Chemical Contaminants in Lake Simcoe and its Tributaries
Fall 2023 and Spring 2024

Lake Simcoe Region
conservation authority

EXECUTIVE SUMMARY

In fall 2023 and spring 2024, studies were undertaken to investigate levels of chemical contaminants in the surface water and sediments of Lake Simcoe and its tributaries. The contaminants included in this study were chosen based on five criteria: 1) historical use within the watershed; 2) previous research undertaken (such as the previous LSRCA 2004 and 2015 studies); 3) literature from similar areas in the Great Lakes Region; and 4) analysis capabilities of commercial laboratories.

Seven contaminants were chosen: 1) organochlorine pesticides (OCPs), including DDT and its metabolites; 2) polychlorinated biphenyls (PCBs); 3) petroleum hydrocarbons (PHCs) and benzene, toluene, ethylbenzene, and xylene (BTEX); 4) semi-volatile organic compounds (SVOCs), including polycyclic aromatic hydrocarbons (PAHs); 5) phenols; 6) per- and polyfluorinated substances (PFASs); and 7) metals.

Generally, the contaminants recorded in the Lake Simcoe Watershed are the result of non-point anthropogenic sources (*e.g.,* fossil fuel combustion) and specific areas of industrial, urban, and agricultural land-use activities (*e.g.,* pesticides). Although some contaminants may be linked to current uses (*e.g.,* PHCs, PAHs), others are likely legacy contaminants (*e.g.,* OCPs) from historical activities.

Throughout the watershed, tributary waters contain fewer contaminants than their underlying sediments. Concentrations of contaminants in tributary waters were predominately lower in the spring than in the fall, presumably due to dilution associated with heavier flows. PCBs, BTEX, phenols, and PFAS were not detected at any tributary sites. Concentrations of heavy metals in urban tributaries and polder sites sometimes exceeded guidelines but fell below the Probable Effect Levels (PEL), meaning that the impact of these metals on biota is unclear. With one exception, polder sites tended to exhibit lower concentrations of PHC and PAH, but higher concentrations of OCP, than urban sites. Concentrations of DDD and DDE, derivates of DDT (a type of OCP), are high in the Holland Marsh, as has been reported in previous studies (LSRCA, 2020; Lembcke et al., 2011).

Analyses of contaminants from Lake Simcoe revealed elevated levels of PAHs and chromium in lake waters, and relatively high concentrations of PAHs and heavy metals in lake sediments compared to provincial and federal guidelines. Metal concentrations in lake sediments were particularly concerning, with heavy metals consistently exceeding the PEL in 2015, 2023, and 2024. Of note are cadmium levels in Kempenfelt Bay sediments, which were measured at 47x the PEL.

It is recommended that regular monitoring of specific contaminants (e.g. DDT and metabolites, cadmium, heavy metals) be undertaken more frequently, particularly in Lake Simcoe. Sampling should target areas of guideline exceedances such as urban centres (Aurora, Barrie, Newmarket), intensive agricultural areas (Holland Marsh and other polders), and Lake Simcoe (*e.g.,* Kempenfelt Bay and Cook’s Bay).

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LIST OF FREQUENTLY USED ACRONYMS AND ABBREVIATIONS

BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
F4G	F4 Gravimetric
ISQG	Interim Sediment Quality Guidelines
LSRCA	Lake Simcoe Region Conservation Authority
MECP	Ministry of the Environment, Conservation and Parks
OCPs	Organochlorine Pesticides
PAHs	Polyaromatic Hydrocarbons
PCA	Principal Component Analysis
PCBs	Polychlorinated Biphenyls
PEL	Probable Effect Levels
PFASs	Per- and Polyfluorinated Substances
PFCAs	Perfluorocarboxylic Acids
PHCs	Petroleum Hydrocarbons
POPs	Persistent Organic Pollutants
PTI	Pesticide Toxicity Index
PWQMN	Provincial Water Quality Monitoring Network
PWQO	Provincial Water Quality Monitoring Objectives
SOSSP	Southern Ontario Stream Sediment Project
SVOCs	Semi-Volatile Organic Compounds

1. INTRODUCTION

The sediment and surface water of aquatic systems can become polluted with harmful chemicals/substances, or *contaminants*, from natural and anthropogenic sources. Two classes of chemical contaminants to aquatic ecosystems are trace organic chemicals and trace elements (Manahan, 1994). Trace organic chemicals include organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs), per- and polyfluoroalkyl substances (PFASs), semi-volatile organic compounds (SVOCs), petroleum hydrocarbons (PHCs), and phenols. Trace elements of interest include heavy metals such as mercury, lead, cadmium, and chromium.

1.1 Trace organic chemicals

Some organic contaminants, called persistent organic pollutants (POPs), are degradation-resistant and persist in the environment for long periods. Examples of POPs include halogenated hydrocarbons (*e.g.,* PCBs) and OCPs. POPs that are no longer being actively discharged to the environment are termed legacy contaminants, meaning current concentrations are from past/historical uses of these contaminants. In Canada, these compounds include halogenated hydrocarbons and many OCPs (e.*g.,* dichlorodiphenyltrichloroethane, or DDT). Legacy OCPs are often associated with areas of intensive agriculture as they were used extensively as herbicides, insecticides, and fungicides in Canada from the 1940s until the 1970s.

Other POPs continue to be discharged, such as SVOCs, PHCs, BTEX, and PFASs. SVOCs and PHCs are components of fossil fuels and are ubiquitous in the environment. An important class of SVOCs are polyaromatic hydrocarbons (PAHs). Four types of PAHs which often co-occur with PHCs include benzene, toluene, ethylbenzene, and xylene (BTEX). Many PAHs, including BTEX, are thought to be carcinogenic. PFASs are a group of nearly 15 000 synthetic compounds used to make coatings that resist heat, oil, stains, grease, and water (CDC, 2022). PFASs do not degrade through normal chemical, physical, or biological processes, except to other PFASs (Gaines, 2022). Such resistance to degradation makes PFASs useful to industry but concerning as a pollutant.

While, on long timescales, POPs present the greatest risk to ecosystem health, short-lived organic contaminants are also concerning. Phenols are discharged from historical and modern industrial sources, including pulp and paper mills and sewage treatment plants. Fortunately, these compounds are water-soluble and readily biodegradable, so are only harmful on short timescales.

1.2 Trace elements

Metals occur naturally, distributed in rocks, soils, and water on the earth's surface, often in the form of minerals or other multi-element complexes. Metals are extracted, used for anthropogenic purposes, and are re-introduced into the environment from sources like industrial wastes. Heavy metals are metallic elements that have a relatively high density and are toxic at low concentrations, such as mercury and lead. Some heavy metals are essential elements for biological processes (*e.g.,* iron), while others are toxic (*e.g.,* cadmium). Both types of heavy metals can cause adverse effects in aquatic ecosystems under certain conditions. Trace metals occur at very low levels in the natural environment and include elements such as copper and zinc. As with heavy metals, some trace metals are essential to living things, but can be toxic in greater amounts.

1.3 Chemical contaminant sampling program in the Lake Simcoe watershed

The LSRCA's contaminant monitoring program was initiated in 2004 (LSRCA, 2006) and continued in 2015 (LSRCA, 2020). The purpose of these monitoring efforts was to assess the presence of a range of organic and metal contaminants in surface water and sediments to identify areas where concentrations were exceeding relevant guidelines.

The 2004 study focused mainly on the polders and did not include any lake sites. The 2015 study re-sampled some of these polder sites and added additional sites in and around Lake Simcoe. In 2023, the contaminants survey was expanded again to include additional tributary and lake sites (Table A-1). For the first time, per- and polyfluoroalkyl substances (PFASs) were analyzed in tributary waters. The 2024 study replicated the 2023 study, but with fewer sites (Table A-2) and targeting areas of interest from 2023. In total, 641 samples were collected for the fall 2023 and spring 2024 contaminants surveys (not including replicate and quality control samples).

2. STUDY OBJECTIVES

This study investigated the levels of chemical contaminants in the surface water and sediments of Lake Simcoe and its tributaries. Sampling was guided by three objectives:

A. Identify what contaminants are present in the surface waters and sediments of Lake Simcoe and its tributaries.
B. Compare measured contaminant concentrations with available guidelines to assess which compounds are most likely to threaten ecosystem and/or human health.
C. Assess intra- and interannual variations in contaminant concentrations within the Lake Simcoe watershed.

3. METHODS

3.1 Sample locations

Sites were selected in urban tributaries of Aurora, Barrie, Innisfil, Newmarket and Orillia (Fig. 1, Table A-1, Table A-2). Agricultural tributary sites included West Holland River, with a focus on Holland Marsh and other polders, as well as the Black, Maskinonge and Beaver rivers. Sites in Lake Simcoe, downstream of these areas, were also targeted. Areas minimally impacted by urbanization and agriculture were assessed to gain an understanding of how underdeveloped sites might differ from developed areas. These underdeveloped sites included Hawkestone Creek and lake sites adjacent to the Oro Creeks South subwatershed and Talbot River. As described in Section 4.5, some sites were selected to replicate previous sampling conducted by the Southern Ontario Stream Sediment Project (SOSSP). In total, 38 tributary sites and 16 lake sites were sampled.

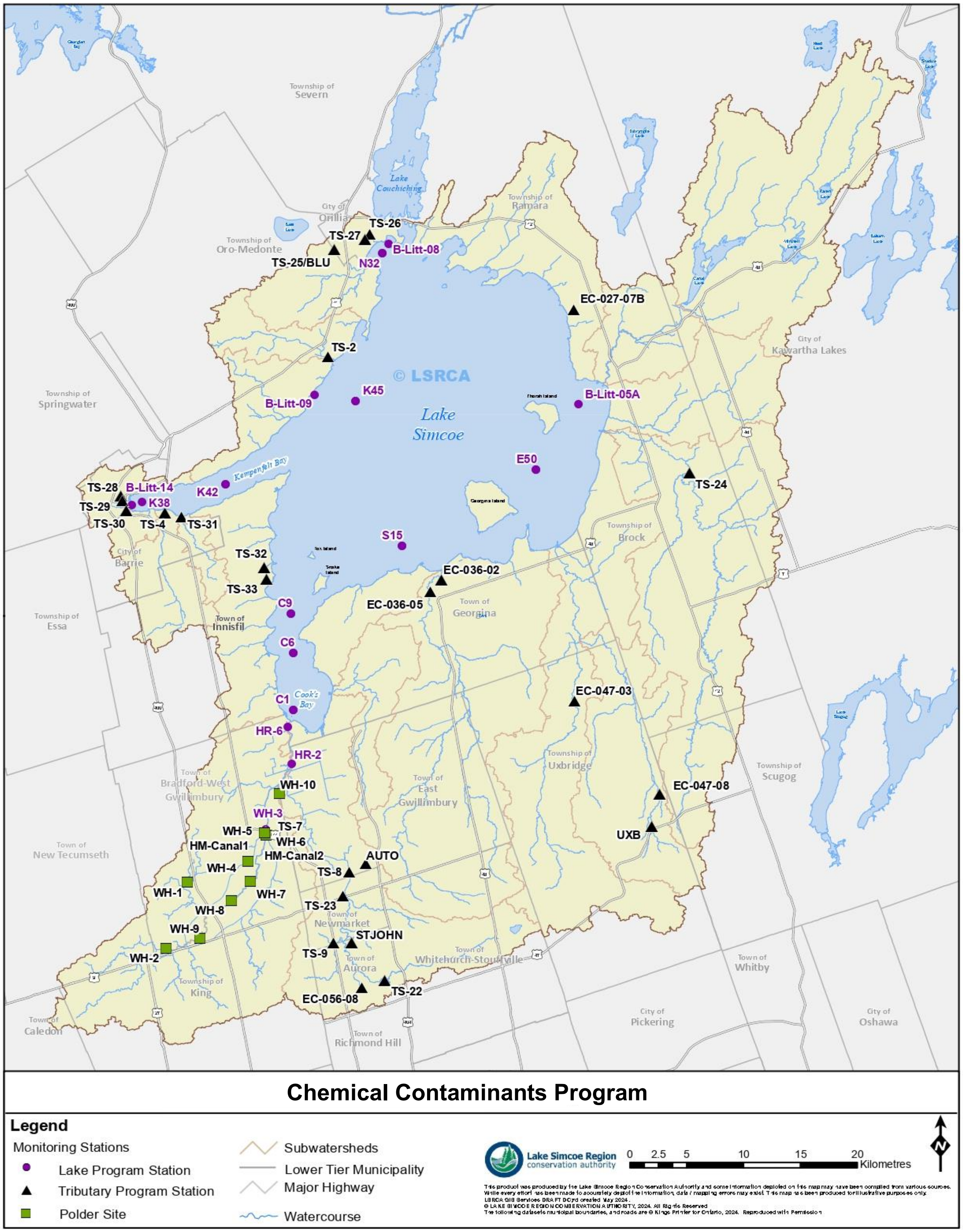

Figure 1. Map showing the sampling locations for the Fall 2023 and Spring 2024 contaminants survey.

3.2 Sampling period and protocols

Tributary/polder water samples were collected in 2023 on October 10, 17, 18, 23, and 24 and in 2024 on March 19-20. Water was collected using an extendable pole fitted with a 500-ml polyethylene (PET) bottle or a drop bucket (*e.g.,* for sampling water from bridges). Water samples for trace metal analysis were filtered through an 80 μm mesh filter. The filter was changed between sites. Samples were kept chilled at 4 ^{o}C until analysis.

