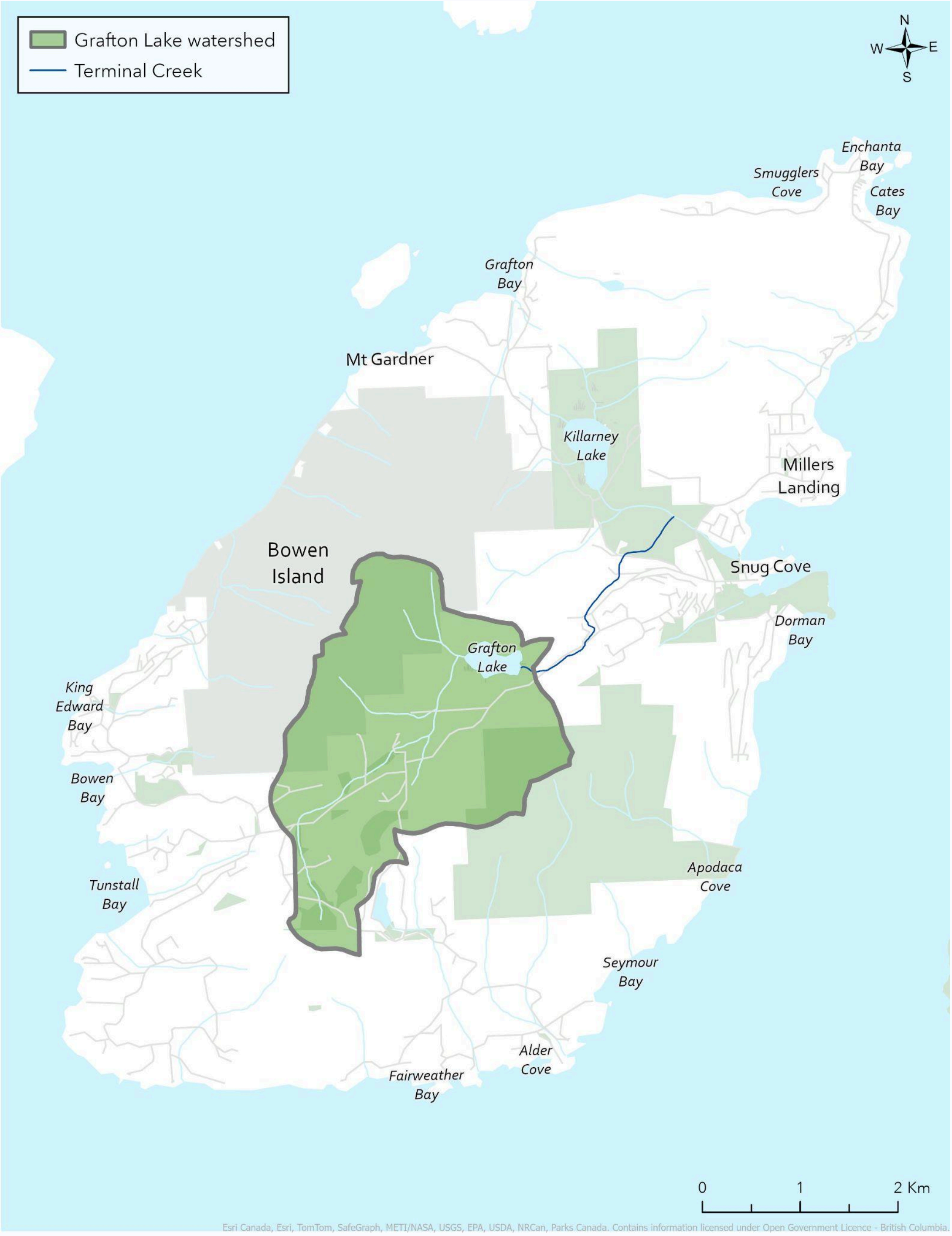
Key findings

- This preliminary assessment of water quality in the Grafton Lake watershed on Bowen Island (BC) reflects a one-time sampling visit, based on a single large sample, and a comprehensive analysis of a variety of contaminants.
- Grafton Lake ranked 8th most contaminated out of 21 source water samples analysed by Raincoast in 12 watersheds across BC, based on the average rankings for the concentrations of all contaminant classes.
- Overall, Grafton Lake had **fair** water quality:
  - There were no exceedances of Health Canada Drinking Water Quality Guidelines (DWGs).
  - There were no exceedances of Environmental Quality Guidelines (EQGs: BC, federal and CCME).
  - There are DWGs for only 6% of the contaminants we measured, and EQGs for just 10%, constraining our ability to evaluate many contaminants of concern.
- Traces of several pharmaceuticals and personal care products, and some industrial chemicals, suggest that human activities in or adjacent to the lake are affecting water quality.
- Concentrations of Arsenic, Zinc and Lead were high relative to other metals and to other BC watersheds, but fell within Drinking Water Quality Guidelines.
- Moderate levels of certain pesticides, PCBs and PAHs suggest that the atmosphere also delivers contaminants to this lake from distant sources.
- Grafton Lake is highly vulnerable to a deterioration of water quality as a function of its small size and relatively shallow nature, an impervious nearby road, recreational access to the shoreline and lake, and an encroaching built-up environment supported by septic fields in the upstream reaches of the watershed.
- Previous assessments have noted water quality concerns related to failing septic systems, and identified the monitoring and mitigation of fecal coliform contamination of the lake.
- Excellent educational materials produced in recent decades for Bowen Island provide an opportunity to update public educational initiatives based on new scientific findings, new project developments on Bowen Island, and consumer awareness concerns (Turner et al 2005).
- Our findings highlight the importance of monitoring, source control and best practices within the watershed in order to protect drinking water for residents and protect aquatic habitats for fish and wildlife into the future.

Acknowledgements

We acknowledge the expert analytical support of Pam MacKenzie and Richard Grace at SGS-AXYS. We thank Raincoast colleagues Brooke Gerle for map design, and Sherwin Arnott for design and formatting. We gratefully acknowledge Margit Brenner, William D. Husby, Gregory Pollard, Kim A. Stephens (Partnership for Water Sustainability in BC) and Bob Turner for invaluable feedback on an earlier version of this report. Photo credits: Peter S. Ross.

Figure 1: The Grafton Lake Watershed, Bowen Island, BC



The Grafton Lake watershed on Bowen Island, BC (Map by Brooke Gerle / Raincoast Conservation Foundation).

General introduction

Background

Raincoast's Healthy Waters Program delivers high-resolution, community-oriented water quality analysis to watersheds across southern British Columbia (Figure 2). The goal of Healthy Waters is to empower communities with the understanding of the status of water quality in their watersheds, and to allow for local stewardship regarding both point and nonpoint source pollution.

"A watershed is the area of land that drains into rivers and lakes, which, in turn, flow to a common outlet. Watersheds are separated from one another by the height of the land" (- Agriculture Canada)

Grafton Lake collects rainwater from a third of the Bowen Island (Nexwlélexwm) landmass. Grafton Lake provides drinking water to approximately 48% of the island's 4,000 residents among 650 homes and businesses as part of the Cove Bay Water System. Freshwater quantity and quality remain significant concerns on islands (Turner et al, 2005).

A lone sign draws attention to the importance of the water quality in Grafton Lake as a drinking water source.

Source water from Grafton Lake is chlorinated to protect human health from potential pathogens, but there exists a boil water advisory for people with compromised immune systems (Bowen Island Municipality). While the addition of chlorine destroys many pathogens prior to distribution to homes and businesses, an unintended consequence is that the chlorine creates carcinogenic by-products (trihalomethanes or THMs) as a result of interactions with organic material in lake water.

With THM levels in treated drinking water chronically exceeding Health Canada Drinking Water Quality Guidelines, the Vancouver Coastal Health Authority asked the Municipality of Bowen Island in 2014 to build a treatment plant to address the issue of *E. coli*, viruses and parasites, turbidity, manganese, THMs and cysts before distribution of drinking water. Grafton Lake also supports fish habitat in downstream Terminal Creek and the estuary at Kwilákm (Deep Bay/Mannion Bay; Bowen Island Conservancy), and supplies water for the Bowen Island fish hatchery (Bowen Island Fish and Wildlife Club).

The Raincoast Healthy Waters program conducted a one-time spot sampling of Grafton Lake water on October 8, 2024, and submitted samples to partnering service laboratories for the analysis of nutrients, metals, physical parameters, fecal coliform, pesticides, polychlorinated biphenyls (PCBs), alkylphenol ethoxylates (APEs), bisphenols (BPs), per- and poly-fluoroalkyl substances (PFAS), pharmaceuticals and personal care products, polycyclic aromatic hydrocarbons (PAHs), and sucralose (*Splenda*).

The Raincoast Healthy Waters program typically collects water twice a year from five water categories within partnering watersheds in BC. These include **source water**, which serves as an upstream reference sample, allowing us to determine which contaminants are being introduced as water traces its path down through the watershed. We also sample **stream and river** samples to investigate the quality of fish habitat; **road runoff** which serves as an impacted sample category of current concern, as many contaminants can be washed off roadways and into fish habitat; **tap water** samples from a dozen residents or businesses provides a means to bring our homes into the conversation - we borrow water from the environment in the form of municipal or well water, and generally return it to aquatic habitats in a more-degraded state in the form of storm and sewage effluent (treated or untreated); and **marine water** samples, which provide insight into those contaminants that end up in the ocean adjacent to our watersheds. Funding is secured by Raincoast from a variety of sources, including MetroVancouver, Capital Regional District, Port of Vancouver, the federal department of Fisheries and Oceans Canada, Indigenous Nations, the Vancouver Foundation and the Whistler Lakes Conservation Foundation.

Figure 2: Water quality results from this Grafton Lake snapshot study were compared against 'source water' samples collected in other BC watersheds, thereby providing a means to interpret findings

Watershed-based partnerships with over a dozen First Nations, local, regional and federal agencies, and foundations have been established under the auspices of the Raincoast Healthy Waters program in BC (Map by Brooke Gerle / Raincoast Conservation Foundation).

High costs precluded a fulsome evaluation of a comprehensive water quality approach across the watershed, but this study provides an initial glimpse into issues of potential concern. The collection and analysis of a **source water sample from Grafton Lake** on Bowen Island provides a snapshot of threats to water quality, the activities likely contributing to its degradation, and data to inform source control or remediation.

Methods

Field sampling

A single, composite water sample (12L) was collected from Grafton Lake on Bowen Island, BC on October 8, 2024, using a pre-cleaned stainless steel container.

A portable water properties meter (YSI-ProDSS) was deployed in situ to measure temperature, pH, conductivity, dissolved oxygen and turbidity.

Samples were submitted to two service labs: ALS Environmental (Burnaby BC) and SGS-AXYS (Sidney BC). Contaminant analyses were determined in water samples according to established protocols (see Appendix 2A).

Data handling

In some cases, contaminants were not detected and concentrations were therefore considered to be 0 for the calculations of totals.

With each batch of samples, analytical laboratories also ran blank samples (e.g. samples that go through the same laboratory processes as our environmental samples) that should, in theory, not contain any contaminants. However, in some cases, blank samples contained low concentrations of some contaminants. These levels were subtracted from the concentrations measured in each of our environmental samples ('blank correction').

Comparison to other Healthy Waters findings

Grafton Lake data were compared to findings from 21 other source water samples collected in 12 BC watersheds as part of the Raincoast Healthy Waters program. Reports are available for these other watersheds and for an assessment of water quality in the Sumas area during the floods of late 2021 (Ross et al 2022).