Tributary/polder sediment samples were collected using a stainless steel Eckman Grab Sampler, or a scoop. The scoop was used in instances where high flow, or rocky sediments, made sampling with the Eckman challenging. In either case, the top 5-15 cm of sediment was collected at each site and scooped into a glass jar provided by the analysis lab. As with water samples, sediment was kept on ice at ~4 ^{o}C for transport to the lab. Large pieces of organic debris (*e.g.,* twigs, leaves, mussels, snails) were removed from the sampled sediment using a gloved hand. After the collection for each site, the dredge samplers were rinsed several times with source water, followed by rinses with distilled water.

Lake water and surface sediment samples were collected on October 2-3, 2023 and April 16, 2024. In this report, samples from the Holland River are treated as "lake" samples since these sites are sampled by boat alongside the other lake samples and closely resemble samples from Cook's Bay. Water was collected from a depth of 2 m (or 1 m for Holland River sites) below the surface using a Van Dorn Beta^{TM} Horizontal Bottle Sampler (Wildco) and poured into glass bottles/vials supplied by the analysis lab. All waters were unfiltered except for one aliquot used for the analysis of metal concentrations, which was filtered with an ~80 μm filter. Sediment samples were collected at each site using a petite Ponar grab sampler (Wildco). Sediment was roughly homogenized by stirring and then placed in 500 mL glass jars. Water and sediment samples were kept on ice at ~4 ^{o}C for transport to the analysis lab.

3.3 Chemical analysis

Caduceon Environmental Laboratories analyzed all samples, except those analyzed to determine their pre- and polyfluorinated substance (PFAS) content. Caduceon subcontracts analyses of PFASs to ALS Canada Ltd. ALS analyzes 40 PFAS analytes in water using LC-MS/MS analysis with Multiple Reaction Monitoring (MRM) according to the US EPA's Method 1633. More information on this method can be found on ALS's website: https://www.alsglobal.com/.

3.4 Sediment and water quality guidelines

Results from water samples were compared to Provincial Water Quality Objectives (PWQO; MECP, 2019a) and Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQG; CCME, 2014). The PWQO were developed to protect and preserve aquatic life and the recreational potential of surface waters within Ontario. The CWQG were developed to protect aquatic species by establishing acceptable levels for substances, or conditions that affect water quality, and are based on toxicity data for the most sensitive species of plants and animals found in Canadian waters.

Sediment results were compared to the Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (CSeQGs; CCME, 2014) and the Reg. 153/04 (Table 1)[1] standards contained in the Soil, Groundwater and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act (MECP, 2019b). The CSeQGs protect aquatic organisms that live on or in lake or river. The Interim Sediment Quality Guidelines (ISQGs) and Probable Effects Levels (PELs) were used as comparative criteria. Sediment chemical concentrations below the ISQGs are not expected to result in any adverse biological effects. Concentrations above the PELs are expected to be frequently associated with adverse biological effects. Chemical concentrations between the ISQGs and PELs represent the range in which effects are occasionally observed. The use of these two values is a practical means of assessing potential toxic concerns at sites. For parameters where an ISQG or PEL guideline is not available the Table 1 standards are utilized. The Reg. 153/04 (Table 1) standards are adverse effects-based values that are within the range of measured background sediment and are considered to provide a level of ecosystem protection.

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[1] Here, “Table 1” refers to the table within the guideline, not a table within this document.

4. RESULTS AND DISCUSSION

4.1 Organochlorine pesticides (OCPs)

Organochlorine pesticides (OCPs) are synthetic chemical compounds used as herbicides, insecticides, and fungicides because of their potent toxicity to pests. The legacy OCP of greatest concern in the Lake Simcoe watershed is the banned insecticide dichlorodiphenyltrichloroethane (DDT) and its derivatives, 1,1-dichloro-2,2-bis-(p-chlorophenyl)ethane (DDD) and 1,1-dichloro-2,2-bis-(4-chloro -phenyl)ethane (DDE). Previous studies from the LSRCA detected DDT, DDD, and DDE in the Holland Marsh at high concentrations relative to other agricultural areas in the U.S. and Canada (*e.g.,* Chaudhuri et al., 2017; CCME, 1999d).

From ~1955 until the banning of DDT in the early 1970s, DDT was sprayed in the Holland Marsh two to four times per year (Miles and Harris, 1978). Breakdown of DDT and its metabolites may be slower in the Holland Marsh compared to other impacted sites because the muck soils could theoretically sequester DDT, inhibiting biodegradation (Aigner et al., 1998). Lembcke et al. (2011) concluded that fish at higher trophic levels may be taking up enough DDT in the vicinity of the Holland Marsh to exceed Canadian consumption guidelines for wildlife of fish tissues (CCME, 1999g; Lembcke, 2011), thus posing a risk to piscivorous birds, mammals, and recreational fish species. In most cases, DDT slowly breaks downs into DDD and DDE (ATSDR, 2002a).

Other legacy OCPs previously detected in the Lake Simcoe watershed include chlordane, aldrin, dieldrin, and endosulfan. Chlordane, aldrin, dieldrin, eldrin, and endosulfan are insecticides and persistent organic pollutants (POPs), that are banned in Canada due to their threat to human and ecosystem health. Aldrin, dieldrin, and chlordane are potential carcinogens and neurotoxins, while endosulfan is a neurotoxin and endocrine disruptor. Aldrin and dieldrin were phased out in Canada by 1984, while chlordane and endosulfan were banned or phased out by 2003 and 2016, respectively.

Modern OCPs of interest include the herbicides metolachlor, picloram, linuron, chlorthal dimethyl, 2,4-D, mecoprop (MCPP-p acid), MCPP, MCPA, clopyralid, dicamba, and triclopyr. These compounds are generally less toxic to human health and the environment than the legacy OCPs listed above so long as concentrations remain below federal/provincial guidelines.

4.1.1 OCPs in water

The Ministry of the Environment, Conservation and Parks (MECP) analyzed the pesticide and herbicide content of water samples from the Holland Marsh as part of the Provincial Water Quality Monitoring Network (PWQMN). From 2018-present, 32 samples from the Holland Marsh were analyzed to determine their pesticide and herbicide contents (Raby et al., 2022). The authors found that, of the 21 study sites sampled across Southern Ontario, the Holland Marsh had the second highest number of detected pesticides (median 13 pesticides). The MECP used these data to calculate the Pesticide Toxicity Index (PTI) for the Holland Marsh, according to the methods described in Nowell et al. (2014). These PTI calculations revealed that the pesticide load of Holland Marsh waters is not toxic to fish, cladocerans or algae. However, the PTI of 18 % of samples exceeded the threshold for chronic toxicity to benthic invertebrates (Raby et al., 2022).

In light of these findings, our spring 2024 sampling included analyses of OCP in water at three tributary sites, and one lake site: Upper Schomberg River at Leonard Road (WH-2), West Holland River at Bridge St. (TS-7), the Maskinonge River (MASK), and K-38 (Lake Simcoe, main basin) (Table 1, Table A-1, Table A-2). Sites WH-2 and TS-7 were chosen because they are situated at the upstream and downstream ends of the Holland Marsh, respectively, and the Holland Marsh is a known hotspot for OCPs. MASK was sampled because no OCP sampling has ever occurred there, either in sediment or water. K-38 was selected because it represents overall conditions in the lake. Ultimately, no OCPs were detected in the water of these sites. OCPs were not measured in surface waters before spring 2024.

Table 1. OCPs, PCBs, and select non-chlorinated pesticides/herbicides analyzed in surface water and sediment samples in fall 2023 and spring 2024.

OCP components (and select non-chlorinated pesticides/herbicides) analyzed in surface waters (excluding analyses by the MECP)	**OCP and PCB components analyzed in sediments**
Alachlor	Poly-Chlorinated Biphenyls (PCB)
Atrazine	Aldrin
Atrazine (Desthyl)	Chlordane (alpha)
Atrazine + N-dealkylated metabolites	Chlordane (gamma)
Azinphos-Methyl	Chlordane (Alpha + Gamma)
Bromoxynil	DDD (Total)
Carbaryl	DDE (Total)
Carbofuran	DDT (Total)
Chlorpyrifos	Dieldrin
Diazinon	Endosulfan (Total)
Diclofop-Methyl	Endrin
Dichlorophenol,2,4-	Heptachlor
Dimethoate	Heptachlor Epoxide
Diuron	Heptachlor + Heptachlor Epoxide
Malathion	Hexachloroethane
Metolachlor	Hexachlorobutadiene
Metribuzin	Hexachlorobenzene
Pentachlorophenol	Lindane (Hexachlorocyclohexane, Gamma)
Phorate	Methoxychlor
Picloram	
Prometryne	
Simazine	
Terbufos	
Tetrachlorophenol,2,3,4,6-	
Triallate	
Trichlorophenol,2,4,6-	
Trifluralin	

4.1.2 OCPs in sediments throughout the watershed

In fall 2023, surface sediments from 22 tributary and polder sites were sampled for OCPs, while nine lake sites were sampled for OCPs. This sampling effort targeted areas of intensive agriculture, including the vegetable polders and downstream lake areas. In spring 2024, OCP sampling targeted 12 polder sites and six lake sites, for reasons explained below.

4.1.2.1 Tributary sites

No DDT was detected at any tributary or lake sites in spring 2023 or fall 2024. However, DDT degradation products, DDD and DDE, were detected in both years. In fall 2023, DDD and/or DDE were detected at 5/22 (23 %): tributary/polder sites, all in the Holland and Colbar marshes: WH-5 (Inner

Canal, Bradford Pumping Station #2, Holland Marsh), WH-7 (Inner Canal, end of Keele Lane, Holland Marsh), WH-8 (Inner Canal, Wanda and Devald, Holland Marsh), WH-9 (Inner Canal, River Road, Holland Marsh), and WH-10 (Colbar Marsh, ditch along Bathurst St.).

Total DDD concentrations at each of these five polder sites ranged from 0.11 to 0.48 μg/g, greatly exceeding all available guidelines for total DDD in freshwater sediments (Reg. 153/04 (Table 1) = 0.008 μg/g; ISQC = 0.00354 μg/g; PEL = 0.00851 μg/g) (Table 2). Likewise, total DDE concentrations ranged from 0.26 to 0.67 μg/g, greatly exceeding all available guidelines for total DDE in freshwater sediment (Reg. 153/04 (Table 1) = 0.005 μg/g; ISQC = 0.00142 μg/g; PEL = 0.00675 μg/g). OCP were not detected in tributary sites outside of the polders.

Table 2. OCP concentrations measured in sediments during the fall 2023 sampling campaign. Non-detects are not shown. Only results exceeding Reg. 153/04 (Table 1) guidelines are shown. Bolded results exceed Interim Sediment Quality Guidelines (ISQG) for DDD and DDE in freshwater sediment. Italicized results also exceed Probable Effect Levels (PEL) for DDD and DDE.

Site	**DDD (Total) (μg/g)**	**DDE (Total) (μg/g)**
Reg. 153/04 (Table 1)	0.008	0.005
ISQG	0.00354	0.00142
PEL	0.00851	0.00675
WH-5	***0.39***	***0.62***
WH-7	***0.11***	***0.28***
WH-8	***0.21***	***0.50***
WH-9	***0.25***	***0.26***
WH-10	***0.48***	***0.67***

Since OCP were not detected outside of the polders in 2023, only the polders were sampled for OCP analysis in spring 2024 (Table 3). This time, DDD and/or DDE were detected at 8/12 polder sites (67%): WH-10, WH-5, WH-6 (Professor Day Pumphouse, ditch alongside Bradford Marsh) WH-7, WH-8, WH-9, HM-Canal 2 (Western outer canal in the Holland Marsh, near WH-6), and TS-7 (West Holland River, bridge at Hwy 11). Total DDD concentrations at each of these five sites ranged from 0.08 to 0.45 μg/g, while total DDE ranged from 0.09 to 0.45 μg/g, which is similar to the concentrations measured in Fall 2023 (Table 2).

Although only DDD and DDE were detected in fall 2023, dieldrin was detected at HM-Canal 2 (0.06 μg/g) in Spring 2024 at concentrations exceeding Reg. 153/04 (Table 1) guidelines, Interim Sediment Quality Guidelines (ISQG), and Probable Effect Levels (PEL) (0.002 μg/g, 0.00285 μg/g, and 0.00667 μg/g, respectively) (Table 3). Differences in OCP content in fall 2023 and spring 2024 have yet to be understood and may simply reflect the spatial heterogeneity of OCP in sediments within each site.

Table 3. OCP concentrations measured in sediments during the spring 2024 sampling campaign. Non-detects are not shown. Only results exceeding Reg. 153/04 (Table 1) guidelines are shown. Bolded results exceed ISQG guidelines for DDD, DDE, and dieldrin in freshwater sediment. Italicized results also exceed PEL guidelines for DDD, DDE, and dieldrin for freshwater sediment.

Site	**DDD (Total) (µg/g)**	**DDE (Total) (µg/g)**	**Dieldrin (µg/g)**
Reg. 153/04 (Table 1)	0.008	0.005	0.002
ISQG	0.00354	0.00142	0.00285
PEL	0.00851	0.00675	0.00667
WH-5	***0.24***	***0.27***	
WH-6		***0.10***	
WH-7	***0.28***	***0.24***	
WH-8	***0.08***	***0.18***	
WH-9	***0.24***	***0.31***	
WH-10	***0.30***	***0.32***	
HM-Canal1		***0.10***	
HM-Canal2	***0.45***	***0.45***	***0.06***

Monitoring in 2004, 2015, 2023, and 2024 indicates that the polders (especially the Holland Marsh) are a hotspot for OCP contamination. However, the exact species of OCP detected have differed from year to year. A major difference between the 2004 and 2015 surveys, and the 2023 and 2024 surveys, is that DDT was detected in sediments in 2004 and 2015, but not in 2023 or 2024. These results suggest that DDT has degraded over the years to DDD and DDE. However, it is also possible that sediments contaminated with DDT were present, but were not sampled, or that DDT is present but at levels below the detection limit. Additional monitoring is needed to verify that DDT has degraded in the watershed.

Aldrin, endosulfan, and chlordanes were not detected in 2023 or 2024. However, aldrin, dieldrin, and endosulfan were detected in 2004 and 2015. This discrepancy could be due to higher detection limits in 2023 and 2024 relative to 2004 and 2015. Chlordanes were detected at the Holland Marsh outlet (WH-5) in 2004, but not in 2015, even though detection limits were slightly lower in 2015 than in 2004. Chaudhuri et al. (2017) found higher levels of chlordanes in the Lake Simcoe watershed, often exceeding the ISQG guidelines in more urbanized areas (e.g. Aurora and Uxbridge). They noted that this was common throughout the province, where chlordane, unlike other OCPs, was higher in areas of higher population density rather than agricultural areas. It is recommended that OCP concentrations continue to be monitored in the polders, especially in the Holland Marsh.

4.1.2.2 Lake sites

OCPs were not detected at any lake sites sampled in fall 2023 or spring 2024. In fall 2023, nine lake sites were sampled for OCPs, including areas downstream of the vegetable polders (Holland River and Cook's Bay), the Kempenfelt Bay, and one site in the main basin of Lake Simcoe. In spring 2024, six lake sites were sampled for OCPs, including two in the Kempenfelt Bay, one in Cook's Bay, one near Orillia, and two in the main basin. In 2015, DDE and/or DDD were detected at five sites in Cook's Bay and the

Holland River, but aldrin, dieldrin and endosulfan were not detected at lake sites. Lower detection limits for OCPs in 2015 relative to 2023 or 2024 could explain this discrepancy. Lake sites were not sampled in 2004.

4.1.3 Summary and recommendations

- Monitoring of pesticides and herbicides by the MECP has demonstrated that the Holland Marsh is a hotspot for pesticide/herbicide contamination.
- Although DDT can no longer be detected in the Lake Simcoe watershed, its degradation products, DDD and DDE, continue to contaminate surface sediments, particularly in the polders.
- Tests for trace concentrations of DDT are needed to evaluate whether DDT has left the watershed.
- Concentrations of DDD and DDE consistently exceeded PEL for freshwater sediments, indicating that levels are sufficiently high to cause adverse biological effects.
- One sample contained levels of dieldrin that exceeded PEL. Additional sampling is needed to confirm this result.
- OCPs were not detected in Lake Simcoe sediments in 2023 or 2024.

4.2 Polychlorinated biphenyls (PCBs)

PCBs (marketed under the trade name “Aroclor”) are a group of synthetic chlorinated organic compounds used historically for hundreds of industrial and commercial purposes (*e.g.,* for dielectric and coolant fluids in electrical equipment, as plasticizers in paint). Bans and restrictions were placed on PCBs in the late 1970s in North America but environmental problems continue because of their persistent and toxic nature. Most PCBs that enter the aquatic environment are adsorbed to sediments.

In 2023, the sediments of 22 tributary/polder sites, and nine lake sites, were analyzed for PCBs. No PCBs were detected. Thus, PCBs were not analyzed in spring 2024. A table listing PCB components analyzed is not included here because total PCBs were measured, not individual components.

In 2015, the sediment of 12 tributary sites and nine lake sites were analyzed for PCBs. A total PCB guideline exceedance occurred at one lake site near Barrie in Kempenfelt Bay (B-LITT-14 at 0.160 μg/g), and for Aroclor 1254, a constituent of total PCBs, at one tributary site (Beaver River; TS-24; 0.054 μg/g; total PCBs guideline = 0.0341 μg/kg). In 2004, sediments from 13 tributary/polder sites were analyzed to determine their PCB contents, but no PCBs were detected.

In another study, Helm et al. (2011) reported PCBs, including one exceedance of the total PCB guideline in Kempenfelt Bay sediment collected in 2008, which they attributed to historical uses. Lower concentrations were reported in Cook’s Bay and the Main Basin that were attributed to atmospheric deposition from regional air masses. Chaudhuri et al. (2017), in an Ontario-wide study, investigated PCBs in the sediment of some Lake Simcoe tributaries in 2008/2009 and found that Tannery Creek (in Aurora) had PCB levels that exceeded the ISQG guideline, noting that PCBs tended to be elevated in association with higher population density and urbanization.

4.2.1 Summary and recommendations

- Although PCBs were previously detected in the Lake Simcoe watershed, they were not detected in fall 2023.
- Future PCB monitoring should target urban areas.

4.3 Petroleum hydrocarbons (PHCs) and benzene, toluene, ethylbenzene, and xylene (BTEX)

PHCs are found in fuel (*e.g.,* for gasoline and home heating), plastics, tires, and fertilizers (Petroleum.co.uk, 2015). Contamination from PHCs is one of the most common types of soil and groundwater pollution in Canada (Canadian Council of Ministers of the Environment (CCME), 2014). Mixtures of PHCs can contain various constituents with a wide range of chemical structures and properties, so different PHC mixtures vary considerably in their bioavailability, toxicity, and persistence.

PHC mixtures are typically comprised of hundreds of components, so it is impractical to measure the toxicity of each component. Thus, components with similar numbers of carbon atoms are analyzed as a group. These groups, or “fractions”, have been identified by CCME (2001b): Fraction 1 (6-10 carbon atoms) is found in gasoline; Fraction 2 (10-16 carbons) is found in diesel, kerosene, and creosote; Fraction 3 (16-34 carbons) is found in heavier diesel, lubricating oils, and polycyclic aromatic hydrocarbons (PAHs); and Fractions 4 (34-50 carbons) and 4G (50+ carbon atoms) are found in lubricating oils, fuel oils, and asphalt.

Fractions 2, 3, 4 and 4G were analyzed in this study. Fraction 2 is a semi-volatile group and can be soluble. Fraction 3 has PHCs of low volatility and solubility and can contain PAHs. Natural hydrocarbons (*e.g., n*-alkanes) derived from plants and algae can be erroneously measured in this fraction, inflating the quantity of measured PHCs (O’Sullivan et al., 2010). Fractions 4 and 4G are heavy with low solubility giving them a propensity to sink in water. Heavier PHCs have low volatility, do not degrade easily, and bind with organic matter. With these characteristics, they tend to build-up in sediments.

Benzene, toluene, ethylbenzene, and xylene (BTEX) are a class of volatile organic compounds (VOC) that often co-occur with PHCs. They usually originate from vehicular exhaust, gas stations, industrial activity, landfill sites, municipal solid waste stations, and combustion for domestic heating (Dehghani et al., 2018). Many BTEX are known carcinogens (Dehghani et al., 2018) and have toxic effects on biota (Salahova et al., 2017).

4.3.1 Surface water results

In fall 2023, PHCs were only identified above detectable levels in Mill Creek, Orillia, perhaps due to the industrial operations situated upstream of the site (Table 4). However, PHCs were not detected at Mill Creek in spring 2024, so it is unclear whether the PHC detection in 2023 was spurious or whether there are seasonal differences in the delivery of PHCs to Mill Creek.

Table 4. PHCs detected in tributary/polder waters in fall 2023. Non-detects are not shown. No PHCs were detected in surface waters in Spring 2024.

Site	PHC F2 (>C10-C16) (μg/L)	PHC F3 (>C16-C50) (μg/L)
TS-26	54	663

In a previous study (LSRCA, 2006), PHCs (reported as Total Extractable Hydrocarbons (TEH), heavy diesel in fraction 3) were detected at Tannery Creek in Aurora (TS-9) during one rain event sample, perhaps delivered via surface run-off. Conversely, the LSRCA's 2015 contaminants survey did not find PHCs above detectable levels in any water samples from the tributaries or lake (LSRCA, 2020).

The Ontario Reg 153/04 (Table 1), Interim Sediment Quality Guidelines (ISQG), and Probable Effect Levels (PEL) do not include guidelines for PHC concentrations in surface waters. Likewise, there are no Provincial Water Quality Objectives (PWQO), or Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQG), limits for PHCs in freshwater. The PWQO states that oil or petrochemicals should not be present in concentrations that: 1) can be detected as a visible film, sheen, or discolouration on the surface; 2) can be detected by colour; 3) can cause tainting of edible aquatic organisms; 4) can form deposits on shorelines and bottom sediments that are detectable by sight or odour, or are deleterious to resident aquatic organisms. Such sightings are rare in the Lake Simcoe watershed.

In 2023 and 2024, samples analyzed for PHCs were also analyzed for BTEX. BTEX were not identified in any water samples collected during the fall 2023 or spring 2024 surveys.

4.3.2 Sediment sample results

4.3.2.1 Tributary/polder sites

In fall 2023, PHCs were detected in sediment from 20/28 (71 %) polder/tributary sites, mostly corresponding to urbanized or intensive agricultural land use areas (Table 5). The highest levels of PHCs (mostly F3 through F4G) were found in Barrie and Newmarket, with other detections occurring in Innisfil and the vegetable polders. The F2 fraction was not detected at any sites in fall 2023, although it was detected in previous years (*e.g.*, at Mill Creek in 2015).

Table 5. PHCs detected in sediments during the Fall 2023 contaminants sampling campaign. Non-detects are not shown.

Site	PHC F3 (>C16-C34) (μg/g)	PHC F4 (>C34-C50) (μg/g)	PHC F4 (Gravimetric) (μg/g)	PHC F4 (Gravimetric) Silica Gel Cleaned (μg/g)
WH-1	28	27	264	88
WH-2	17			
WH-3	95	25		
WH-5	81			
WH-6	34			
WH-8	17			
WH-9	12	34	439	116
BLU	11			
TS-7	58			
TS-8	13			
TS-9	64	98	126	
TS-23	28	96	981	438
TS-24		31	15	
TS-27	10			
TS-28	21	23		
TS-29	34	35	428	270
TS-30	65	87	1110	488
TS-31	14			
TS-32	15			
TS-33	28	46	446	233

In spring 2024, six additional sites were monitored for PHCs: Uxbridge (UXB), the Maskinonge River (MASK), Bluffs Creek (BLUFFS), North Newmarket (AUTO), and the Pumphouse (HM-Canal1 and HM-Canal2). PHCs were detected at all sites and at higher concentrations relative to the Fall 2023 results (Table 6). In 2024, the spatial variations in PHC concentrations mirrored those in fall 2023. However, the Mill Creek sites exhibited much higher PHC concentrations in spring 2024, with F4 concentrations reaching 8000 μg/g at TS-27 and 10 200 μg/g at TS-26. Unlike in Fall 2023, the F2 fraction was detected at five sites: WH-6 (Professor Day Pumphouse, Holland Marsh); TS-31 (Hewitts Creek, Barrie); BLU (Bluff's Creek, Orillia); TS-26 and TS-27 (Mill Creek, Orillia); and TS-24 (Beaver River, Beaverton).

Table 6. PHCs detected in sediments during the spring 2024 contaminants sampling campaign. Non-detects are not shown.

Site	PHC F2 (>C10-C16) (µg/g)	PHC F3 (>C16-C34) (µg/g)	PHC F4 (>C34-C50) (µg/g)	PHC F4 (Gravimetric) (µg/g)	PHC F4 (Gravimetric) (Silica Gel Cleaned) (µg/g)
WH-1		17		439	208
WH-2		48	15	648	278
WH-4		12		237	91
WH-5		37		570	253
WH-6	11	140	76	2510	1400
WH-7		34		1080	481
WH-8		59	16	1360	606
WH-9		29		577	311
WH-10		43	15	6830	3320
HM-Canal1				304	133
HM-Canal2	7	76	28	2670	1330
BLU		47	21	1050	571
TS-2				116	58
TS-4				254	98
TS-7		151	47	1900	893
TS-8		42	38	715	339
TS-9		58	47	843	410
TS-22				259	100
TS-23		127	132	1560	858
TS-24		14	731	499	262
TS-26	14	1240	631	10200	4890
TS-27		804		8000	3190
TS-28	6	20		617	318
TS-29		218	148	1660	828
TS-30		54	47	575	287
TS-31	5	61	24	883	429
TS-32				140	60
TS-33		94	163	945	422
STJOHN		170	141	1490	774
AUTO		103	77	1350	729

The drivers of these seasonal differences are not fully understood and warrant further investigation. Since samples in both campaigns were collected using the same staff and the same methodology – and samples were analyzed using the same laboratory – it is likely that these variations represent real differences in PHC concentrations rather than sampling or analytical artifacts. The most obvious difference between fall and spring is that the spring freshet increases overland flow, accelerating the delivery of PHC-rich suspended particles to tributaries (Pham et al., 1993; Chambers et al., 2018; Marvin et al., 2021).