Comparison to Drinking Water (DWQGs) and Environmental Quality Guidelines (EQGs)

While the majority of analytes that we measured have no Guidelines available against which to evaluate, those with Guidelines available were compared against pertinent Drinking Water Quality Guidelines from Health Canada (n=35), Environmental Quality Guidelines from BC (n=56), the Canadian Council of Ministers of the Environment (n=43), and Federal Environmental Quality Guidelines (n=7) (Appendix 5A).

Water properties

Capsule

A YSI ProDSS portable meter was used to take three measurements for the following parameters: temperature (°C), dissolved oxygen (mg/L and %), specific conductivity (uS/cm), pH, and turbidity (FNU). Basic water properties provided elementary information on water quality in Grafton Lake.

- The turbidity measurement (0.65 FNU) does not exceed the Health Canada Drinking Water Quality Guideline of 1.0 NTU (or 1.0 FNU).
- The pH measurement (7.3) falls within the Health Canada Drinking Water Quality Guideline range of 7.0-10.5.
- Water temperature, pH, and dissolved oxygen were all within Environmental Quality Guideline ranges for protection of aquatic life.
- Basic water properties were suitable for healthy fish habitat.

Table 1: Average water property results for water sampled at the outflow of Grafton Lake, Bowen Island

Parameter	Grafton Lake (composited from n=3)
Temperature (℃)	14.3
DO %	86.2
DO (mg/L)	8.82
pH	7.3*
Conductivity (uS/cm)	86.7
Turbidity (FNU)	0.65*

Data presented above represent the average of three replicate measurements. DO = Dissolved Oxygen. uS/cm = MicroSiemens per cm. FNU = Formazin Nephelometric Units. The pH and Turbidity measurements were carried out on Feb. 16, 2025 owing to technical constraints on the original sampling date of Oct 8, 2024.

Coliform bacteria

Capsule

Fecal coliform bacteria in water represent a potentially serious threat to human health with the greatest risk associated with *E. coli*, viruses and parasites. Low levels of fecal coliform and *E. coli* suggest that bacteria of concern to human health are entering Grafton Lake. We cannot distinguish between humans, pets, livestock and/or wildlife as the source of these coliform bacteria. Chlorination prior to use as drinking water is in place to mitigate the risk of pathogen exposure by people. Total coliform is a non-specific measure of these bacteria originating from soils, animals and people; fecal coliform originates from warm blooded animals, including humans; *E. coli* is a more specific measure of the fecal coliform found in the sample, and provide a measure of risk from other pathogens.

- All three categories of coliform bacteria were detected in the Grafton Lake water sample.
- Source water samples were just within Health Canada guidelines for raw drinking water sources (*E. coli* <10 MPN/100ml), with this guideline assuming that municipal, reserve or domestic disinfection processes destroy all coliform prior to drinking.
- We did not detect any *E. coli* bacteria counts that exceeded recommended levels for recreational use (<235 MPN/100 mL).
- There are no EQGs available for coliform bacteria.
- The source of the coliforms is not clear, and may come from humans, pets, livestock or wildlife. The detection of additional contaminants (below) that likely originate from domestic wastewater suggest that there is strong potential for fecal contamination entering Grafton Lake from human waste.
- The Grafton Lake water sample ranked 9th out of 21 for *E. coli* in source water samples in BC.

Table 2: Mean counts (MPN/100ml) of coliform bacteria in water sampled from Grafton Lake, Bowen Island, and comparison to 21 other source water samples from 12 BC watersheds

Analyte	Grafton Lake (n=1)	Mean all samples (Min-Max)	Rank out of 21	Number of water samples with detection
Total coliform	548	522 (23-1410)	9	21
Fecal Coliform	2	114 (1-649)	11	14
E. coli	4	81 (1-921)	9	15

Nutrients and Physical parameters

Capsule

Nutrients can readily degrade fish habitat by increasing plant and algal growth, resulting in a reduction in dissolved oxygen.

- Two nutrients (nitrogen and phosphate), out of six that were analyzed for, were detected in the Grafton Lake sample.
- No nutrient values exceeded available DWQGs.
- No nutrient values exceeded available EQGs for the protection of aquatic life.
- The Grafton Lake water sample ranked 6th out of 21 source water samples in BC for Nitrogen, but 21st for phosphate.
- Findings may reflect a combination of natural (organic matter) or human (wastewater) influences.

Table 3: Concentrations (mg/L) of physical and chemical properties in water sampled from Grafton Lake, Bowen Island, and comparison to 21 other source water samples from 12 BC watersheds

Analyte	Grafton Lake (n=1)	Mean All Samples (Min-Max)	Rank out of 21	Number of water samples with detection
Hardness (as CaCO3)	27.6	50.7 (11.9-211)	9	21
Solids, total dissolved [TDS]	76	76.3 (9.1-287)	8	21
Solids, total suspended [TSS]	<3.0	0.43 (0-9.1)	21	1
Carbon, total organic [TOC]	4.72	68.5 (0.54-180)	5	16
Biochemical oxygen demand [BOD]	<2.0	4.2 (2-8.3)	21	5
Chemical oxygen demand [COD]	15	18.2 (10.0-29.0)	4	5

Concentrations (mg/L) of physical and chemical properties in water sampled from Grafton Lake, Bowen Island, and comparison to 21 other source water samples from 12 BC watersheds.

Table 4: Nutrient concentrations (mg/L) in water sampled from Grafton Lake, Bowen Island, and comparison to 21 other source water samples from 12 BC watersheds

Analyte	Grafton Lake (n=1)	Mean All Samples (Min-Max)	Rank out of 21	Number of water samples with detection
Ammonia, total (as N)	0.0114	0.032 (0.0052-0.136)	4	7
Nitrate (as N)	<0.0050	0.122 (0.0061-0.621)	21	17
Nitrate + Nitrite (as N)	<0.0051	0.123 (0.0061-0.621)	21	17
Nitrite (as N)	<0.0010	0.0014 (0.0010-0.0018)	21	2
Nitrogen, total	0.297	0.232 (0.030-0.628)	6	21
Phosphate, ortho-, dissolved (as P)	<0.0010	0.019 (0.0010-0.064)	21	4

Metals

Capsule

Metals can be present in water due to both natural and anthropogenic inputs. Watershed geology has a significant impact on the concentrations of metals in waterways. Mining, industrial discharges, road runoff and certain fertilizers can introduce additional metals into waterways.

- 18 metals were detected in the Grafton Lake sample, out of 35 that were analyzed.
- There were no exceedances of Health Canada DWQGs.
- There were no exceedances of BC MoE or CCME EQGs for the protection of freshwater aquatic life.
- The Grafton Lake water sample ranked 15th out of 21 source water samples for the total concentration of metals.
- The Grafton Lake water sample ranked 1st for arsenic, lead and zinc among the 21 samples we analysed.

Table 5: Concentrations (mg/L) of the 18 metals that were detected in water sampled from Grafton Lake, Bowen Island, and comparison to 21 other source water samples from 12 BC watersheds

Analyte	Grafton Lake (n=1)	Mean All Samples (Min-Max)	Rank out of 21	Number of water samples with detections
Aluminum	0.0315	0.0821 (0.0112-0.618)	10	21
Arsenic	0.00077	0.000263 (0.00011-0.00077)	1	15
Barium	0.00823	0.0105 (0.00265-0.0494)	7	21
Calcium	8.63	16.6 (4.16-61.2)	11	21
Copper	0.00066	0.000965 (0.00053-0.00172)	15	17
Iron	0.196	0.125 (0.012-0.426)	5	16
Lead	0.000104	0.000086 (0.000077-0.000094)	1	4
Magnesium	1.46	2.58 (0.221-14.1)	9	21
Manganese	0.0164	0.00528 (0.00034-0.025	3	21

Molybdenum	0.000101	0.000638 (0.000075-0.0034)	17	20
Potassium	0.649	0.743 (0.114-5.42)	4	20
Selenium	0.000064	0.000631 (0.000064-000138)	7	7
Silicon	2.32	3.78 (1.34-9.06)	13	20
Sodium	6.24	3.03 (0.557-8.14)	3	21
Strontium	0.0405	0.0928 (0.0128-0.4440)	8	21
Sulfur	1.36	3.85 (0.580-17.8)	6	14
Titanium	0.00065	0.0031 (0.00052-0.0218)	12	14
Zinc	0.0058	0.00365 (0.00010-0.0058)	1	2
Total metals	**20.96**	**27.6 (8.51-111)**	**15**	**21**

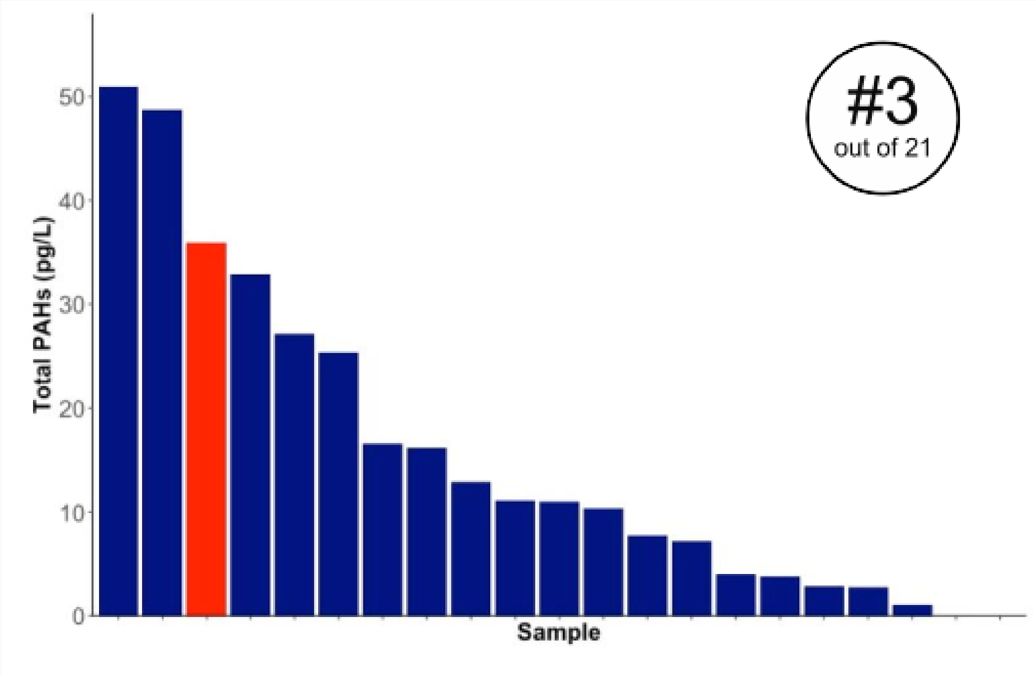
Polycyclic Aromatic Hydrocarbons (PAHs)

Capsule

Polycyclic aromatic hydrocarbons (PAHs) are a complex group of compounds found in coal, petroleum and plant materials. They can occur naturally (forest fires) or as a result of human activities (residential wood heating, road runoff, creosote-treated products, spills of petroleum products). They can enter waterways through direct discharge or via atmospheric deposition.

- We detected 20 different parent and alkylated PAHs out of a total of 76 analyzed in the Grafton Lake water sample.
- The total PAH level reported in the Grafton Lake sample was three to four orders of magnitude lower than those reported in some of the surface water samples impacted by the 2021 floods in the Sumas Lake area (Ross et al. 2022).
- The total PAH concentration was 35.9 pg/L, 3rd highest out of 21 BC source water samples analysed.
- There are no DWGs for the PAHs detected in the Grafton Lake water sample.
- The Grafton Lake water sample was well below the EQGs available for individual PAHs (naphthalene, acenaphthene, fluorene, anthracene, phenanthrene, fluoranthene, pyrene, chrysene, benzo-a-pyrene and benzo-a-anthracene).
- While we were unable to characterise the PAH sources found in this sample, pyrogenic PAHs found in other source water samples in BC suggest an influence of forest fire smoke in surface waters across BC. However, the high ranking among BC source water samples indicates a possible local source within the watershed.