While, in spring 2024, we did not detect PHCs in any water samples, we purposely avoided sampling on rainy/stormy days to gain a better understanding of background contaminant concentrations. Thus, it is likely that we missed periods of rapid PHC delivery to the tributaries. Zhao et al. (2015) observed that spring PHC concentrations were low in waters but high in sediments. They attributed this phenomenon to high flows during spring, which dilute PHCs dissolved in water but deliver PHC-rich particles to sediments.

The locations of PHC-rich sediments, and concentrations of PHCs in those sediments, differ substantially among the 2004, 2015, 2023, and 2024 studies. Such variations could be due to heterogeneity of sediment at the sites and/or differences in detection limits from year to year. A comparison of detection limits suggests that detection limits were similar between the 2023, 2024, and 2004 studies, but much higher for the fall 2015 study. Other explanations for differences in results between years include other laboratory quality controls (i.e., moisture content of the sample), or perhaps changing concentrations at some sites.

4.3.2.2 Lake sites

In 2023, PHCs were detected in sediments from 6/12 sites (50 %) (Table 7). The highest levels (including F3 to 4G), occurred at one main basin site (TS-10). Lower concentrations, having only F3 PHCs, were detected at all other areas of the lake except for Cook's Bay. F3 could be related to natural hydrocarbon compounds (*e.g., n*-alkanes produced by aquatic plants and algae) and/or diesel from boats. F4 and 4G likely reflect contamination from lubricating and heavy fuel oils, perhaps originating from industrial activities in the watershed.

Table 7. PHCs detected in lake sediments during the fall 2023 sampling campaign. Non-detects are not shown.

Site	**PHC F3 (>C16-C34) (*μ*g/g)**	**PHC F4 (>C34-C50) (*μ*g/g)**	**PHC F4 (Gravimetric) (*μ*g/g)**	**PHC F4 (Gravimetric) (Silica Gel Cleaned) (*μ*g/g)**
B-Li -05A	15			
B-Li -08	12			
EH-1	119			
HR-2	33			
K-38	12			
TS-10	29	78	593	246

In spring 2024, PHCs were detected in sediments from 6/6 sites (Table 8). The highest levels (including F3 to 4G) again occurred at one Kempenfelt Bay site (K-42), one main basin site (K-45), and one Cook's Bay site (C-6). PHC concentrations were higher in spring 2024 than in fall 2023, perhaps due to enhanced delivery of PHCs to Lake Simcoe during the spring freshet. No BTEX was found in Lake Simcoe sediments in fall 2023 or spring 2024.

Table 8. PHCs detected in lake sediments during the spring 2024 sampling campaign. Non-detects are not shown.

Site	PHC F3 (>C16-C34) (µg/g)	PHC F4 (>C34-C50) (µg/g)	PHC F4 (Gravimetric) (µg/g)	PHC F4 (Gravimetric) (Silica Gel Cleaned) (µg/g)
K-38	149	61	972	374
K-42	114	42	1370	114
K-45	40		1560	223
N-32	49		752	54
S-15	26		651	65
C-6	67		1230	206

PHC/BTEX contents in Lake Simoce sediments were monitored in 2015, but not 2004. BTEX were not found in 2015. The relative spatial distribution of PHCs was similar in 2015 to 2023 and 2024. However, the concentrations of PHCs detected in Lake Simcoe, particularly in the Kempenfelt Bay and East Holland River, were higher in 2015 than in 2023 or 2024. This result was unexpected considering that detection limits in 2015 were higher than in other years. The observed variability in PHC concentrations could reflect changes in the concentration of PHCs contained in lake sediments, or could point to spatial and/or temporal heterogeneity of PHCs in Lake Simcoe and Holland River sediments.

4.3.3 Summary and recommendations

- BTEX has not been detected in any LSRCA contaminants survey.
- PHC concentrations are difficult to characterize in the Lake Simcoe watershed, owing to interannual and seasonal differences in PHC concentrations, and the absence of federal or provincial guidelines.
- Tributary sites in and around Orillia consistently exhibit high PHC concentrations, including in surface waters, suggesting a modern source of petroleum waste to ecosystems in this area.
- The chain length of PHCs measured indicate that most PHCs in the watershed originate from a mixture of natural hydrocarbons and heavier fuel/lubricating oils.
- The PHC contents of Lake Simcoe sediments are elevated in the main basin and the Kempenfelt Bay, near Barrie. However, concentrations of PHCs in the lake are lower than those in the tributaries.

4.4 Semi-Volatile Organic Compounds (SVOCs), including Polycyclic Aromatic Hydrocarbons (PAHs)

Semi-Volatile Organic Compounds (SVOCs) are a broad class of contaminants produced through industrial emissions, leaching from building materials and furnishings, and everyday activities such as cooking, cleaning, use of consumer products, etc. (Liu et al., 2022). One type of SVOC, polyaromatic hydrocarbons (PAHs) have been found to be carcinogenic, mutagenic (*i.e.,* can cause mutations), teratogenic (*i.e.,* can cause an abnormality following fetal exposure during pregnancy), and/or toxic to aquatic organisms (Baldwin et al., 2020; Eisler, 1987). As a result, the International Joint Commission has identified carcinogenic PAHs as a "critical pollutant" in the Great Lakes Region (Agency for Toxic Substances and Disease Registry 2008).

Forest fires are the single most important natural source of PAHs in Canada (ECCC, 2022). Anthropogenic sources of PAHs to the environment include combustion from gasoline and diesel engines, industrial emissions, as well as the burning of fossil fuels or organic material. Even commonplace activities such as barbequing, smoking cigarettes, and/or using a wood-burning stove can produce PAHs (Abdel-Shafy and Mansour, 2016).

PAHs are relatively non-volatile, poorly soluble, and easily settled out of the water column. Through settling, PAHs can build up in the sediment over time. The contamination of soils and sediment in Canada by PAHs is widespread because sources of PAHs are so ubiquitous (CCME, 2010; CCME, 1999e).

In 2015, and 2004, various PAH constituents were observed in the surface waters and sediments of Lake Simcoe and its tributaries, mostly associated with urbanized areas. Due to their low solubility, PAHs tend to be more often found in sediment, but they can be present in surface water. In 2023, water samples were analyzed for a wider range of SVOC, not just PAHs (Table 9). These extra SVOC included phthalates (*i.e.,* chemicals added to make plastics more durable), phenols (described in more detail in section 4.6), and other compounds. These extra compounds were added because PAHs are among the most numerous pollutants detected in the Lake Simcoe watershed, so it was thought that other SVOC may also be present.

Table 9. PAHs and other SVOCs analyzed in surface water and sediment samples.

PAH/SVOC compounds in water samples	PAH/SVOC compounds in sediment samples
Acenaphthene	Acenaphthene
Acenaphthylene	Acenaphthylene
Anthracene	Anthracene
Benzo[a]anthracene	Benzo[a]anthracene
Benzo(a)pyrene	Benzo(a)pyrene
Benzo(b)fluoranthene	Benzo(b)fluoranthene
Benzo(b+k)fluoranthene	Benzo(g,h,i)perylene
Benzo(g,h,i)perylene	Benzo(k)fluoranthene
Benzo(k)fluoranthene	Chrysene
Biphenyl, 1, 1-	Dibenzo(a,h)anthracene
Bis(2-Chloroethyl)ether	Fluoranthene
Bis(2-Chloroisopropyl)ether	Fluorene
Bis(2-ethylhexyl) Phthalate	Indeno(1,2,3,-cd)Pyrene
Chloroaniline,4-	Methylnaphthalene,1-
Chlorophenol,2-	Methylnaphthalene,2-(1-)
Chrysene	Methylnaphthalene,2-
Dibenzo(a,h)anthracene	Naphthalene
Dichlorobenzidine,3,3'-	Phenanthrene
Dichlorophenol,2,4-	Pyrene
Diethyl Phthalate	
Dimethylphenol,2,4-	
Dimethyl Phthalate	
Dinitrophenol,2,4-	
Dinitrotoluene,2,4-	
Dinitrotoluene,2,4 & 2,6-	
Dinitrotoluene,2,6-	
Fluoranthene	
Fluorene	
Indeno(1,2,3,-cd)Pyrene	
Methylnaphthalene,1-	
Methylnaphthalene,2-(1-)	
Methylnaphthalene,2-	
Naphthalene	
Pentachlorophenol	
Phenanthrene	
Phenol	
Pyrene	
Trichlorobenzene,1,2,4-	
Trichlorophenol,2,4,5-	
Trichlorophenol,2,4,6-	

4.4.1 Surface water results

4.4.1.1 Tributary/polder sites

PAHs were found in the surface water of 3/36 (8 %) tributary/polder sites in fall 2023 and 0/32 (0 %) tributary/polder sites in spring 2024. In fall 2023, three PAH exceeded the Provincial Water Quality Objectives (PWQO), and two exceeded the Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQG) (Table 10). Other than PAHs, no other SVOCs were measured at detectable concentrations. Similar to the PHCs, lower PAH concentrations in spring waters may be caused by dilution associated with the spring freshet. No PAHs were detected during the spring 2024 sampling campaign.

Table 10. PAHs detected in tributary/polder waters during the fall 2023 sampling campaign. Only concentrations that exceed PWQO guidelines are shown here. Results in bold exceed the CWQG. Non-detects are not shown.

Site	**Benz[a]anthracene (μg/L)**	**Fluoranthene (μg/L)**	**Phenanthrene (μg/L)**
PWQO	0.0004	0.0008	0.03
CWQG	0.018	0.04	0.4
AUTO	**0.06**		
TS-27		**0.06**	
WH-6			**0.06**

PAHs were detected at 2/23 (9 %) tributary sites in 2015, and 6/23 sites in 2004 (26 %). In 2004, the PAH content of precipitation samples was also analyzed, and PAHs were detected at 6/21 (29 %) rain sites, suggesting that atmospheric deposition serves as an input of PAH. In 2015, no surface waters contained PAH concentrations that surpassed guidelines, despite the similar detection limits in 2015 and 2023. In 2004, detection limits were slightly lower than in 2015, 2023, and 2024. Yet, in 2004, the seven PAH constituents surpassed the PWQO and CWQG, particularly in Newmarket, Aurora, and Uxbridge. Such variable results among studies could be due to the insolubility of PAHs. These compounds settle out of the water column so quickly that any PAHs observed are likely the result of recent transport to the watershed. Thus, much like characterizing flow in a flashy river, the conditions vary wildly depending on the timing of sample collection (*i.e.,* immediately after a contamination event, or days later).

4.4.1.2 Lake sites

PAHs were detected at 3/13 (23 %) of lake sites in fall 2023 and 2/6 (33 %) of lake sites in spring 2024. PAHs that exceeded the PWQO included chrysene at B-Litt-14 and K-42 (lake sites near Barrie); dibenzo[a,h]anthracene at K-42; fluoranthene at B-Litt-14, K-42, and K-38 (lake site near Barrie); and phenanthrene at B-Litt-14, K-42 (Table 11, Table 12). These findings differ from the State of the Great Lakes Report (2022), which identified naphthalene, phenanthrene, fluoranthene, fluorene, and pyrene as the most abundant PAH compounds in the Great Lakes region. Other than PAHs, no other SVOC were measured at detectable concentrations.

Table 11. PAHs detected in lake waters during the fall 2023 sampling campaign. Non-detects are not shown. Only concentrations that exceed PWQO guidelines are shown here. Results in bold exceed the CWQG. Non-detects are not shown.

Site	**Chrysene (µg/L)**	**Dibenzo(a,h)anthracene (µg/L)**	**Fluoranthene (µg/L)**	**Phenanthrene (µg/L)**
PWQO	0.0001	0.002	0.0008	0.03
CWQG	N/A	N/A	0.04	0.4
B-Li -14	0.01		**0.15**	0.06
K-38			**0.06**	
K-42	**0.24**	0.22	**0.24**	0.22

Table 12. PAHs detected in lake waters during the spring 2024 sampling campaign. Non-detects are not shown. There is no PWQO guideline for benzo[a]pyrene. Results in bold exceed the CWQG.

Site	**Benzo[a]pyrene (µg/L)**
PWQO	N/A
CWQG	0.015
K-38	0.01
K-42	**0.02**

4.4.2 Sediment sample results

4.4.2.1 Tributary and polder sites

In 2024, PAHs were detected in the sediments of 12/32 (38 %) of tributary sites sampled, compared with 8/34 (24 %) in 2023, 24/27 (89 %) in 2015 and 9/13 (69 %) in 2004. PAH concentrations were slightly higher in spring 2024 than in fall 2023, although more sampling is needed to confirm this trend (Table 13, Table 14). Higher PAH concentrations in spring 2024 could be due to higher flows, which transport PAHs from roadways to tributaries, and/or more atmospheric deposition related to more precipitation.

Table 13. PAHs detected in tributary/polder sediments during the fall 2023 sampling campaign. Only concentrations that exceed Reg. 153/04 (Table 1) guidelines are shown here. Results that exceed the Interim Sediment Quality Guidelines for the Protection of Aquatic Life (ISQG) are shown in bold. Results that exceed the Probable Effect Levels (PEL) are shown in italics. Non-detects are not shown.