Figure 2: Total PAH concentrations in water sampled from Grafton Lake, Bowen Island, and comparison to 21 other source water samples from 12 BC watersheds



Source water from Grafton Lake (red bar) had the third highest PAH concentrations (35.9 pg/L) compared to 21 other source water samples.

Pesticides

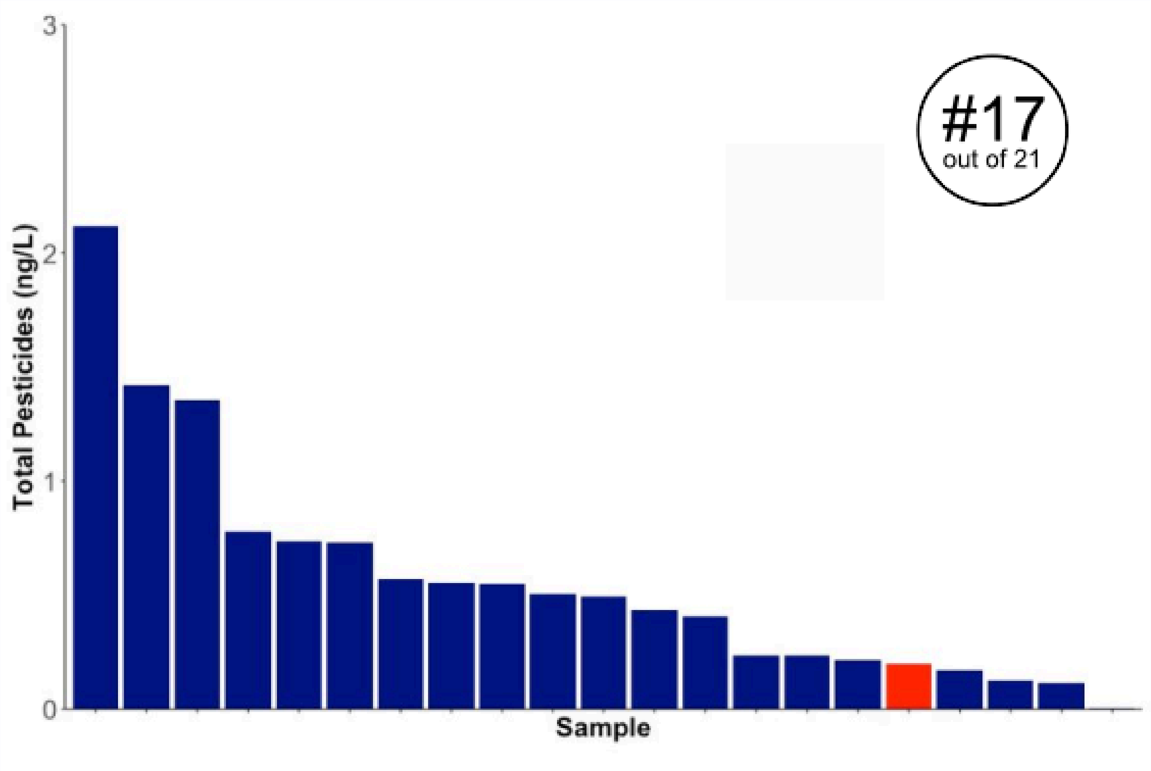
Capsule

Pesticides have been developed to control, destroy or inhibit the activities of pests. They have a wide range of applications in agriculture and forestry, and while they are mostly applied on terrestrial habitats, they can reach aquatic environments through overspray or drift during application, surface runoff, and through long range atmospheric transport and deposition.

- Five pesticides were detected out of a total of 62 measured in the Grafton Lake water sample.
- The five pesticides detected in Grafton Lake are considered 'legacy pesticides', as they are no longer in use in Canada.
    - Endosulphan is a restricted-use insecticide and acaricide used to control a broad range of insect and arthropod pests on a wide variety of food, feed and ornamental crops (Health Canada 2011). It has been banned in Canada since 2016 and is banned or restricted in most other countries (ECCC 2023).
    - Hexachlorobenzene is a fungicide to treat seeds of food crops. While it is banned in Canada and most other countries, it can be produced unintentionally as a by-product of the manufacture of certain industrial chemicals (Government of Canada 2017).
    - Chlordane is an insecticide used to control termites and agricultural insect pests. It was never manufactured in Canada and its use was discontinued in 1998 (Government of Canada 2010).
    - Heptachlor is an insecticide for soil insects and termites, crop pests and malaria-carrying mosquitoes. The registration and use of heptachlor under the Canadian Pest Control Products Act was discontinued as of January 1, 1991 (CCME 1999).
    - DDT is a broad spectrum pesticide that was routinely used for insect control on crops. DDE, which was detected in the Grafton Lake water sample, is a breakdown product of DDT. DDT was banned in Canada in 1985 but is highly persistent and is still used in some parts of the world to control malaria-carrying mosquitoes (Health Canada 2020).
- There are no DWGs available for any of the pesticides detected.

- Endosulfan was the only pesticide detected with an available EQG for water. The concentration in the Grafton Lake sample did not exceed the BC (0.7 ng/L) and CCME (60 ng/L) guidelines.
- The Grafton Lake sample ranked 8th in the number of pesticides detected among 21 source water samples in BC.
- The Grafton Lake sample ranked 17th in total pesticide concentration among 21 source water samples in BC.

Figure 3: Total pesticide concentrations in water sampled from Grafton Lake, Bowen Island, and comparison to 21 other source water samples from 12 BC watersheds



Source water from Grafton Lake (red bar) had the 17th highest pesticide concentrations (0.197 ng/L) compared to 21 other source water samples.

Table 6: Pesticide concentrations (ng/L) in water sampled from Grafton Lake, Bowen Island, and comparison to 21 other source water samples from 12 BC watersheds

Analyte	Grafton Lake (n=1)	Mean concentration All Samples (Min-Max)	Rank out of 21	Number of water samples with detection
Hexachlorobenzene	0.001	0.014 (0-0.081)	15	15
Heptachlor epoxide	0.036	0.014 (0-0.069)	5	7
Gamma Trans Chlordane	0.032	0.008 (0-0.134)	2	2
Alpha endosulphan	0.109	0.124 (0-0.384)	12	17
4,4' DDE	0.019	0.006 (0-0.059)	4	4
Total pesticide concentration	**0.197**	**6.31 (0.005-122.7)**	**17**	**21**
Total number of pesticides detected	*5*	*5 (1-12)*	*8*	*21*

Pharmaceuticals and Personal Care Products

Capsule

Pharmaceuticals and Personal Care Products (PPCPs) comprises a wide variety of contaminants that enter the environment via wastewater streams, and may not be fully not removed during treatment of municipal wastewater or through septic systems.

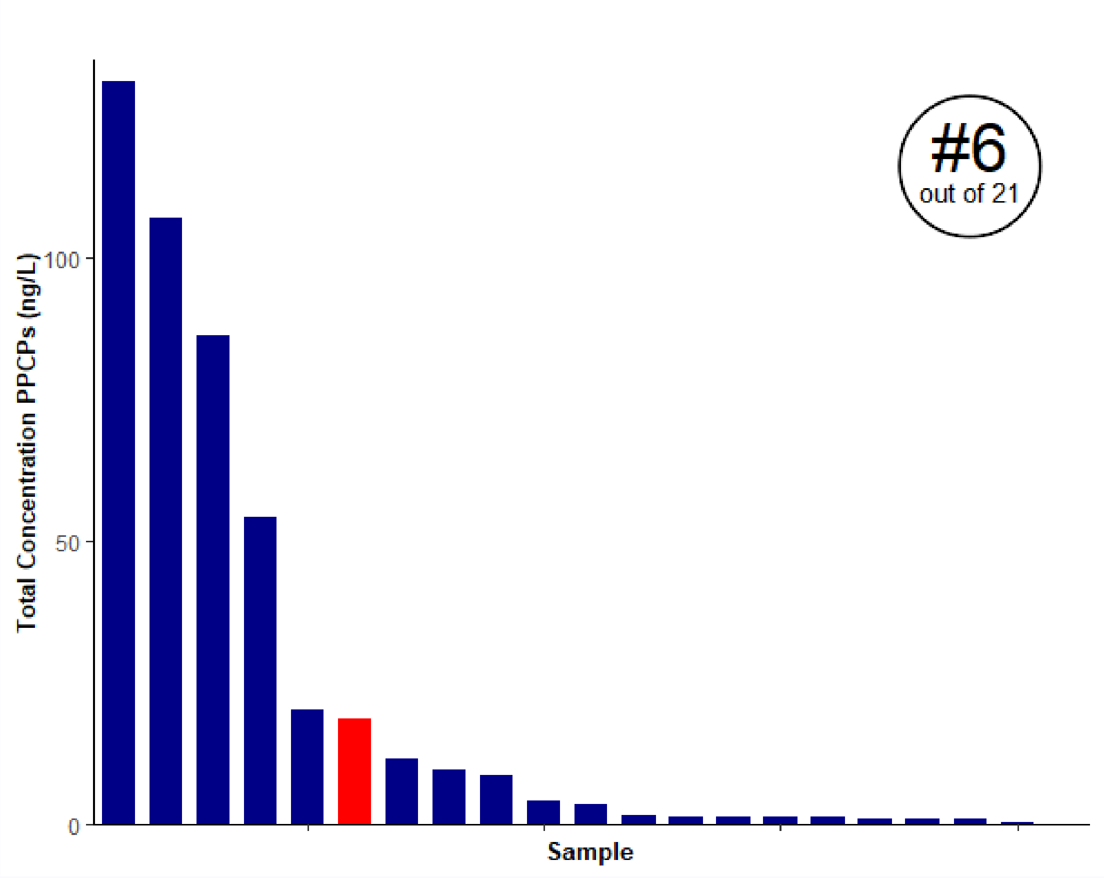
- Six PPCPs were detected in the Grafton Lake sample, out of 141 analytes that were measured.
- Caffeine, Cotinine, Metformin, Cocaine, Benzoylecgonine, and DEET were detected in Grafton Lake water at concentrations that were relatively high compared to other source water samples in BC.
- There are no DWQGs available in Canada for any of the PPCPs detected in the Grafton Lake water sample.
- There are no EQGs available in Canada for any of the PPCPs detected in the Grafton Lake water sample.
- The only PPCP for which there is an Drinking Water or Environmental Quality Guideline in Canada is Ethinylestradiol (EE), which is used widely as one of the hormonal components of birth control - as it has been shown to negatively impact both reproductive and immune function in some fish species. EE was not detected in the Grafton Lake sample.
- The detection of PPCPs may reflect discharge from wastewater systems, faulty sewer connections, septic failures, overflows from wastewater systems during rainfall events or localised inputs from recreational users.
- The Grafton Lake sample ranked 3rd in the number of PPCPs detected among 21 source water samples in BC.
- The Grafton Lake sample ranked 6th in total PPCP concentration among 21 source water samples in BC.