Site	Anthracene (µg/g)	Benz[a] anthracene (µg/g)	Benzo(a) pyrene (µg/g)	Benzo(g,h,i) perylene (µg/g)	Benzo(k) fluoranthene (µg/g)	Chrysene (µg/g)	Dibenz(a,h) anthracene (µg/g)	Fluoranthene (µg/g)	Phenanthrene (µg/g)	Pyrene (µg/g)
Reg. 153/04 (Table 1)	0.22	0.32	0.37	0.17	0.24	0.34	0.06	0.75	0.56	0.49
ISQG	0.0469	0.0317	0.0319	N/A	N/A	0.0571	0.00622	0.111	0.0419	0.053
PEL	0.245	0.385	0.782	N/A	N/A	0.862	0.135	2.355	0.515	0.875
TS-7	***0.32***	***0.94***	***0.92***	0.48	0.35	***0.88***	**0.11**	**0.53**	***1.57***	***1.7***

Table 14. PAHs detected in tributary/polder sediments during the spring 2024 sampling campaign. Non-detects are not shown. Only concentrations that exceed Reg. 153/04 (Table 1) guidelines are shown here. Results that exceed ISQG guidelines are shown in bold. Results that exceed ISQG guidelines are shown in italics. Non-detects are not shown.

Site	**Anthracene (µg/g)**	**Benz[a] anthracene (µg/g)**	**Benzo(a) pyrene (µg/g)**	**Benzo(g,h,i) perylene (µg/g)**	**Benzo(k) fluoranthene (µg/g)**	**Chrysene (µg/g)**	**Dibenz(a,h) anthracene (µg/g)**	**Indeno(1,2,3 -cd) pyrene (µg/g)**
Reg. 153/04 (Table 1)	0.22	0.32	0.37	0.17	0.24	0.34	0.06	0.2
ISQG	0.0469	0.0317	0.0319	N/A	N/A	0.0571	0.00622	N/A
PEL	0.245	0.385	0.782	N/A	N/A	0.862	0.135	N/A
TS-7	***0.34***	***1.14***	***1.1***	0.68	0.49	***1.14***	**0.11**	0.68
TS-26			**0.57**	0.47	0.26	**0.39**	**0.11**	0.51

In both seasons, PAHs were nearly absent from all polder sites. Conversely, in both seasons TS-7 (bridge over the Holland River) exhibited higher PAHs than any other site (11.45 μg/g total in fall 2023, 5.83 μg/g in spring 2024). Such high concentrations could be related to creosote-impregnated bridge timbers and railway ties, and/or settling of PAH-rich sediments (Marcotte et al., 2014). Creosote, a coal-based compound containing PAHs and other compounds, is used to prevent bridge timbers and railway ties from rotting.

The PAH benzo[*a*]pyrene, which far exceeded all available guidelines at TS-7, is especially concentrated in creosote (Marcotte et al., 2014). TS-7 is situated beside a bridge (Fig. 2). Although the bridge itself has metal supports, older wooden supports are visible underneath. Wooden bridge ties can source PAHs to the nearby tributary (Poston, 2001; Marvin et al., 2021). Also possible is that the bridge interrupts water flow, causing PAH-rich suspended particles derived from the upstream Holland Marsh to settle out of the water column. This option is less likely since the Holland Marsh does not appear to be a source of PHCs. Moreover, contaminants detected at high concentrations in Holland Marsh sediments, such as organic pesticides, are not concentrated at TS-7.

Figure 2. Wooden supports visible beside site TS-7, where elevated concentrations of PAHs were detected.

Other areas with high sedimentary PAHs included urban centres such as the East Holland River near Newmarket and Aurora (TS-8, TS-23), Barrie (Bunker's Creek/TS-29), and Orillia (Mill Creek/TS-26). In a study of sediment PAH concentrations across southern Ontario in 2008-9, Chaudhuri et al. (2017) found that elevated concentrations of total PAHs occurred in areas of higher population density and urban activity. Our results support this assertion.

Relative spatial variations in sedimentary PAH concentrations were similar in 2004, 2015, 2023, and 2024. In all years, most sites had at least one PAH constituent that exceeded Ontario Reg. 153/04 (Table 1) guidelines. The constituents that exceeded the available guidelines included anthracene, benzo[*a*]anthracene, benzo[*a*]pyrene, benzo[*g*,*h*,*i*]perylene, benzo[k]fluoranthene, chrysene, dibenzo[*a*,*h*,]anthracene, fluoranthene, fluoranthene, fluorene, indeno[1,2,3,-*cd*]pyrene, phenanthrene, and pyrene. Benzo[*b*/*j*]fluoranthene, which was monitored in 2015 but not in 2004 or 2023, was another PAH constituent that exceeded available guidelines and occurred in most of the sites. For unknown reasons, higher sedimentary PAH concentrations were reported in the 2015 survey than in other years. This result was unexpected considering that forest fires can source PAHs, and the incidence of forest fires in Ontario in 2015 was low relative to other years (NFDP, 2023).

In the LSRCA's 2015 contaminants survey, it was noted that – except for TS-7 and TS-25 – the levels of total sedimentary PAHs generally correspond with total sedimentary PHCs, likely due to both contaminants having similar sources (fossil fuels, lubricant oils, etc.). This trend is not observed in fall 2023 or spring 2024, suggesting that, at most sites, PAHs and PHCs currently originate from two different sources. This could mean that (1) the source of PAHs and/or PHCs has changed in the last seven years; (2) transport mechanisms to/from the stream, or within the stream, have changed; (3) one compound is degrading faster than the other; and/or (3) the correlation between PAHs and PHCs in past years was coincidental.

4.4.2.2 Lake sites

In fall 2023, sedimentary PAHs were detected at 3/15 (20 %) lake sites, compared with detected at 2/6 sites (33 %) in spring 2024. In 2023, only one of these sites had sedimentary PAH concentrations that exceeded guidelines (Table 15) while, in 2024, none of these sites had sedimentary PAH concentrations that exceeded guidelines.

Table 15. PAHs detected in lake sediments during the fall 2023 sampling campaign. Non-detects are not shown. Only concentrations that exceed Reg. 153/04 (Table 1) guidelines are shown here. Results that exceed ISQG guidelines are shown in bold (**benzo[g,h,i]perylene = no data; dibenz[a,h]anthracene = 0.00622 μg/g; fluorene = 0.0212 μg/g; indeno[1,2,3-cd]pyrene = no data).** Results that exceed PEL guidelines are shown in italics. Non-detects are not shown.

Site	**Benz(g,h,i) perylene (μg/g)**	**Dibenz(a,h) anthracene (μg/g)**	**Fluorene (μg/g)**	**Indeno(1,2,3-cd) Pyrene (μg/g)**
Reg. 153/04 (Table 1)	0.17	0.06	0.19	0.2
ISQG	N/A	0.00622	0.0212	N/A
PEL	N/A	0.135	0.144	N/A
K-42	0.22	***0.22***	***0.20***	0.22

In 2015, 10/12 (83 %) lake sites had exceedances of guideline concentrations for PAHs. Again, the highest levels were found near Barrie in Kempenfelt Bay (B-LITT-14, K-38). The constituents that most commonly exceeded the guidelines in the lake sites were benzo(a)anthracene, benzo[a]pyrene, benzo[g,h,i]perylene, benzo[k]fluoranthene, chrysene, fluoranthene, indo[1,2,3-cd]pyrene, phenanthrene, and pyrene. Lake sites were not sampled in 2004.

4.4.3 Summary and recommendations

- In surface waters, concentrations of SVOCs/PAHs typically fall between IWQG and PEL, indicating that these compounds may or may not be deleterious to ecosystem health.
- The continued presence of PAHs in surface waters at certain sites (*e.g.,* Kempenfelt Bay) suggests that these compounds are being actively discharged into the environment through sediment resuspension or, more likely, modern industrial/urban sources.
- Reduced surface water PAH concentrations in the spring indicate that high flows associated with the spring freshet can dilute pollutant concentrations.
- PAHs were not detected in sediments from most sites. However, at sites where these compounds were detected in sediment, they greatly exceeded PEL, indicating probable toxicity to aquatic organisms.

4.5 Per- and Polyfluorinated Substances (PFASs)

Per- and polyfluorinated substances (PFASs) are a broad class of chemicals comprised of thousands of different man-made compounds used in personal, commercial, and industrial products. They have been used to resist stains (*e.g.,* in Teflon), repel water, create non-stick surfaces, or spread foam (*e.g.,* fire-fighting foam).

Some PFASs are chemically stable and resistant to degradation and are therefore persistent in the environment. Biota absorb PFASs faster than they can naturally break them down or expel them, causing the contaminant to accumulate in their tissue. This process is known as *bioaccumulation*. PFAS can also undergo *biomagnification*, meaning that they become more concentrated at higher trophic levels.

In Ontario, PFASs were measured in sediment as part of the Southern Ontario Stream Sediment Project (SOSSP). The authors of this study identified detectable levels of PFSAs (mainly as PFOS) in the Tannery Creek branch of the East Holland River and in some rural/agricultural tributaries (including Beaver, Black and Talbot Rivers and a creek of the Ramara subwatershed) (Chaudhuri, 2017). Provincial and federal sediment guidelines are not currently available for PFAS compounds.

Measuring PFASs in waters and sediments is difficult because PFASs are very expensive to analyze and can only be characterized by a handful of specialized laboratories throughout Ontario. Nevertheless, in Fall 2023, waters from eight sites were sampled to determine their PFAS content: Mill Creek in Orillia (TS-26), Brechin (EC-027-07B), Bradford Pumping Station #2 in the Holland Marsh (WH-5), Bunkers Creek in Barrie (TS-29), the East Holland River at Green Lane (TS-8), the Tannery Creek (TS-9), the Black River at

Sutton (EC-036-05), and the East Holland River at Vandorf Sideroad (EC-056-08) (Table 16). These sites were chosen based on the results of the SOSSP study. PFASs were not detected in any water samples, suggesting that any PFASs present are bound to the sediment, or that our sampling campaign missed periods of peak PFAS concentration.

Table 16. PFAS compounds analyzed in surface waters by the LSRCA in 2023.

PFAS compounds analyzed in surface waters
Eicosafluoro-3-oxaundecane-1-sulfonic acid, 11-chloro- [11Cl-PF3OUdS]
Ethyl perfluorooctanesulfonamide, n- [NEtFOSA]
Ethyl perfluorooctanesulfonamidoacetic acid, n- [NEtFOSAA]
Ethyl perfluorooctanesulfonamidoethanol, n- [NEtFOSE]
Fluorotelomer carboxylic acid, 3:3 [3:3 FTCA]
Fluorotelomer carboxylic acid, 5:3 [5:3 FTCA]
Fluorotelomer carboxylic acid, 7:3 [7:3 FTCA]
Fluorotelomer sulfonic acid, 4:2 [4:2 FTS]
Fluorotelomer sulfonic acid, 6:2 [6:2 FTS]
Fluorotelomer sulfonic acid, 8:2 [8:2 FTS]
Hexadecafluoro-3-oxanonane-1-sulfonic acid, 9-chloro- [9Cl-PF3ONS]
Hexafluoropropylene oxide dimer acid [HFPO-DA]
Methyl perfluorooctanesulfonamide, N- [NMeFOSA]
Methyl perfluorooctanesulfonamidoacetic acid, n- [NMeFOSAA]
Methyl perfluorooctanesulfonamidoethanol, n- [NMeFOSE]
Nonafluoro-3,6-dioxaheptanoic acid [NFDHA]
Perfluoro-3-methoxypropanoic acid [PFMPA]
Perfluoro-4-methoxybutanoic acid [PFMBA]
Perfluorobutanesulfonic acid [PFBS]
Perfluorobutanoic acid [PFBA]
Perfluorodecane sulfonic acid [PFDS]
Perfluorodecanoic acid [PFDA]
Perfluorododecanesulfonic acid [PFDoS]
Perfluorododecanoic acid [PFDoA]
Perfluoroheptanesulfonic acid [PFHpS]
Perfluoroheptanoic acid [PFHpA]
Perfluorohexanesulfonic acid [PFHxS]
Perfluorohexanoic acid [PFHxA]
Perfluorononanesulfonic acid [PFNS]
Perfluorononanoic acid [PFNA]
Perfluorononanoic acid, 4,8-dioxa-3H- [ADONA]
Perfluorooctanesulfonamide [PFOSA]
Perfluorooctanesulfonic acid [PFOS]
Perfluorooctanoic acid [PFOA]
Perfluoropentanesulfonic acid [PFPeS]
Perfluoropentanoic acid [PFPeA]
Perfluorotetradecanoic acid [PFTeDA]
Perfluorotridecanoic acid [PFTrDA]
Perfluoroundecanoic acid [PFUnA]
perfluoro(2-ethoxyethane)sulfonic acid [PFEESA]
PFAS, total (EPA 1633)

4.5.1 Summary and recommendations

- The Southern Ontario Stream Sediment Project (SOSSP) detected PFASs in the surface sediments of tributaries within the Lake Simcoe watershed.
- Our report analyzed the surface waters of eight tributary sites to evaluate their PFAS content, but no PFASs were detected.
- In the future, PFASs should be analyzed in lake sediments and waters to determine if they have migrated from tributaries to Lake Simcoe.