Table 7: Pharmaceutical and personal care product (PPCP) concentrations (ng/L) in water sampled from Grafton Lake, Bowen Island, and comparison to 21 other source water samples from 12 BC watersheds

Analyte	Grafton Lake (n=1)	Mean All Samples (Min-Max)	Rank out of 21	Number of water samples with detection
Caffeine[1]	7.24	1.06 (0-15.1)	**2**	2
Cotinine[2]	0.84	0.11 (0-0.84)	**1**	3
Metformin[3]	2.11	0.88 (0-8.09)	**3**	8
Benzoylecgonine[4]	0.376	0.092 (0-1.56)	**2**	2
Cocaine[5]	0.175	0.058 (0-0.389)	**4**	5
DEET[6]	7.92	6.69 (0-102)	**3**	19
Total PPCP concentration	**18.7**	**22.2 (0.060-131)**	**6**	**21**
Total number of PPCPs detected	*6*	*3 (1-8)*	***3***	*21*

1- natural stimulant found in coffee, tea and other beverages; 2- the metabolic breakdown product of nicotine; 3- diabetes medication; 4- metabolic breakdown product of cocaine; 5- alkaloid used as illicit recreational drug from the South American coca (*kúka*) plant; 6- Insecticide (N,N-diethyl-meta-toluamide) used in many repellent products.

Figure 4: Total PPCP concentration (ng/L) in water sampled from Grafton Lake, Bowen Island, and comparison to 21 other source water samples from 12 BC watersheds



The Grafton Lake sample (18.7 ng/L) had the sixth highest concentration of total PPCPs among all source water samples that were analyzed as a part of Raincoast's Healthy Waters Program.

Per- and poly-fluoroalkyl substances (PFAS)

Capsule

Per- and poly-fluoroalkyl substances (PFAS) are a large group (~15,000 compounds) of human-made substances used in a wide variety of products such as food packaging, non-stick cookware, clothing, and cosmetics, but also lubricants, oil/water repellents, and notably - aqueous firefighting foams (AFFF). They are often referred to as 'forever chemicals'.

- Two PFAS compounds (PFOA and PFHpA) were detected in the Grafton Lake water sample out of 40 measured.
    - PFOA was banned in Canada in 2016; it was a key component of Teflon.
    - PFHpA is a breakdown product of stain and grease-proof coatings used in food packaging, packages and furniture.
- PFAS concentrations were in the lower range of PFAS levels (0 - 138 ng/L) reported for 29 ambient surface freshwater sites across Canada between 2013 and 2020 (ECCC and Health Canada 2023).
- Total PFAS levels were
    - below the new Health Canada DWQ Objective of 30 ng/L sum for 25 different PFAS compounds.
    - below the European DWQG of 500 ng/L.
- The detected PFOA concentration was:
    - below the Health Canada DWQG of 200 ng/L.
    - below the new and more protective USA DWQG of 4 ng/L.
- There are no EQGs for PFOA and PFHpA in Canada.
- The broader PFAS family of substances is under review by the Government of Canada and is likely to face restrictions.
- The Grafton Lake sample ranked 3rd in the number of PFAS compounds detected among 21 source water samples in BC.
- The Grafton Lake water sample ranked 6th in total PFAS concentration among 21 source water samples in BC.

Table 8: PFAS concentrations (ng/L) in water sampled from Grafton Lake, Bowen Island, and comparison to 21 other source water samples from 12 BC watersheds

Analyte	Grafton Lake (n=1)	Mean All Samples (Min-Max)	Rank out of 21	Number of water samples with detection
Perfluorooctanoic Acid (PFOA)	0.632	0.103 (0-0.919)	2	3
Perfluoroheptanoic Acid (PFHpA)	0.582	0.051 (0-0.582)	1	2
Total PFAS concentration	**1.21**	**1.81 (0-11.9)**	**6**	**9**
Total number of PFAS detected	*2*	*1 (0-8)*	*3*	*9*

The average total among all 21 source water samples for only those two PFAS detected in the Grafton Lake water sample was 1.08 ng/L.

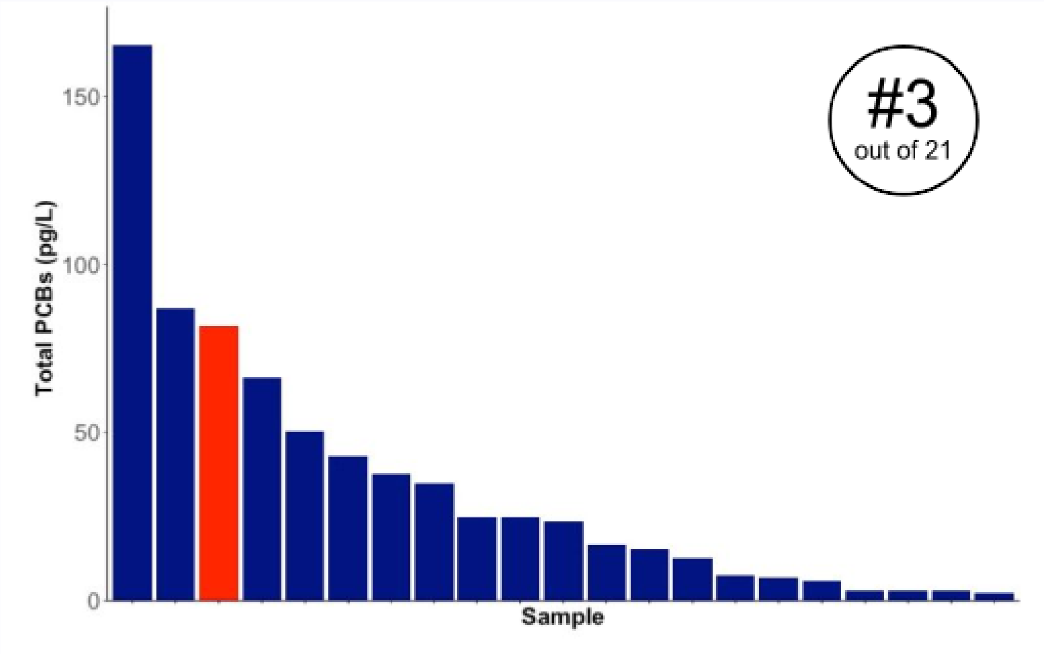
Polychlorinated Biphenyls (PCBs)

Capsule

The commercial production of PCBs began in 1929, after which they were heavily used in electrical and hydraulic equipment around the world, as well as in paint additives, sealing and caulking compounds and inks. Despite having been targeted for phase out in Canada in 1977, with some closed uses allowed until December 31, 2029, industrial PCBs continue to be found in the environment, reflecting their stability and persistence. PCBs are not water-soluble, meaning that they have a strong affinity for particles in water and lipids in plants, invertebrates, fish and wildlife. The Endangered Southern Resident killer whales have some of the highest level of PCBs among the world's marine mammals, in part due to their long lifespan and their high position in the food chain (Ross et al 2000).

- Seventy-two (out of 209) individual PCB congeners were detected in the Grafton Lake water sample.
- PCB levels in source water from Grafton Lake were in the range of concentrations measured in stream water samples from remote (10 pg/L) and urban (4,100 pg/L) areas in Ontario (Zhang et al. 2020).
- There are no DWQGs for PCBs.
- There were no exceedances for available PCB EQGs (PCB-77, -105, -126 and -169; total PCBs) in the Grafton Lake water sample.
- The Grafton Lake sample ranked 4th in the number of PCBs detected among 21 source water samples in BC.
- The Grafton Lake sampled ranked 3rd in total PCB concentration among 21 source water samples in BC.

Figure 5: Total PCB concentrations in water sampled from Grafton Lake, Bowen Island, and comparison to 21 other source water samples from 12 BC watersheds



PCB levels in the Grafton Lake source water sample were the third highest levels (81.7 pg/L, red bar) amongst all 21 source water samples studied.

Alkylphenol Ethoxylates

Capsule

Alkylphenol ethoxylates (APEs) are industrial grade surfactants that are widely used in detergents and cleaning products. They have been found in wastewater and industrial discharges.

- One APE (4-n-Octylphenol) was detected out of the four APE compounds that were analyzed.
- There are no DWGs for alkylphenol ethoxylates.
- The concentration for the detected alkylphenol ethoxylate in the Grafton Lake water sample was well below the long-term CCME guideline for the protection of freshwater aquatic life for nonylphenol and its ethoxylates of 1000 ng/L.
- The Grafton Lake water sample ranked 8th out of 21 source water samples for alkylphenol ethoxylates in BC.

Table 9: Alkylphenol concentration (ng/L) in water sampled from Grafton Lake, Bowen Island, and comparison to 21 other source water samples from 12 BC watersheds

Analyte	Grafton Lake (n=1)	Mean All Source Samples (Min-Max)	Rank out of 21	Number of water samples where detected
4-Nonylphenols	0	4.22 (0-28.4)	21	6
4-Nonylphenol monoethoxylates	0	0 (0-0)	NA	0
4-Nonylphenol diethoxylates	0	0 (0-0)	NA	0
4-n-Octylphenol	1.14	1.28 (0-21.6)	2	5
Total Alkylphenols	**1.14**	**5.50 (0-28.4)**	**8**	**9**

The only alkylphenol compound that was detected in the source water sample from Grafton Lake was 4-n-octylphenol.

Bisphenols

Capsule

Bisphenols are plastic additives with widely reported estrogenic (endocrine disrupting) properties. We did not detect any bisphenol compounds that were analyzed in water samples from Grafton Lake in the dry (summer) season.

- As no bisphenols were detected in Grafton Lake, we conclude that there does not appear to be any significant discharge of these contaminants.
- There are no current Health Canada Drinking Water Guidelines (DWQG) available for bisphenols.
- There is a Canadian FEQG of 3,500 nanograms per litre (ng/L) for BPA.
- Grafton Lake ranked 21st out of 21 source water samples in BC.

Table 10: Concentration (ng/L) of bisphenols in water sampled from Grafton Lake, Bowen Island, and comparison to 21 other source water samples from 12 BC watersheds

Analyte	Grafton Lake (n=1)	Mean All Samples (Min-Max)	Rank out of 21	Number of water samples with detection
Bisphenol E (BPE)	0	0 (0-0)	-	0
Bisphenol F (BPF)	0	0 (0-0)	-	0
Bisphenol A (BPA)	0	2.92 (0-22.0)	21	10
Bisphenol AF (BPAF)	0	0 (0-0)	-	0
Bisphenol B (BPB)	0	0 (0-0)	-	0
Bisphenol S (BPS)	0	0 (0-0)	-	0
Total bisphenols	**0**	**2.92 (0-22.0)**	**21**	**10**

*10 source water samples out of 21 had no detectable BP; all of these, including Grafton Lake, were assigned a rank of 21.

Sucralose

Capsule

Sucralose is a popular artificial sweetener (trade name '*Splenda*') used in foods and beverages. Because it is poorly metabolized by humans, and survives the wastewater treatment process, sucralose has become a useful tracer of domestic wastewater. It is thought to be non-toxic, but concerns are being raised about possible health effects in humans and wildlife.

- Sucralose was detected in the source water sample at a relatively high concentration, ranking 1st out of 21 source water samples in BC.
- There are no current Health Canada Drinking Water Guidelines available for sucralose.
- There are no current Canadian Environmental Quality Guidelines (EQGs) available for sucralose.

Table 11: Sucralose concentration (ng/L) in water sampled from Grafton Lake, Bowen Island, and comparison to 21 other source water samples from 12 BC watersheds

Analyte	Grafton Lake (n=1)	Mean All Samples (Min-Max)	Rank out of 21	Number of water samples with detection
Sucralose (ng/L)	32.9	4.34 (0-32.9)	1	3

Grafton Lake water was one of only three source water samples where Sucralose was detected, out of a total of 21 samples.

6PPD-Quinone

Capsule

The tire chemical 6PPD represents up to 2% of the weight of a vehicle tire; its intended use is to protect the tire from ozone- caused degradation. The breakdown product of this chemical in the environment, 6PPD-quinone (*(1,3-Dimethylbutyl)-N′-phenyl-p-phenylenediamine quinone*) - has been associated with significant and repeated instances of pre-spawn coho salmon mortality events in Washington State and in British Columbia. These are often associated with rainfall events, where the road runoff causes pulses of this highly toxic chemical after its accumulation on roads during dry spells.

- Results of 6PPD-quinone analysis from our partners are expected in spring 2025.
- There are no current Health Canada Drinking Water Guidelines available for 6PPD-quinone.
- A new BC EQG has been set at 11 ng/L for 6PPD-q.
- 6PPD and its breakdown product is under priority review by the federal government, following a request from Raincoast and other groups (Raincoast Conservation Foundation, 2025).
- Rainfall events have been associated with mortalities of up to 90% of local coho salmon stocks as a function of this chemical.

Table 12: 6PPD-Quinone concentration (ng/L) in water sampled from Grafton Lake, Bowen Island, and comparison to 21 other source water samples from 12 BC watersheds

Analyte	Grafton Lake (n=1)	Mean All Samples (Min-Max)	Rank out of 21
6PPDq (ng/L)	pending		

Grafton Lake water quality summary

This report encapsulates a dry season water sampling event comprising a single bulk sample of source water collected from Grafton Lake on Bowen Island. Results suggest that Grafton Lake water quality was **fair**, but a follow-up study is warranted to confirm or build upon initial observations of some contaminants of concern.

Our findings provide an integrated evaluation of the contaminants and activities that are influencing water quality in Grafton Lake. This may inform mitigation, stewardship and restoration initiatives that protect and restore water quality in the lake, and in fish habitat throughout the watershed. While we did not detect any exceedances of available Drinking Water Quality Guidelines (to protect human health) or Environmental Quality Guidelines (to protect fish and wildlife health), we note that guidelines are only available for a small minority (6-10%) of the analytes we measured.

There exists no sanctioned method to assess the health significance of the traces of caffeine, metformin, sucralose and cocaine detected in Grafton Lake, but these 'tracers' point to the release of human waste into this important drinking water source.

"With this in mind, Grafton Lake's watershed must be considered to have as its prime management task the preservation or improvement of the water quality and quantity. Necessarily, this would entail restricting public access within the watershed." (From Hirvonen, 1976).

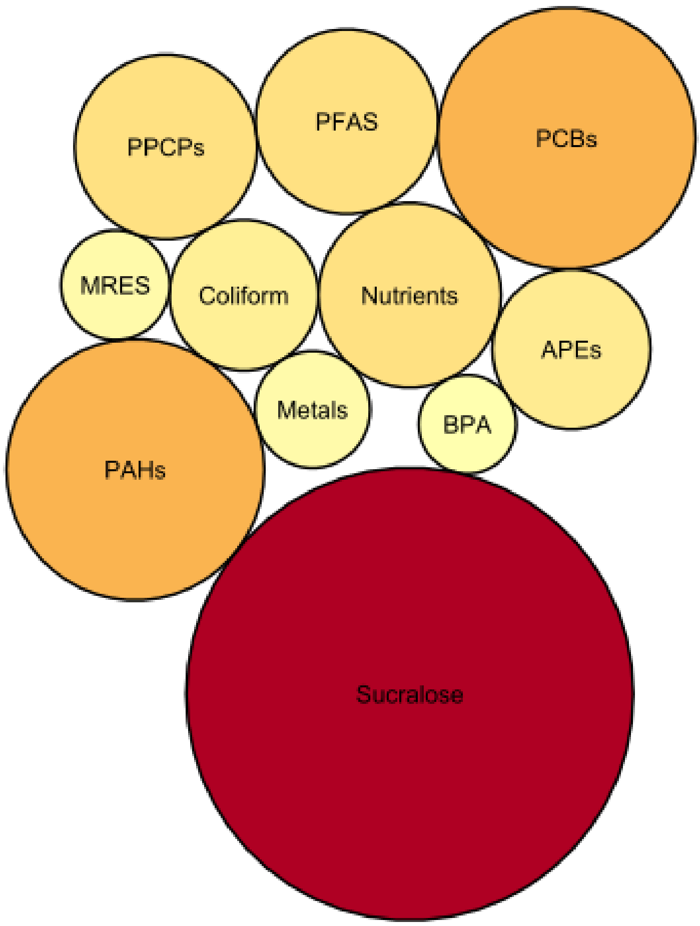
This report was intended to present findings from a snapshot assessment of water quality in the primary drinking water source for Bowen island residents. We employed sampling protocols that we have used in more fulsome studies in 12 other watersheds in BC, along with the best available laboratory methods for the detection of the target compounds. Our collective data suggest that:

- some pollutants in Grafton Lake are atmospherically delivered from distant sources;
- there are strong indications of human waste entering the lake via septic failures and/or local uses;
- Grafton Lake is a small and relatively shallow lake which renders it vulnerable to contamination by local activities and atmospheric inputs.
- Best practices in the watershed may be considered by the community so as to reduce contaminant releases into Grafton Lake, for example:

- septic installation, inspection and maintenance: our findings suggest a clear release of human waste into Grafton Lake, highlighting the opportunity for education, source control and regulatory initiatives. Type 1 septic systems should be pumped out at least every 5 years, while Type 2 and 3 systems should be maintained 1-2 times per year. Some jurisdictions require maintenance records or pump out reports.
- riparian zone protections: "*Riparian areas form a transition zone between aquatic and upland habitats. Aquatic ecosystems interact closely with riparian areas—the zones of lush, green, moisture-loving vegetation that surround wetlands, lakes, streams, and rivers*." (British Columbia 2025). A minimum of 30 m to 50 m riparian buffer is recommended to protect fish habitat in BC - something that would help to protect fish habitat and drinking water quality.
- Residential education and best practices: MetroVancouver and other organizations provide educational resources on best practices to prevent water pollution for homeowners (MetroVancouver 2025). Ideas include pesticide- and artificial fertilizer- free lawns and gardens, sustainable cleaning products for indoors and outside, and toxic-free cosmetics and soaps (Georgia Strait Alliance 2025).
- Residential education about the BC Medications Return Plan; *Pharmasave Cates* participates in this program, and asks that residents deliver pills and tablets in a sealed plastic bag. These are picked up periodically from the pharmacy by Environmental 360 Solutions (2025) for destruction.
- Recreational education and practices: access to Grafton Lake and its shoreline area increases the likelihood of human and pet waste entering the lake. Educational materials, signage and access restrictions offer opportunities to reduce the risks associated with people and their pets to lake water quality.
- Road runoff: Runoff from paved surfaces can introduce road salts, oils, metals, antifreeze and the tire breakdown chemical 6PPD-Quinone to nearby waterways. This 'nonpoint source' pollution threatens water quality in urban areas, and has been implicated in the deaths of coho salmon in the region. Best practices and green infrastructure offer opportunities to reduce such releases into waterways by up to 90% (UBC 2025).

- Water quality monitoring: we recommend that Grafton Lake water be monitored for key tracers of human waste and for contaminants of potential concern. A bi-annual approach could sample twice per year, capturing the summer (dry) and winter (wet) seasons. Such monitoring would provide reassurance on the quality of Grafton Lake as the drinking water source for many residents of Bowen island, identify priority concerns, enable targeted initiatives to reduce contamination, and track progress in protecting and improving water quality.

The following image displays the relative ranking for each contaminant class against the 21 other source water samples in BC. The smallest circle demonstrates that Grafton Lake has relatively good water quality compared to 21 other source water samples, while the bigger circles demonstrate that Grafton Lake has relatively poor water quality:



List of acronyms

Abbreviation	Meaning
APE	Alkylphenol ethoxylates
BC EMA	British Columbia Environmental Management Act
CCME	Canadian Council of Ministers of the Environment
CEC	Contaminants of Emerging Concern
CEPA	Canadian Environmental Protection Act
CUP	Current-use pesticide
DO	Dissolved oxygen
DRIPA	Declaration on the Rights of Indigenous Peoples Act
ECCC	Environment and Climate Change Canada
MOE	Ministry of Environment
MST	Microbial Source Tracking
NP	Nonylphenol
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyls
PFAS	Polyfluoroalkyl substances
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate
POP	Persistent organic pollutant
PPCP	Pharmaceutical and personal care products
PVC	Polyvinyl chloride

TDS	Total dissolved solids
TOC	Total organic carbon
TSS	Total suspended solids
TWP	Tire wear particle
WQGs	Water Quality Guidelines
WQI	Water Quality Index
WWTP	Wastewater treatment plant

Appendix A: Methods

Table 1A: Environmental and Drinking water quality guidelines relevant for the present study. These guidelines were retrieved in May 2024.

Analyte Class	Federal EQGs[1]	BC WQGs		CCME EQGs[2]		Drinking WQGs
		Freshwater	Marine	Freshwater	Marine	
Basic Water Properties						
Temperature	-	19 C(short-term)	+1°C per hour change from background	narrative	max change of +0.5°C per hour	-
pH	-	6.5-9.0	7.0-8.7	6.5-9.0	7.0-8.7	7.0-10.5
Dissolved oxygen	-	>8.0 mg/L (long-term) >5.0 mg/L (short-term)	-	6.5-9.5 mg/L	80 mg/L	-
Conductivity	-	-	-	-	-	-
Turbidity	-	-	-	narrative	narrative	≤ 1.0 NTU
Metals (mg/L)						
Aluminum, total	-	variable	-	0.005 if pH < 6.5	-	2.9
Lead, total	-	3 when ≤ 8 mg/L CaCO3 (short-term)	<140 ug/L	equation	-	0.005
Nutrients (mg/L)						
Nitrate (as N)	-	3.0 (long-term) 32.8 (short-term)	3.7 (long-term)	550	200 (long-term) 1500 (short-term)	10
Nitrite (as N)	-	table	0.02 when Cl- ≤ 2 (long-term) 0.06 when Cl- ≤ 2 - (short-term)	0.06	-	1.0
Ammonia (Total as N)	-	table	table	table	-	-
Phosphate	-	0.015 (long-term)	-	-	-	-
Coliform						
Total coliform	-	-	-	-	-	0
Fecal coliform	-	-	-	-	-	0
E. coli	-	-	-	-	-	0
PAHs (ug/L)						

Naphthalene	-	1	-	1.1	1.4	-
Acenaphthene	-	6	6	5.8	-	-
Fluorene	-	12	12	3	-	-
Anthracene	-	4	-	0.012	-	-
Phenanthrene	-	0.3	-	4.4	-	-
Fluoranthene	-	4	-	0.04	-	-
Pyrene	-	0.02	-	0.025	-	-
Chrysene	-	-	0.1	-	-	-
Benzo-a-anthracene	-	0.1	-	0.018	-	-
Benzo-a-pyrene	-	0.01	-	0.015	-	0.04
PCBs (ng/L)						
Total PCBs	-	0.1	-	-	-	-
PCB-105	-	0.09	-	-	-	-
PCB-169	-	0.06	-	-	-	-
PCB-77	-	0.04	-	-	-	-
PCB126	-	0.00025	-	-	-	-
Bisphenols (ug/L)						
BPA	1.4	-	-	-	-	-
Alkylphenols (ug/L)						
4-Nonylphenols	-	1 (long-term)	-	-	-	-
PFAS (ug/L)						
Perfluorooctane Sulfonate (PFOS)	6.8 (fresh)	3.4	-	-	-	0.6
Perfluorooctanic acid (PFOA)	-	-	-	-	-	0.2
Pesticides (ug/L)						
Atrazine	-	1.8[3]	-	1.8	-	5
Chlorothalonil	-	-	-	0.18	-	-
Cyanazine	-	2	-	-	-	-
Chlorpyrifos	-	0.02	0.002	-	-	90
Diazinon	-	0.0043	-	-	-	-
Dimethoate	-	-	-	6.2	-	20
Endosulfan	-	0.0007 (active ingredient)	-	0.06 (short-term) 0.003 (long-term)	0.09 (short-term) 0.002 (long-term)	-
Malathion	-	0.1	-	-	-	290
Metribuzin	-	1[3]	-	1.0	-	80

Permethrin	-	0.004[3]	-	0.004	0.001	-
Picloram	-	29	-	-	-	-
Simazine	-	10[3]	-	10	-	10

[1] Federal EQGs apply to both fresh and marine waters unless otherwise stated. [2] CCME EQGs are reported for long-term effects unless otherwise stated. [3] Represents CCME guidelines that the BC government has adopted as working water guidelines.