4.6 Phenols

Phenols are organic compounds composed of benzene rings with various configurations and numbers of hydroxyl groups. Phenols are commonly used to produce resins that are used in the construction, automotive, and appliance industries. They are also found in automobile exhaust, pesticides, and household disinfectants. They do not tend to persist or accumulate in the environment and are most dangerous when found in large quantities, as in an industrial spill. They are highly soluble in water, so can leach from soils/sediment into the water column. Thus, our sampling of phenols has focused on surface water. The analytical method used (4AAP Phenols) gives the minimum phenol content of the sample.

In fall 2023, phenols were detected in 0/40 tributary/polder and lake sites (0 %). For this reason, phenols were only investigated at four sites in spring 2024: Mill Creek, Orillia (TS-26 and TS-27), the Maskinonge River (MASK), and the Kempenfelt Bay (K-38). Sites TS-26, TS-27, and K-38 were chosen because PHCs and PAHs – compounds also produced by industry – were identified in the waters of these sites. The site MASK was sampled because phenols had not been sampled there in a previous study. No phenols were detected at any of these four sites.

Detection limits for phenols were identical in 2024, 2023, 2015, and 2004. In the 2004 study, phenols were present at eight of 21 sample sites, seven of which were located in urban areas (Aurora, Barrie, Cannington, Newmarket, Orillia, Uxbridge). Five of these eight sites were sampled in the 2015 study, with an additional two sites in close proximity to 2004 sites. In 2015, phenols were not reported at any of these common sites. However, in 2015, phenols were detected at two other sites: the Colbar Marsh (WH-10), where concentrations exceeded PWQO guidelines; and the lake site Kempenfelt Bay (K-38), where concentrations equalled the PWQO guidelines.

4.6.1 Summary and recommendations

- While phenols were detected in 2004 and, to a lesser extent, 2015, they were not detected in 2023 or 2024.
- The rare presence of phenols in the watershed suggests that these compounds do not currently pose a substantial threat to ecosystem health in this area.
- Future monitoring of phenols should be targeted towards areas with past detections.

4.7 Metals

Trace and heavy metals can occur naturally; however, excessive metal concentrations related to anthropogenic activities such as mining and smelting can adversely impact aquatic ecosystems. Metal pollution can be delivered to waterbodies from distant industrialized regions via atmospheric deposition. The fate of metals in surface waters is dependent on several factors, including the properties of a given metal, the chemistry of the water, and whether the metal is bound to particulate matter.

In fall 2023 and spring 2024, metal concentrations were determined for sediments and surface waters from tributary/polder and lake sites (Table 17). This sampling effort targeted urban areas and agricultural areas, including the vegetable polders and naturalized areas. Among the trace metals detected were chromium and cadmium. These elements were introduced to the Lake Simcoe watershed from historical leather tanneries.

Table 17. Metals analyzed in surface waters and sediments in fall 2023 and spring 2024.

Metals analyzed in surface waters	Metals analyzed in sediments
Antimony (Sb)	Antimony (Sb)
Arsenic (As)	Arsenic (As)
Barium (Ba)	Barium (Ba)
Beryllium (Be)	Beryllium (Be)
Boron (B)	Boron (B)
Cadmium (Cd)	Cadmium (Cd)
Chromium (Cr)	Chromium (Cr)
Chromium (VI) (CrVI)	Chromium (VI) (CrVI)
Cobalt (Co)	Cobalt (Co)
Copper (Cu)	Copper (Cu)
Lead (Pb)	Lead (Pb)
Mercury (Hg)	Mercury (Hg)
Molybdenum (Mo)	Molybdenum (Mo)
Nickel (Ni)	Nickel (Ni)
Selenium (Se)	Selenium (Se)
Silver (Ag)	Silver (Ag)
Sodium (Na)	Thallium (Tl)
Thallium (Tl)	Uranium (U)
Uranium (U)	Vanadium (V)
Vanadium (V)	Zinc (Zn)
Zinc (Zn)	

4.7.1 Surface water results

In fall 2023, metals were detected at all 38 tributary/polder sites but only exceeded PWQO guidelines at 1/38 (2 %) sites (Table 18). Arsenic concentrations at WH-6 were slightly elevated (6.2 μg/L) relative to Provincial Water Quality Objectives (PWQO) interim guidelines (5 μg/L or 0.005 mg/L) and Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQG) (5 μg/L or 0.005 mg/L) (Table 18).

Such elevated concentrations are likely the result of inputs of arsenic-containing phosphate fertilizers (Jayasumana et al., 2015), pesticides, and/or natural sources (Wang and Mulligan, 2006).

Table 18. Metals detected in tributary/polder waters during the fall 2023 sampling campaign. Only results that exceed PWQO guidelines are shown. The result below also exceeds the CWQG, so is bolded. Non-detects are not shown.

Site	**Arsenic, As (mg/L)**
PWQO	0.006 (interim guidelines), or 0.1 (guidelines)
CWGC	0.005
WH-6	**0.0062**

In spring 2024, metals were again detected at all 32 tributary/polder sites, but concentrations exceeded PWQO guidelines at 5/32 (16 %) sites: WH-5 (Holland Marsh at Bradford Pumping Station #2), WH-6 (Holland Marsh at the Professor Day Pumphouse), HM-Canal 2 (Holland Marsh Outer Canal Opposite WH-6), WH-7 (Holland Marsh), WH-8 (Holland Marsh) (Table 19). This finding was surprising since higher flows in the spring would be expected to dilute metal concentrations.

Table 19. Metals detected in tributary/polder waters during the spring 2024 sampling campaign. Only results that exceed PWQO (interim) guidelines are shown. No results below exceed the CWQG. Non-detects are not shown.

Site	**Boron (mg/L)**	**Zinc (mg/L)**	**Cobalt (mg/L)**	**Copper (mg/L)**
PWQO	0.200 (interim)	0.02 (interim)	0.0009 (interim)	0.005 (interim)
CWQG	1.5 (long term)	N/A	N/A	N/A
WH-5	0.29			
WH-6		0.033		0.01
WH-7	0.28			0.007
WH-8	0.33			
HM-Canal2		0.039	0.002	0.027

In fall 2023, no metals measured in Lake Simcoe waters exceeded PWQO or CWQG guidelines. In spring 2024, one exceedance of chromium was detected at S-15 (main basin) (Table 20). In 2015 and 2004, metals were not analyzed in any surface waters from tributaries/polders or the lake.

Table 20. Metals detected in lake waters during the spring 2024 sampling campaign. Only results that exceed PWQO guidelines are shown. There are no proposed CWQG limits for chromium in freshwater. Non-detects are not shown.

Site	**Chromium (mg/L)**
PWQO	0.001 (Cr VI) to 0.0089 (Cr III)
CWQG	N/A (for total Cr)
S-15	0.168

4.7.2 Sediment results

4.7.2.1 Tributary/polder results

In fall 2023, metals were detected in the sediments of all 28 tributary/polder sites. At least one metal exceeded Reg. 153/04 (Table 1) guidelines at 10/28 sites (36%): WH-3 (Holland Marsh), WH-5 (Holland Marsh at Bradford Pumping Station #2), WH-6 (Holland Marsh at Professor Day Pumphouse), WH-7 (Holland Marsh), WH-8 (Holland Marsh), WH-10 (Colbar Marsh), TS-8 (East Holland River at Green Lane), TS-23 (Western Creek, Newmarket), TS-26 (Mill Creek, Orillia), and TS-30 (Hotchkiss Creek, Barrie) (Table 21). Metal concentrations at several of these sites also exceeded the Interim Sediment Quality Guidelines (ISQG), but not the Probable Effect Levels (PEL), suggesting that metals at these sites may or may not negatively affect biota.

Table 21. Metals detected in tributary/polder sediments during the fall 2023 sampling campaign. Only concentrations that exceeded the Reg. 153/04 (Table 1) guidelines are shown here. Results in bold surpass the ISQG guidelines. Results in italics surpass the PEL guidelines. Non-detects are not shown.

Site	**Chromium (µg/g)**	**Copper (µg/g)**	**Lead (µg/g)**	**Zinc (µg/g)**	**Arsenic (µg/g)**
Reg. 153/04 (Table 1)	26	16	31	120	6
ISQG	37.5	35.7	35	123	5.9
PEL	90	197	91.3	315	17
WH-3		33			
WH-5		**60**			
WH-6		**76**		121	**6.7**
WH-7		**43**			
WH-8		**38**			
WH-10		30			
TS-8	***63***				
TS-23		**142**			
TS-26	28	**39**	**55**	**273**	
TS-30		30			

In spring 2024, metals were detected in the sediments of all 32 tributary/polder sites. At least one metal exceeded Reg. 153/04 (Table 1) guidelines at 14/32 sites (44%): WH-2 (Upper Schomberg River at

Leonard Rd.), WH-10, WH-9 (Holland Marsh, Inner Canal), WH-8, WH-7, WH-6, WH-5, HM-Canal2 (Holland Marsh Outer Canal), TS-7 (West Holland River at Bridge St.), STJOHN (Vandorf Sideroad, Aurora), TS-9 (Tannery Creek, Newmarket), TS-8, TS-27 (Mill Creek, Orillia), and TS-26 (Table 22). Again, many levels surpassed ISQG, but not PEL.

Table 22. Metals detected in tributary/polder sediments during the spring 2024 sampling campaign. Only concentrations that exceeded the Reg. 153/04 (Table 1) guidelines are shown here. Results in bold surpass the ISQG guidelines (**cadmium = 0.6 µg/g; chromium = 37.3 µg/g; copper = 35.7 µg/g; lead = 35 µg/g; nickel = no data; zinc = 123 µg/g; arsenic = 5.9 µg/g; silver = no data**). Results in italics surpass the PEL guidelines. Non-detects are not shown.

Site	**Cadmium (µg/g)**	**Chromium (µg/g)**	**Copper (µg/g)**	**Lead (µg/g)**	**Nickel (µg/g)**	**Zinc (µg/g)**	**Arsenic (µg/g)**	**Silver (µg/g)**
Reg. 153/04 (Table 1)	0.6	26	16	31	16	120	6	0.5
ISQG	0.6	37.3	35.7	35	N/A	123	5.9	N/A
PEL	3.5	90	197	91.3	N/A	315	17	N/A
WH-2				**50**				
WH-5			**48**					
WH-6			26					
WH-7			**69**					
WH-8			**52**					
WH-9			22					
WH-10			**39**					
TS-7			25					
TS-8		31						3.6
TS-9		**40**						
TS-26	**0.7**	29	**42**	**63**		**281**		
TS-27		**36**	**49**	**54**		**275**		
HM-Canal2			**98**				**7**	
STJOHN		32	34		18	**221**		

In 2023 and 2024, the tributary/polder sites with the most metal exceedances were TS-26 and TS-27 in Mill Creek, Orillia. These sites exceeded guidelines for cadmium (0.6 to 0.7 µg/g), chromium (28 to 36 µg/g), copper (39 to 49 µg/g), lead (55 to 63 µg/g), and zinc (273 to 281 µg/g). Metal contamination at this site is almost certainly due to upstream industrial operations, such as a previous tannery site located near Mississauga Street in Orillia.

Elevated copper was detected in the Holland Marsh TS-7 and at some urban sites (*e.g.,* TS-27, TS-30, TS-23 in Orillia, Barrie, and Newmarket). Copper can be elevated in agricultural areas because it is used as a soil treatment. Also, the application of pesticides can increase copper concentrations (Czuba and Hutchinson, 1980). In 2023, copper concentrations at TS-7 fell under Reg. 153/04 (Table 1) guidelines while, in 2024, they exceeded guidelines. Elevated copper at the urban sites may be due to pollution from historical tanneries and/or leaching from nearby railways since all three sites are situated near railway corridors. Although it is possible that a large landfill in Barrie (the Barrie Landfill & Environmental Centre) is a source of copper to TS-30, this explanation is less likely since no other metals at this site exceed guidelines. Elevated zinc and arsenic concentrations at WH-6 in the Holland Marsh, are probably related to agricultural sources (*e.g.,* fertilizers containing zinc and arsenic) (Jayasumana et al., 2015) and/or pesticides (Wang and Mulligan, 2006).

Metal contents of tributary/polder sediments were also investigated in previous years. In 2015, 27 tributary/polder sites were sampled. In 2004, sediments from 13 tributary/polder sites were sampled for metals. Metals were not measured in tributary/polder or lake waters in 2015 or 2004. Most patterns observed in 2023 and 2024 were also observed in 2015 and 2004. As in recent years, the site with the most metal exceedances in 2015 was TS-26 (Mill Creek, Orillia), which exceeded guidelines for chromium, copper, lead, and zinc. TS-26 was not analyzed in 2004.

All years reported excessive chromium along the East Holland River. This trend was thoroughly investigated in the LSRCA's 2015 contaminants report (LSRCA, 2020). As in 2004 and 2015, copper exceedances were detected at most polder sites. Elevated arsenic at a nearby site, WH-10 (Colbar Marsh), was also detected in 2015. Other minor differences were observed among reports. For instance, elevated lead was detected at TS-8 in 2004 and 2024, but not in 2015 or 2023. Elevated chromium was detected at nearby TS-9 (Tannery Creek) in 2004 and 2024, but not in 2015 or 2023.