Appendix 2A: List of analytes, analysis locations, analytical methods, instruments, and number of samples submitted to service labs

Analyte	Laboratory	Analytical Method	Instruments	No. samples analysed
Tier 1				
Temperature (℃)	in situ		YSI ProDSS	12
Dissolved Oxygen (%, mg/L)	in situ	optical sensor	YSI ProDSS	12
Turbidity (FNU)	in situ		YSI ProDSS	12
Conductivity (uS/cm)	in situ		YSI ProDSS	12
pH	in situ		YSI ProDSS	12
Tier 2				
Total Suspended Solids (TSS)	ALS Environmental	APHA 2540 D (mod)	gravimetry	5
Total Dissolved Solids (TDS)	ALS Environmental	APHA 2540 C (mod)	gravimetry	5
Hardness	ALS Environmental	APHA 2340B	calculated	5
Total Organic Carbon (TOC)	ALS Environmental	APHA 5310 B (mod)	combustion	5
Chemical Oxygen Demand (COD)	ALS Environmental	APHA 5220 D (mod)	colorimetry	5
Biological Oxygen Demand (BOD)	ALS Environmental	APHA 5210 B (mod)	dissolved oxygen meter	5
Nitrate	ALS Environmental	EPA 300.1 (mod)	ion chromatography	5
Ammonia	ALS Environmental	Method Fialab 100, 2018	fluorometry	5
Phosphate	ALS Environmental	APHA 4500-P F (mod)	colorimetry	5

Total Nitrogen	ALS Environmental	Chinchilla Scientific Nitrate Method, 2011	colorimetry	5
Total Metals	ALS Environmental	EPA 200.2/6020B (mod)	Collision/Reaction Cell ICPMS	5
Total coliform	ALS Environmental	APHA 9223 (mod)	MPN	5
Fecal coliform	ALS Environmental	APHA 9223 (mod)	MPN	5
E. coli	ALS Environmental	APHA 9223 (mod)	MPN	5
MST (in Development)	RCF Conservation Genetics Lab (PSEC)	In development		5
6PPD-quinone	Pending		LCMS	5
Tier 3				
Alkylphenol Ethoxylates (APEs)	SGS Axys Analytical	SGS AXYS METHOD MLA-004 Rev 07	GC-MS	5
Bisphenols	SGS Axys Analytical	SGS AXYS METHOD MLA-113 Rev 01	LC-MS/MS	5
Multiresidue Pesticides	SGS Axys Analytical	EPA 1699 (mod)	HRMS	5
Per and Poly-fluoroalkyl substances (PFAS)	SGS Axys Analytical	EPA 1633 Draft	LC-MS/MS	5
Pharmaceuticals and Personal Care Products (PPCPs)	SGS Axys Analytical	EPA 1694	HPLC/MS/MS	5
Polychlorinated biphenyls (PCBs)	SGS Axys Analytical	SGS AXYS METHOD MLA-210 Rev 01	GC-MS/MS	5
Polycyclic Aromatic Hydrocarbons (PAHs)	SGS Axys Analytical	EPA 8270/ EPA 1625	GC-MS	5
Sucralose	SGS Axys Analytical	MLA-116	LC-MS/MS	5
6PPD-quinone	Pending		LCMS	5

Environmental Quality Guidelines

We interpreted contaminant concentrations using three sets of Canadian environmental quality guidelines (EQGs): provincial (British Columbia (BC)), federal, and those developed by the Canadian Council of the Ministers of the Environment (CCME). The latter CCME guidelines are derived in consultation with the environment ministers from the federal, provincial and territorial governments. Relevant EQGs and DWQGs are summarized in Appendix 1.

The British Columbia Ministry of Environment and Climate Change Strategy (BC MoECCS 2025) has developed Water Quality Guidelines (WQGs) that are considered as protective for different water uses. We apply WQGs for the protection of stream and rivers aquatic life (source, stream and rivers and Road runoff samples) and marine aquatic life (marine water samples). All approved BC WQGs are available online (BC MoECCS 2025).

Federal Environmental Quality Guidelines (FEQGs) are developed to support emerging federal environmental quality monitoring, risk assessment and risk management activities, and are derived to complement those developed by the CCME. They are only available for a limited number of chemicals captured in this list of EQGs (Government of Canada 2025).

In addition, Working Water Quality Guidelines (WWQGs) are available for some contaminants for which a completed WQG is not yet available. and are obtained from various Canadian provincial and federal jurisdictions (primarily the Canadian Council of the Ministers of the Environment (CCME)). WWQGs can be found online (BC MWLRS 2025).

It is important to note that exceeding a WQG/EQG or WWQG does not imply that unacceptable risk exists but rather that the potential for adverse health effects is increased. Conversely, WQGs may not fully capture the sensitivity of all species to different contaminants, such that adverse effects may occur in some species even at levels below a WQG. WQGs, therefore, serve as a benchmark based on best available evidence, and are subject to change as new evidence emerges.

Drinking Water Quality Guidelines

Guidelines are available to protect human health from different contaminants in drinking water. These have been developed at the federal level by Health Canada in collaboration with the Federal-Provincial-Territorial Committee on Drinking Water (CDW) and other federal government departments (Health Canada 2022). Guidelines for Canadian Drinking Water Quality are developed specifically for contaminants that meet all of the following criteria (Health Canada 2022):

- Exposure to the contaminant could lead to adverse health effects in humans;
- The contaminant is frequently detected or could be expected to be found in a large number of drinking water supplies throughout Canada; and,
- The contaminant is detected, or could be expected to be detected, in drinking water at a level that is of possible human health significance.

IN BC, the First Nations Health Authority (FNHA 2025) oversees drinking water safety on reserves, where the Chief and Council are responsible for drinking water infrastructure and monitoring. Monitoring of drinking water relies on meeting the Health Canada DWQGs. Drinking water quality guidelines are available from Health Canada (2025).

Table 5A: Analyte classes and number of available Environmental (or Water) Quality Guidelines (EQGs or WQGs) and Drinking Water Quality Guidelines (DWQGs)

Analyte Class	Number of Analytes Measured	Drinking WQGs	Federal EQGs	BC WQGs	CCME EQGs
Basic Water Properties	5	1	0	4	5
Coliform	3	2	0	0	0
Nutrients	6	3	0	4	4
Metals	37	20	4	20	17
PAHs	76	1	0	10	10
Pesticides	62	6	0	10	7
PPCPs	141	0	1	1	0
PFAS	40	2	1	1	0
PCBs	209	0	0	5	0
Alkylphenols	4	0	0	0	0
Bisphenols	6	0	1	1	0
Sucralose	1	0	0	0	0
6PPD-Quinone	1	0	0	0	0
Total	*587*	*35*	*7*	*56*	*43*

We applied three sets of EQGs and one set of DWQGs to our water quality data: The Federal government's *Federal Environmental Quality Guidelines* (FEQGs), the BC Government's Approved *Water Quality Guidelines* (BC WQGs), and the Canadian Council of Ministers of the Environment's (CCME) *Canadian Environmental Quality Guidelines* (CCME CEQGs); and Health Canada's Drinking Water Quality Guidelines. These guidelines were all designed to protect aquatic life.

Appendix B: Water Properties

Water properties including temperature (℃), dissolved oxygen, conductivity, pH, and turbidity are commonly measured as a preliminary method of assessing the quality of fish habitat. Temperature and dissolved oxygen are of particular significance to fish - as increased temperatures and low dissolved oxygen are often associated with summertime fish kills (La 2011), a particular concern for sensitive cold-water species such as salmonids. Conductivity and turbidity measurements can act as proxies for total dissolved solids (TDS)

(Rusydi 2018) and total suspended solids (TSS) respectively (Rügner et al 2013). These parameters can be relevant as increased TDS and TSS in a body of water can indicate contamination from road salt, nutrients, or flushing of disturbed sediments into the waterway. Unusual conductivity measurements suggest the need for more in-depth analysis for contaminants (Ribeiro de Sousa 2014).

Appendix C: Coliform

Coliform bacteria have historically been used to gauge water quality with respect to implications for human recreational use and drinking water consumption (van Elsas et al. 2013). Most recently, the spotlight has been on counts (MPN of CFU) of the gram-negative coliform bacteria species *Escherichia coli* as an indicator of recent contamination with wastewater, and to determine the risk to human health posed by consumption and recreational use of waterways (Li 2021). There are no Environmental Quality Guidelines for coliform bacteria, reflecting the general idea that these potentially pathogenic bacteria are not likely to present a risk to aquatic life.

Appendix D: Nutrients

Nutrients such as nitrogen and phosphorus compounds can be naturally occurring, and are critical for the health and growth of plants and animals (CCME 2016). However, nutrients from fertilizers and wastewater that are released into a body of water can put it at risk of eutrophication - a process which is characterized by an overgrowth of plants and algae and resulting in oxygen depletion (Putt et al. 2019). Eutrophication poses a significant risk to aquatic life, as low oxygen levels create an inhospitable environment for the survival of fish - in particular salmonids who require relatively high levels of dissolved oxygen for survival and reproduction (Davis 1975).

In addition, some nutrients such as total ammonia are considered to be acutely toxic to freshwater fish species at concentrations that vary by pH and temperature of the water (CCME 2010).

Appendix E: Metals

Metals are present in aquatic environments as a result of both natural and anthropogenic sources, with baseline levels reflecting the unique geology of the area surrounding a body of water (Jadaa et al. 2023). Anthropogenic sources of metal contamination in waterways may originate from industrial effluent, municipal wastewater, agricultural practices, and urban runoff.

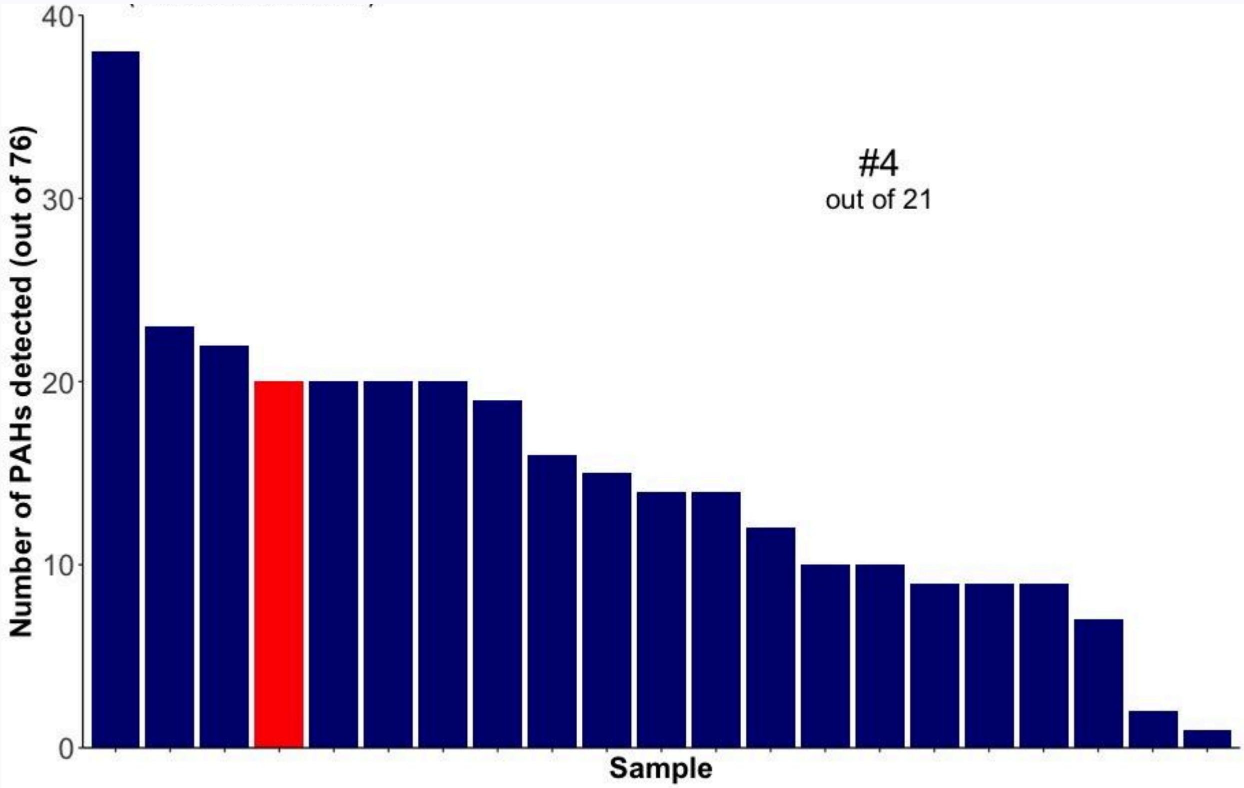
Many metals are capable of impacting the health of aquatic life, with some representing a priority concern in fish habitat, including zinc (Giardina et al. 2009) and copper (Malholtra et al. 2020).

Appendix F: PAHs

Polycyclic aromatic hydrocarbons (PAHs) are a complex group of compounds found in coal, petroleum and plant materials. They can enter waterways in the form of liquid petroleum products (gasoline, diesel, oil) or via the incomplete combustion of coal, oil, gas, wood garbage or other organic substances. They can occur naturally or as a result of human activities (anthropogenic). In Canada, forest fires are the single most important natural source of PAHs, while anthropogenic sources include residential wood heating, aluminum smelters, creosote-treated products, spills of petroleum products and metallurgical and coking plants (Marvin et al. 2021).

Hydrocarbons can enter aquatic ecosystems either directly through oil spills or discharges from vessels (Morales-Caselles et al. 2017) or indirectly through atmospheric deposition, runoff and discharge from wastewater treatment plants. Depending on their molecular size, PAHs vary in toxicity and have been classified as toxic under the Canadian Environmental Protection Act (CEPA).

Table 1F: Number of PAHs detected in water samples from Grafton Lake and 20 other source samples (DRY Season)



20 PAHs were detected in the source water from Grafton Lake (red bar), the fourth highest number of congeners detected amongst all source water samples.

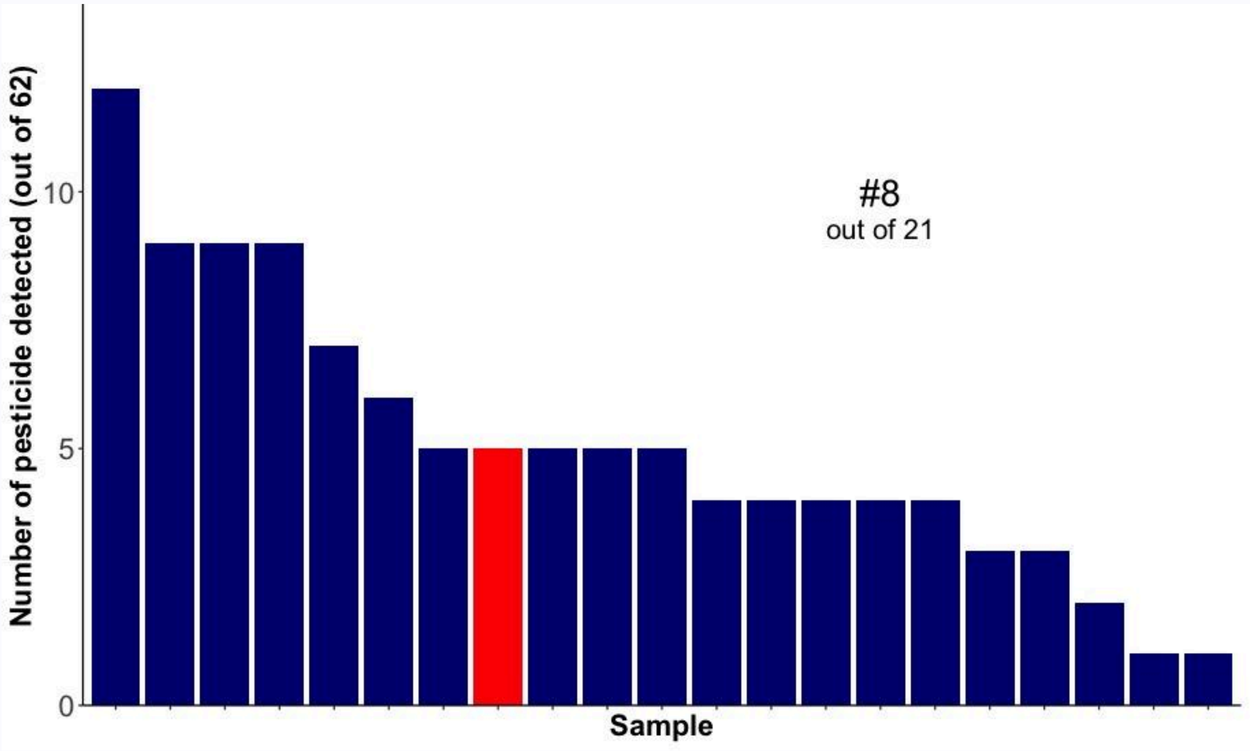
Appendix G: Pesticides

Pesticides have been developed to control, destroy or inhibit the activities of pests. They have a wide range of applications in agriculture such as insecticide to prevent crop damage and fungicides to prevent plant disease but also in forestry, industry as well as in our own backyards for lawn care or weed and insect control. In Canada, all pesticides used, sold or imported are regulated by Health Canada's Pest Management Agency (PMRA 2025).

While pesticides are mostly applied on terrestrial habitats, they can reach aquatic environments through overspray or drift during application, surface runoff, and through long range atmospheric transport and deposition. It is estimated that 10% of pesticides applied to soil reach non-target areas, leading to their widespread presence in surface waters worldwide (Schulz 2004; Anderson et al. 2022).

Organochlorine pesticides (OCP) were heavily used from the 1940s to the 1980s, but have been restricted due to their persistence, toxicity and potential for bioaccumulation. Current-use pesticides (CUPs) were subsequently favoured as an alternative to OCPs, and have been widely applied in recent decades (Ding et al. 2023). These tend to be more water-soluble and may be more mobile in fish habitat (Harris et al. 2008).

Table 1G: Number of pesticides detected in water samples from Grafton Lake and 20 other source samples (DRY Season)



Five pesticides were detected in the source water from Grafton Lake (red bar), the eighth highest number of pesticides detected amongst all source water samples.

Appendix H: PPCPs

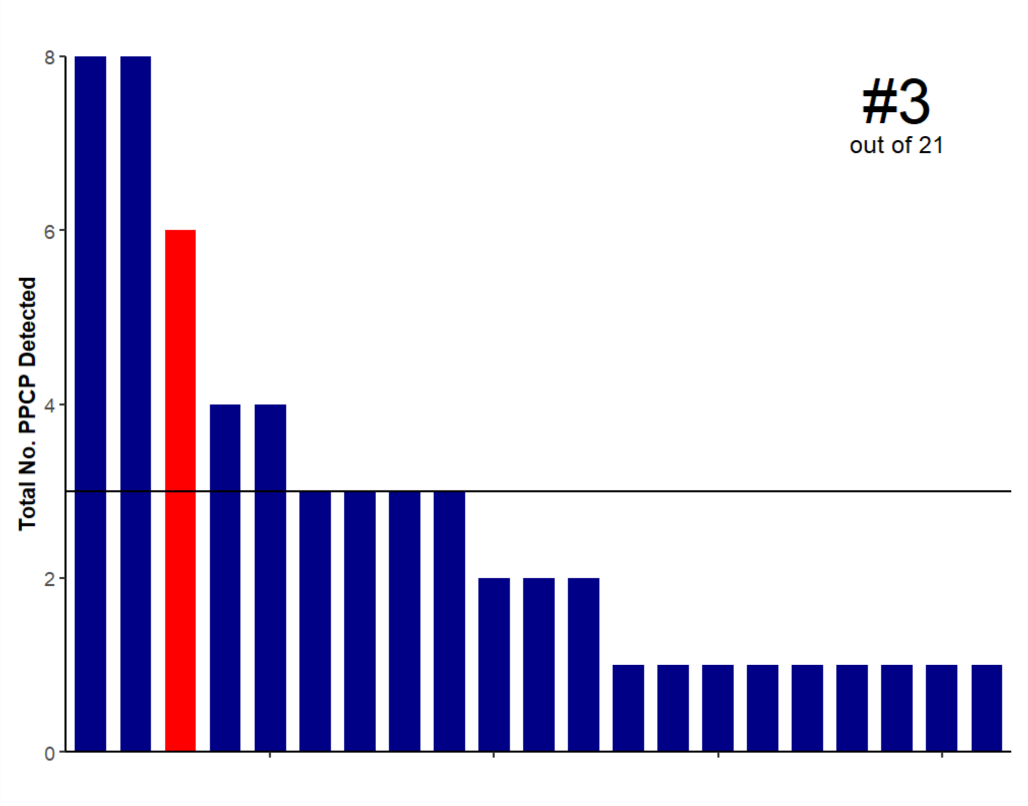
Pharmaceuticals and Personal Care Products (PPCPs) comprise a wide range of products and chemical formulations. The common link among these compounds is their use in human health, veterinary health and personal care. Many PPCPs are introduced into the environment via wastewater streams, and are not reliably removed during treatment at wastewater treatment plants (WWTPs).

Pharmaceuticals may enter the environment by way of WWTP effluent, land-applied biosolids and/or septic tank failures (Metcalfe et al 2004). Monitoring of source water is deemed an important means of assuring the safety of drinking water, especially First Nations (Schwartz et al. 2021). However, the lack of Environmental Quality Guidelines and Drinking Water Quality Guidelines in Canada for PPCPs and internationally constrains a fulsome risk-based evaluation of environmental concentrations (Lee and Choi 2019).

DEET (N,N-diethyl-meta-toluamide) is a widely used insect repellent. Metformin is a drug commonly prescribed for the treatment of diabetes and pre-diabetes, and functions to lower the blood glucose levels of users. Caffeine is a plant-derived stimulant found in widely-consumed beverages. Cocaine is a recreational drug, and co-occurs with its metabolic product benzoylecgonine. Cotinine is the metabolic breakdown product of nicotine.

Caffeine has been used as an indicator of human wastewater in the environment - as it is relatively stable and persistent in surface waters, but sucralose is increasingly used in its place.

Table 1H: PPCP counts for analytes detected in source water samples in all seasons (DRY Season)



Appendix I: PFAS

Per- and poly-fluoroalkyl substances (PFAS) are large group (~15,000 compounds) of human-made substances used in a wide variety of products such as food packaging, non-stick cookware, clothing, and cosmetics, but also lubricants, oil/water repellents, and notably - aqueous firefighting foams (AAAF; Barzen-Hanson et al. 2017). They are extremely stable and therefore persistent in the environment, which has led to the use of the term "forever chemicals" for this category of chemical.