4.7.2.2 Lake results

In 2024, 2023, and 2015 metals were reported at all lake sites. Lake sites were not sampled in 2004. In 2024, 4/6 sites (67 %) had metal concentrations exceeding PWQO limits, compared with 5/12 (42 %) sites in 2023 and 6/12 (50 %) sites in 2015 (Table 23, Table 24). In all three years, areas with the highest exceedances were usually located near Barrie in the Kempenfelt Bay. Metals detected at concentrations above the Reg. 153 (Table 1) limits included cadmium, chromium, copper, lead, nickel, and zinc. In all three years chromium concentrations in Kempenfelt Bay were especially high. In 2023, for example, the total chromium concentration in the Kempenfelt Bay (B-Litt-14 and K-38) was 474 and 523 μg/g (Table 23). In comparison, the Reg. 153/04 (Table 1) guideline for total chromium in sediments is 26 μg/g.

Table 23. Metals detected in lake sediments during fall 2023 sampling. Only concentrations that exceeded the Reg. 153/04 (Table 1) guidelines are shown here. Results in bold surpass the ISQG. Results in italics surpass the PEL. Non-detects are not shown.

Site	**Cadmium (µg/g)**	**Chromium (µg/g)**	**Copper (µg/g)**	**Lead (µg/g)**	**Nickel (µg/g)**	**Zinc (µg/g)**	**Silver (µg/g)**	**Mercury (µg/g)**
Reg. 153/04 (Table 1)	0.6	26	16	31	16	120	0.5	0.2
ISQG	0.6	37.3	35.7	35	N/A	123	N/A	0.170
PEL	3.5	90	197	91.3	N/A	315	N/A	0.486
B-Li -14	***28***	***474***	**57**	***98***	26	**173**	1	**0.29**
C-6	**0.7**	**46**	18					
HR-2		**49**	23					
K-38	**1.8**	***523***	**69**	***132***	32	**203**	0.9	**0.36**
EH-1		***119***	33			**142**		

Table 24. Metals detected in lake sediments during the spring 2024 sampling campaign. Only concentrations that exceeded the Reg. 153/04 (Table 1) guidelines are shown here. Results in bold surpass the ISQG. Results in italics surpass the PEL. Non-detects are not shown.

Site	**Cadmium (µg/g)**	**Chromium (µg/g)**	**Copper (µg/g)**	**Lead (µg/g)**	**Nickel (µg/g)**	**Silver (µg/g)**	**Mercury (µg/g)**
Reg. 153/04 (Table 1)	0.6	26	16	31	16	0.5	0.2
ISQG	0.6	37.3	35.7	35	N/A	N/A	0.170
PEL	3.5	90	197	91.3	N/A	N/A	0.486
K-38						1.2	**0.38**
K-42	**1**			**45**	17		
K-45	**0.8**	**55**	22	**37**			
C-6					17		

4.7.3 Summary and recommendations

- Trace amounts of heavy metal pollution (*e.g.,* cadmium, chromium, mercury, lead) can negatively impact aquatic ecosystems, particularly if concentrations exceed federal and/or provincial guidelines.
- Except for one sample from the Holland Marsh, surface waters in the Lake Simcoe watershed did not contain concentrations of metals that exceed applicable guidelines.
- Sediments from tributaries/polders often contain metal concentrations that exceed Reg. 153/04 (Table 1) and ISQG limits, but not PEL, suggesting that metals may or may not be adversely impacting biota.
- Sediments from Lake Simcoe, particularly in the Kempenfelt Bay near Barrie, contain concerning levels of heavy metals that sometimes exceed all applicable guidelines.

- Levels of cadmium in sediments from B-Litt-14 (Kempenfelt Bay off Centennial Beach, Barrie) were measured at 47x the PEL.
- Future studies should increase the number of metal analyses performed on lake sediment to better gauge the extent of heavy metal pollution in Lake Simcoe.
- Given that metal analyses of water samples are cost effective and easy to collect, annual sampling is recommended to gain a better understanding of long-term trends in heavy metal concentrations.

5. CONCLUSIONS

The Lake Simcoe Watershed has long been the setting for anthropogenic activity including industry (e.g., tanneries), urban development, intensive agriculture, and recreational pursuits. These activities can introduce contaminants to aquatic systems that, in some cases, adversely impact aquatic organisms. The purpose of this study was to investigate likely contaminants in the watershed, identify areas of potentially high concentrations (e.g., urban centres, current and former industrial lands, and intensive agricultural areas), and compare contaminant locations and concentrations with a study carried out in 2004 and 2015 by LSRCA.

This study has determined that urban areas such as Newmarket, Aurora, Barrie, and Orillia typically have low concentrations of contaminants in surface waters. No OCPs, PCBs, BTEX, SVOCs/PAHs, phenols, or PFASs were detected in surface waters from these areas. Likewise, metal concentrations fell below provincial and federal limits. PHCs and SVOCs/PAHs were detected in surface waters of Mill Creek, Orillia, indicating a modern source of fossil fuel contamination in this area, and/or or the resuspension of PHC- and PAH-rich sediment. SVOCs/PAHs were also detected in waters from one tributary in Newmarket.

Sediments from these urban areas did not contain OCPs, PCBs, BTEXs, phenols, or PFASs. However, they did contain PHCs, PAHs, and metals. While there is no guideline for PHCs in freshwater sediments, PHC levels at Mill Creek (Orillia) were much higher (F4G = 10 200 μg/g) than the seasonal, tributary-wide mean F4G = 1676, n= 30). Heavy metals (e.g., cadmium, chromium, lead) were detected in tributary sediments at multiple urban sites at concentrations that exceeded some provincial and federal guidelines but fell below PEL. The profile of contaminants detected in these urban tributaries is consistent with pollution from historical tanneries and/or upstream industrial point sources.

In comparison to the urban areas, the surface waters of polder sites contain fewer PHCs and PAHs, but more OCPs. Monitoring of Holland Marsh water by the Ministry of Environment, Conservation, and Parks (MECP) has determined that ~18 % of samples were chronically toxic to benthic invertebrates (Raby et al., 2022). No PHCs, BTEX, phenols, or PFASs were identified in polder surface waters. SVOCs/PAHs were detected at one polder site at concentrations above provincial and federal guidelines. Metal concentrations in polder surface waters fell below provincial and federal guidelines, except for one arsenic concentrations at one Holland Marsh site, which exceeded some provincial and federal guidelines but fell below the PEL.

Although PCBs and BTEX were not found in polder sediments, concentrations of OCPs, PAHs, PHCs, and metals exceeded all available guidelines at multiple sites. Concentrations of DDT-derivates, DDD and DDE, are particularly concerning as they were measured at 53x the PEL and 67x the PEL, respectively. The legacy insecticide dieldrin was also detected at one Holland Marsh site at levels 9x the PEL. Fortunately, no DDT was detected in sediments or surface waters, which is an improvement relative to previous reports that did detect DDT. Additional sampling should focus on screening for DDT using a test with a low detection limit (*e.g.,* 0.005 μg/L for sediment).

PAHs were generally absent from polder sediments except for one downstream site, TS-7, where sedimentary PAH concentrations were the highest in the watershed. PAHs at this site are likely continuously sourced from nearby creosote-soaked rail ties. PHCs, particularly the F3 and F4G fractions, were sometimes present in polder sediments at high concentrations (e.g., F4G = 6830 µg/g at WH-10) but were generally lower than in the urban areas. Metal concentrations in polder sediments exceeded some guidelines for cadmium, chromium, copper, lead, zinc, and arsenic, but fell below the PEL. It is therefore unclear whether heavy metals are negatively impacting biota in the polders.

Lake waters almost always contained fewer contaminants, and lower concentrations of contaminants, than underlying lake sediments. Lake Simcoe water samples did not contain OCPs, PCBs, BTEX, PHCs, or phenols at levels exceeding PWQO guidelines. Lake waters did contain levels of PAHs, and chromium, that exceeded PWQO and, at times, CWQG guidelines. PHCs were found in Lake Simcoe sediments, particularly in the Kempenfelt Bay, but concentrations were generally lower than in the surrounding tributaries. In fall 2023, PAHs were detected in lake sediment at levels far surpassing Reg. 153/04 (Table 1), ISQG and PEL guidelines; however, such high concentrations were not detected in the following spring, suggesting that additional research is needed to confirm these elevated results. Metal concentrations in lake sediments were particularly concerning, with heavy metals consistently exceeding all available guidelines in 2015, 2023, and 2024. Cadmium levels in some Kempenfelt Bay sediments are especially elevated and exceed the PEL by 47x.

Generally, the contaminants recorded in the Lake Simcoe Watershed are mostly the result of non-point anthropogenic sources (e.g. automobile exhaust, fossil fuel combustion) and specific areas of industrial, urban, and agricultural land-use activities (e.g., pesticides). Although some contaminants may be linked to current uses (e.g. PHCs, PAHs, phenols), others are likely legacy contaminants (i.e. DDT and chromium) from historical activities. Overall, it is recommended that regular monitoring of specific contaminants (e.g. DDT and metabolites, chromium, heavy metals) be undertaken more frequently as trends in chemical contaminants are difficult to ascertain from two sampling events, spaced 11 years apart. Routine sampling should target areas of guideline exceedances such as urban centres (Aurora, Barrie, and Newmarket) and intensive agricultural areas (Holland Marsh and other polders). More frequent and targeted sampling will aid in better evaluating our understanding of changes in chemical contaminants, including decreases or increases in concentration, movement through the watershed, and the potential risks to aquatic organisms or human health.

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APPENDIX A. Sites sampled in the Lake Simcoe watershed

Table A-1. List of sites and locations for fall 2023 contaminant samples (38 tributary/polder sites, 16 lake sites).

Subwatershed	Site ID	Latitude	Longitude	Site Description
Hawkestone Creek subwatershed	TS-2	44.49688	-79.468	Hawkestone Creek (EC flow gauge station)
Beaver River subwatershed	TS-24	44.39694	-79.0708	Beaver River at Conc. 2 (EC flow gauge station)
Uxbridge Brook subwatershed	UXB	44.11121	-79.1217	Uxbridge at Dominion and Main, near stormwater pond
	EC-047-08	44.13744	-79.1124	Southern Ontario Stream Sediment Project (SOSSP) site near Davis Dr., Uxbridge
Pefferlaw Brook subwatershed	EC-047-03	44.21412	-79.2037	SOSSP site on Zephyr Rd, Uxbridge, downstream of Mud Lake
Black River subwatershed	EC-036-02	44.31459	-79.3473	SOSSP site on Black River Rd, Sutton, upstream of the Black River
	EC-036-05	44.305	-79.36	SOSSP site at Mill Pond Park, Sutton (different from Mill Creek)
Maskinonge River subwatershed	TS-10/MASK	44.34091	-79.3994	Maskinonge River (PWQMN/LSPP site)
East Holland River subwatershed	TS-8	44.07902	-79.4547	East Holland River at Green Lane, East Gwillimbury GO Train Station
	TS-9	44.02196	-79.4735	Tannery Creek (PWQMN site), Aurora
	TS-22	43.99097	-79.4189	East Holland River at Vandorf Sideroad (LSRCA flow gauge station), Aurora
	TS-23	44.05988	-79.4621	Western Creek (LSPP site), Newmarket
	AUTO	44.08575	-79.437	Downstream of Princess Auto
	STJOHN	44.02208	-79.4537	St. John’s Sideroad
	EC-056-08	43.98547	-79.4434	SOSSP site near Vandorf Sideroad, Aurora
Oro Creeks North subwatershed	TS-25/BLU	44.58369	-79.4587	Mill Creek, Old Barrie Road and Line 15N, Orillia
	TS-26	44.59541	-79.4186	Mill Creek, James St. West, Orillia
	TS-27	44.59121	-79.4241	Mill Creek, Memorial Drive and Hwy 12, Orillia
Ramara subwatershed	EC-027-07B	44.53086	-79.1942	SOSSP site near corner of Ramara Rd. 47 and Concession Rd 3, Brechin

Table A-1 (cont). List of sites and locations for fall 2023 contaminant samples (38 tributary/polder sites, 16 lake sites).

Subwatershed	Site ID	Latitude	Longitude	Site Description
Lovers Creek subwatershed	TS-4	44.37277	-79.6512	Lovers Creek (PWQMN/LSPP site), Barrie
Barrie Creeks subwatershed	TS-28	44.38702	-79.6993	Kidds Creek (LSPP site), Barrie
	TS-29	44.38294	-79.6973	Bunkers Creek (LSPP site), Barrie
	TS-30	44.37511	-79.6936	Hotchkiss Creek (LSPP site), Barrie
Hewitts Creek subwatershed	TS-31	44.36902	-79.6326	Hewitts Creek (LSPP site), Barrie
Innisfil Creeks subwatershed	TS-32	44.32705	-79.5423	Leonards Creek (LSPP site), Alcona
	TS-33	44.31771	-79.5399	Bon Secours Creek, 25th Sideroad and Innisfill Beach Road, Alcona
West Holland River subwatershed	TS-7	44.11323	-79.5458	West Holland River, bridge at Hwy 11 (PWQMN/LSPP site)
Vegetable Polders and Canals	WH-1	44.07322	-79.6327	North Schomberg River (LSPP site)
	WH-2	44.02037	-79.6581	Upper Schomberg River at Leonard Rd.
	WH-4	44.08922	-79.5663	North Canal at Simcoe St.
	WH-5	44.11029	-79.5459	Inner Canal, Bradford Pumping Station #2, Holland Marsh
	WH-6	44.1123	-79.5476	Professor Day Pumphouse, ditch alongside Bradford Marsh
	WH-7	44.07312	-79.5637	Inner Canal, end of Keele Lane, Holland Marsh
	WH-8	44.05773	-79.5854	Inner Canal, Wanda and Devald, Holland Marsh
	WH-9	44.0277	-79.6205	Inner Canal, River Road, Holland Marsh
	WH-10	44.14377	-79.5302	Colbar Marsh, ditch along Bathurst St.
	HM-Canal1	44.11049	-79.5456	Eastern outer canal in the Holland Marsh, near Bradford Pumping Station #2 and WH-5
	HM-Canal2	44.11218	-79.5475	Western outer canal in the Holland Marsh, near WH-6

Table A-1 (cont). List of sites and locations for fall 2023 contaminant samples (38 tributary/polder sites, 16 lake sites).