PFAS can be released into the environment from point sources such as manufacturing plants, or sites where firefighting foams have been used. PFAS can also be released through consumer use and disposal of PFAS-containing products. PFAS has been found in all environmental compartments (Moller et al. 2010).

Evidence of adverse effects on the environment and on human health has led Canada to prohibit the manufacture, use, sale, offer for sale and import of a limited number of PFAS including perfluorooctanesulfonic acid (PFOS), perfluorooctanoic Acid (PFOA), long-chain perfluorocarboxylic acids and their salts and precursors under the *Prohibition of Certain Toxic Substances Regulations* and the *Canadian Environmental Protection Act* (CEPA). Advancing regulatory aspects pertaining to rapidly emerging concerns about the many PFAS being detected in the environment is a current priority in Canada (Longpre et al. 2020)

International Guidelines and emerging PFAS concerns

Since it takes many years to finalize guidelines and in light of increasing concerns over PFAS as a contaminant of concern has led to toxicity, Health Canada has also established screening values for nine PFAS (Appendix 4). These screening values provide guidance where there is a need for quick response. In addition, more recently, a 'proposed objective' of 30 ng/L for total PFAS was developed which set out a goal for a maximum level of PFAS in drinking water. This proposed objective is based on the sum of specific individual PFAS (25 individual PFAS that are quantified by US EPA methods 533 and 537.1). This objective, when finalized, will replace the two existing drinking water guidelines and nine screening values (Health Canada 2023).

There exist several thousand PFAS compounds, but only two are regulated in Canada: PFOA and PFOS, which were banned in 2011. Given the increasing concern over the presence, persistence and toxicity of per- and poly-fluoroalkyl substances (PFAS), Health Canada has developed screening values for a number of PFAS compounds. These are considered as approved guidelines for drinking water quality, and based on risk assessment approaches that are similar to formal guidelines (Health Canada 2023). They therefore serve as guidance when evaluating the risk of PFAS exposure from tap water consumption and are considered in the present report.

Given the limited guidance afforded by Canadian guidelines for the rapidly emerging PFAS concerns, we have included guidelines derived internationally for this contaminant class (USA, European Union and WHO).

Table 1I: Environmental Quality Guidelines for PFAS (Canada and USA)

Compound	Guideline (mg/L)	Issuing Agency	Notes
PFOS	0.0068	Canadian FEQG	EQG - PFOA under development
PFOS	0.0034	BC MoE	Working WQG
PFOS	3	US EPA	DRAFT EQG - Acute
PFOS	0.0084	US EPA	DRAFT EQG - Chronic
PFOA	49	US EPA	DRAFT EQG - Acute
PFOA	0.094	US EPA	DRAFT EQG - Chronic

Very few Environmental Quality Guidelines are available for PFAS. A Canadian Federal EQG was set for PFOS, while a guideline value for PFOA is currently in development.

Table 2I: Drinking Water Quality Guidelines for PFAS

Compound	Guideline (ng/L)	Issuing Agency	Notes
PFOS	600	Health Canada	
PFOA	200	Health Canada	
∑PFAS	30	Health Canada WQ Objective (2024)	Objective expected to become Guideline
PFOS	4	US EPA	
PFOA	4	US EPA	
PFHxS	10	US EPA	
PFNA	10	US EPA	

HFPO-DA	10	US EPA	
Total PFAS	500	EU - Drinking Water Directive	

Any "guidelines" which used other language, or which were not enforceable (recommended limits, etc.) were omitted from this table. Most available guidelines address the two PFAS compounds of greatest concern to human health: PFOA and PFOS.

TableTable 3I: Health Canada Screening values for nine different PFAS compounds

Compound Name	Acronym	Screening value (mg/L)	Screening value (ug/L)
perfluorobutanoate	PFBA	0.03	30
perfluorobutane sulfonate	PFBS	0.015	15
perfluorohexanesulfonate	PFHxS	0.0006	0.6
perfluoropentanoate	PFPeA	0.0002	0.2
perfluorohexanoate	PFHxA	0.0002	0.2
perfluoroheptanoate	PFHpA	0.0002	0.2
perfluorononanoate	PFNA	0.00002	0.02
6:2 fluorotelomer sulfonate	6:2 FTS	0.0002	0.2
8:2 fluorotelomer sulfonate	8:2 FTS	0.0002	0.2

Adapted from:
https://www.canada.ca/en/services/health/publications/healthy-living/water-talk-drinking-water-screening-values-perfluoroalkylated-substances.html

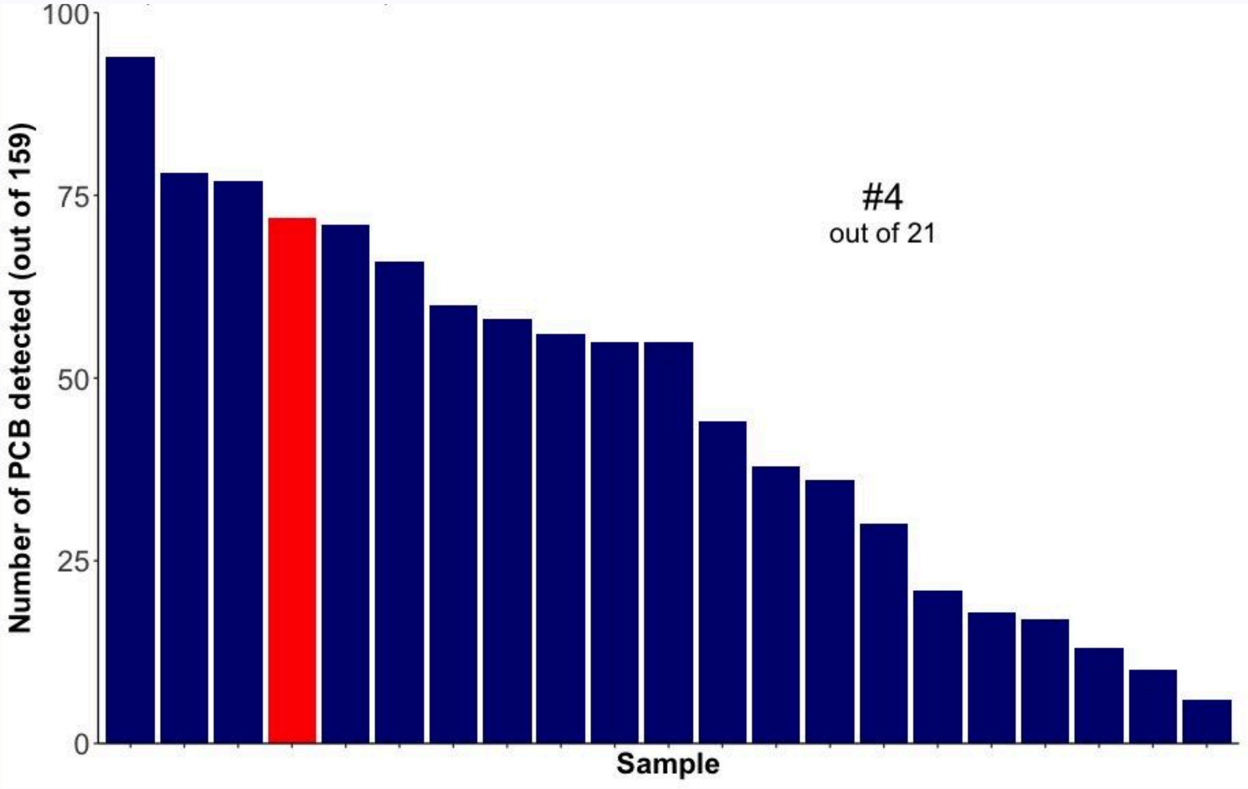
Appendix J: PCBs

Polychlorinated biphenyls (PCBs) comprise 209 congeners that are structurally related but have differing degrees of chlorination. The commercial production of PCBs began in 1929, after which they were heavily used in electrical and hydraulic equipment, as well as in paint additives, sealing and caulking compounds and inks. Due to their adverse health effects, the production of PCBs was banned in the late 1970s around the world (Othman et al., 2022). PCBs are among the first 12 Persistent Organic Pollutants (POPs) - often referred to as the "dirty dozen" - defined by the Stockholm Convention, an international treaty aimed at eliminating or restricting the production and use of POPs (Stockholm Convention 2025).

PCBs were never produced in Canada, but were widely used, and are currently specified on the List of Toxic Substances under the Canadian Environmental Protection Act (ECCC 2010). Despite restrictions beginning in 1977, PCBs continue to pose a threat due to their persistence in the environment and their release from products that were manufactured before the ban, and/or were improperly disposed of (Othman et al., 2022). Closed use applications in the electricity generation sector may continue in Canada until final phase out in December 2029 (ECCC 2023) . Military uses of PCBs may continue thereafter.

In British Columbia (BC), PCBs remain the number one contaminant of concern in marine food webs with the iconic killer whales being among some of the most-PCB contaminated marine mammals in the world (Ross et al., 2000). Regulatory steps in the 1970s and since have led to declining PCB concentrations in aquatic animals in BC (Ross et al., 2013).

Figure 1J: Number of PCB detections in source water samples from Grafton Lake and 20 other source samples (DRY Season)



72 PCBs were detected in the source water from Grafton Lake (red bar), the fourth highest number of congeners detected amongst all source water samples.

Appendix K: APEs

Alkylphenol ethoxylates are non-ionic surfactants used in industrial and consumer applications. APEs and their breakdown products are considered estrogenic and can disrupt reproductive development in fish. These surfactants can be released into the environment via municipal and industrial discharges (Lalonde et al. 2021). Once released, APEs may reside in aquatic sediments and/or undergo some breakdown into shorter chain APEs; their half-life is estimated at over 60 years (Shang et al. 1999).

The endocrine-disrupting potential of APEs and their breakdown products in fish and wildlife has represented a concern in receiving waters around municipal wastewater treatment plants (La Guardia et al. 2001).

Appendix L: Bisphenols

Bisphenols are used widely in the manufacturing sector, and are primarily used in the production of plastics and resins. Both single and multi-use plastic containers are frequently produced using bisphenol compounds, the most popular of which is Bisphenol A (BPA). Bisphenols are endocrine-disrupting chemicals that have been found to negatively impact reproductive development in fish, amphibians, and mammals (Faheem and Bhandari 2021; Marlatt et al. 2022).

BPA has come under intense regulatory scrutiny in recent years. The widespread use of these chemicals in food packaging, beverage containers, and in water delivery systems has led to exposure in the general population, and associations with adverse outcomes in humans (Rochester 2013).

Appendix M: Sucralose

Sucralose (*Splenda*) is an artificial sweetener used in the production of sugar-free food and beverage products. Its popularity and its resistance to breakdown during the wastewater treatment process have led to its adoption as a useful tracer of human wastewater infiltration (Oppenheimer et al. 2011). It is not generally considered to be toxic, such that its utility as a tracer provides an opportunity to better understand the source of other more harmful pollutants in a given body of water.

Sucralose is not fully metabolized by the human body following consumption, and is not removed during the wastewater treatment process. Therefore, its detection in environmental samples indicates the presence of treated or untreated sewage (van Stempvoort et al. 2020).

Appendix N: 6PPD-quinone

6PPD is an anti-ozonant chemical that is added to automotive tire rubber during the manufacturing process in order to extend the life of tires. When 6PPD comes into contact with air, it oxidizes and becomes 6PPD-quinone - a transformation product that in recent years was discovered to be lethal to Coho salmon (*Onchorhynchus kitsutch*) at low concentrations (Lo et al. 2023; Tian et al. 2021). 6PPD-Quinone is the causative agent of what has been deemed Urban Runoff Mortality Syndrome (URMS) - which has seen mortality rates of up to 90 percent. Research is being conducted to assess the risk to other fish species.

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