Subwatershed	Site ID	Latitude	Longitude	Site Description
Lake Sites	WH-3	44.11525	-79.5456	West Holland River, at Hwy 11, downstream of bridge, north of marina. Mud / peat material bottom, 2.2 m deep
	HR-2	44.16755	-79.5165	East Holland River, downstream of Queensville Sideroad West, mud bottom, 1.8 m deep
	HR-6	44.19761	-79.5196	Holland River, just downstream of confluence of East and West Holland River sites, mud bottom, 2.7 m deep
	C-1	44.2116	-79.513	Holland River, mouth at green buoy, mud bottom, 2.4 m deep
	C-6	44.25759	-79.5122	Cook's Bay, south, at entrance to Holland River. Mud bottom, abundant plant growth, 3.1 m deep
	B-Litt-14	44.37942	-79.6871	Cook's Bay, north, east of DeGrassi Pt. Mud and mussel shell bottom, 15 m deep
	K-38	44.38205	-79.6761	Kempenfelt Bay, east of drop off, mud bottom, 20.1 m deep
	K-42	44.39905	-79.5705	Kempenfelt Bay, east of drop off, 39.8 m deep
	S-15	44.36443	-79.3878	Main Basin, 20.1 m deep
	C-9	44.28953	-79.5139	Cook’s Bay, 15.8 m deep
	K-45	44.46065	-79.4379	Main Basin (Parkside Beach Oro-Medonte), 28.6 deep
	E-50	44.40226	-79.24031	Main Basin (west)
	B-Litt-09	44.46632	-79.4831	Main Basin (west), littoral zone, mud/ cobble bottom, 7 m deep. Parkside Beach Oro-Medonte, west of 9 Line S
	B-Litt-08	44.58741	-79.3978	Shannon Bay, littoral zone, 4.2 m deep. Mud bottom, abundant plant growth
	N-32	44.57997	-79.4048	Shingle Bay, in line with Victoria Point, mud bottom, 6.4 m deep
	B-Litt-05A	44.45454	-79.1908	Main Basin (east), between Trent Canal and Thorah Island, littoral zone, 7.1 m deep, sand bottom with sparse plant growth

Table A-2. List of sites and locations for spring 2024 contaminant samples (32 tributary/polder sites and 6 lake sites).

Subwatershed	Site ID	Latitude	Longitude	Site Description
Hawkestone Creek subwatershed	TS-2	44.49688	-79.468	Hawkestone Creek (EC flow gauge station)
Maskinonge River subwatershed	TS-10/MASK	44.34091	-79.3994	Maskinonge River (PWQMN/LSPP site)
Beaver River subwatershed	TS-24	44.39694	-79.0708	Beaver River at Conc. 2 (EC flow gauge station)
Uxbridge Brook subwatershed	UXB	44.11121	-79.1217	Uxbridge at Dominion and Main, near stormwater pond
East Holland River subwatershed	TS-8	44.07902	-79.4547	East Holland River at Green Lane, East Gwillimbury GO Train Station
	TS-9	44.02196	-79.4735	Tannery Creek (PWQMN site), Aurora
	TS-22	43.99097	-79.4189	East Holland River at Vandorf Sideroad (LSRCA flow gauge station), Aurora
	TS-23	44.05988	-79.4621	Western Creek (LSPP site), Newmarket
	AUTO	44.08575	-79.437	Downstream of Princess Auto
	STJOHN	44.02208	-79.4537	St. John’s Sideroad
Oro Creeks North subwatershed	TS-25/BLU	44.58369	-79.4587	Mill Creek, Old Barrie Road and Line 15N, Orillia
	TS-26	44.59541	-79.4186	Mill Creek, James St. West, Orillia
	TS-27	44.59121	-79.4241	Mill Creek, Memorial Drive and Hwy 12, Orillia
Lovers Creek subwatershed	TS-4	44.37277	-79.6512	Lovers Creek (PWQMN/LSPP site), Barrie
Barrie Creeks subwatershed	TS-28	44.38702	-79.6993	Kidds Creek (LSPP site), Barrie
	TS-29	44.38294	-79.6973	Bunkers Creek (LSPP site), Barrie
	TS-30	44.37511	-79.6936	Hotchkiss Creek (LSPP site), Barrie
Hewitts Creek subwatershed	TS-31	44.36902	-79.6326	Hewitts Creek (LSPP site), Barrie
Innisfil Creeks subwatershed	TS-32	44.32705	-79.5423	Leonards Creek (LSPP site), Alcona
	TS-33	44.31771	-79.5399	Bon Secours Creek, 25th Sideroad and Innisfill Beach Road, Alcona
West Holland River subwatershed	TS-7	44.11323	-79.5458	West Holland River, bridge at Hwy 11 (PWQMN/LSPP site)
Vegetable Polders and Canals	WH-1	44.07322	-79.6327	North Schomberg River (LSPP site)
	WH-2	44.02037	-79.6581	Upper Schomberg River at Leonard Rd.
	WH-4	44.08922	-79.5663	North Canal at Simcoe St.
	WH-5	44.11029	-79.5459	Inner Canal, Bradford Pumping Station #2, Holland Marsh
	WH-6	44.1123	-79.5476	Professor Day Pumphouse, ditch alongside Bradford Marsh

Table A-2 (cont.). List of sites and locations for spring 2024 contaminant samples (32 tributary/polder sites and 6 lake sites).

Subwatershed	Site ID	Latitude	Longitude	Site Description
Vegetable Polders and Canals (cont.)	WH-7	44.07312	-79.5637	Inner Canal, end of Keele Lane, Holland Marsh
	WH-8	44.05773	-79.5854	Inner Canal, Wanda and Devald, Holland Marsh
	WH-9	44.0277	-79.6205	Inner Canal, River Road, Holland Marsh
	WH-10	44.14377	-79.5302	Colbar Marsh, ditch along Bathurst St.
	HM-Canal1	44.11049	-79.5456	Eastern outer canal in the Holland Marsh, near Bradford Pumping Station #2 and WH-5
	HM-Canal2	44.11218	-79.5475	Western outer canal in the Holland Marsh, near WH-6
Lake Sites	C-6	44.25759	-79.5122	Cook's Bay, south, at entrance to Holland River. Mud bottom, abundant plant growth, 3.1 m deep
	K-38	44.38205	-79.6761	Kempenfelt Bay, east of drop off, mud bottom, 20.1 m deep
	K-42	44.39905	-79.5705	Kempenfelt Bay, east of drop off, 39.8 m deep
	S-15	44.36443	-79.3878	Main Basin, 20.1 m deep
	K-45	44.46065	-79.4379	Main Basin (Parkside Beach Oro-Medonte), 28.6 deep
	N-32	44.57997	-79.4048	Shingle Bay, in line with Victoria Point, mud bottom, 6.4 m deep

Table A-3. Date of sample collection in fall 2023. Each date corresponds to one sample.

Site type	Site ID	Water					Sediment			
		PFAS	PHC + BTEX	SVOC/PAH	Phenols	Metals	OCP + PCB	PHC + BTEX	PAH	Metals
Polder	**WH-2**		Oct 17	Oct 17	Oct 17	Oct 17		Oct 17	Oct 17	Oct 17
Polder	**WH-9**		Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17
Polder	**WH-1**		Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17
Polder	**WH-8**		Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17
Polder	**WH-7**		Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17
Polder	**WH-4**		Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17
Polder	**WH-5**	Oct 24	Oct 24	Oct 24	Oct 24	Oct 24	Oct 24	Oct 24	Oct 24	Oct 24
Polder	**HM-Canal1**			Oct 24		Oct 24	Oct 24		Oct 24	
Polder	**WH-6**		Oct 24	Oct 24	Oct 24	Oct 24	Oct 24	Oct 24	Oct 24	Oct 24
Polder	**HM-Canal2**						Oct 24		Oct 24	
Polder	**TS-7**		Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17
Polder	**WH-10**		Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17	Oct 17
Tributary	**TS-22**		Oct 18	Oct 18	Oct 18	Oct 18		Oct 18	Oct 18	Oct 18
Tributary	**TS-23**		Oct 18	Oct 18	Oct 18	Oct 18		Oct 18	Oct 18	Oct 18
Tributary	**STJOHNS**			Oct 18		Oct 18			Oct 18	
Tributary	**TS-9**	Oct 18				Oct 18				
Tributary	**TS-8**	Oct 18	Oct 18	Oct 18	Oct 18	Oct 18		Oct 18	Oct 18	Oct 18
Tributary	**AUTO**			Oct 18					Oct 18	Oct 18
Tributary	**TS-33**		Oct 24	Oct 24	Oct 24	Oct 24		Oct 24	Oct 24	Oct 24
Tributary	**TS-32**		Oct 24	Oct 24	Oct 24	Oct 24		Oct 24	Oct 24	Oct 24
Tributary	**TS-31**		Oct 24	Oct 24	Oct 24	Oct 24		Oct 24	Oct 24	Oct 24
Tributary	**TS-4**		Oct 24	Oct 24	Oct 24	Oct 24		Oct 24	Oct 24	Oct 24
Tributary	**TS-30**		Oct 24	Oct 24	Oct 24	Oct 24	Oct 24	Oct 24		Oct 24
Tributary	**TS-29**	Oct 24	Oct 24	Oct 24	Oct 24	Oct 24	Oct 24	Oct 24	Oct 24	Oct 24
Tributary	**TS-28**		Oct 24	Oct 24	Oct 24	Oct 24	Oct 24	Oct 24	Oct 24	Oct 24
Tributary	**TS-2**		Oct 10	Oct 10	Oct 10	Oct 10		Oct 10	Oct 10	Oct 10

Table A-3 (cont.). Date of sample collection in fall 2023. Each date corresponds to one sample.

Site type	Site ID	Water					Sediment			
		PFAS	PHC + BTEX	SVOC/PAH	Phenols	Metals	OCP + PCB	PHC + BTEX	PAH	Metals
Tributary	**TS-25/BLU**			Oct 23	Oct 23	Oct 23		Oct 23	Oct 23	Oct 23
Tributary	**TS-27**			Oct 23	Oct 23	Oct 23		Oct 23	Oct 23	Oct 23
Tributary	**TS-26**	Oct 23	Oct 23	Oct 23	Oct 23	Oct 23	Oct 23	Oct 23	Oct 23	Oct 23
Tributary	**TS-24**		Oct 10	Oct 10	Oct 10	Oct 10	Oct 10	Oct 10	Oct 10	Oct 10
Tributary	**UXB**					Oct 18				
Tributary	**TS-10/MASK**		Oct 10	Oct 10	Oct 10	Oct 10	Oct 10	Oct 10	Oct 10	Oct 10
Tributary	**EC-036-02**			Oct 18		Oct 18	Oct 18		Oct 18	
Tributary	**EC-036-05**	Oct 18							Oct 18	Oct 18
Tributary	**EC-047-08**			Oct 18			Oct 18		Oct 18	Oct 18
Tributary	**EC-056-08**	Oct 18		Oct 18		Oct 18	Oct 18		Oct 18	
Tributary	**EC-047-03**		Oct 18	Oct 18	Oct 18	Oct 18		Oct 18	Oct 18	Oct 18
Tributary	**EC-027-07B**	Oct 23		Oct 23		Oct 23			Oct 23	
Tributary	**WC-034-06**		Oct 24	Oct 24		Oct 24			Oct 24	
Lake Simcoe	**K-38**		Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2
Lake Simcoe	**K-42**			Oct 2		Oct 2		Oct 2	Oct 2	
Lake Simcoe	**C-6**		Oct 3		Oct 3	Oct 3	Oct 3	Oct 3		Oct 3
Lake Simcoe	**N-32**		Oct 3	Oct 3	Oct 3	Oct 3		Oct 3	Oct 3	Oct 3
Lake Simcoe	**S-15**					Oct 3				
Lake Simcoe	**K-45**					Oct 3				
Lake Simcoe	**C-9**		Oct 3	Oct 3		Oct 3			Oct 3	
Lake Simcoe	**C-1**		Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2
Lake Simcoe	**B-Li -14**		Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2
Lake Simcoe	**B-Li -09**		Oct 3	Oct 3	Oct 3	Oct 3		Oct 3	Oct 3	Oct 3
Lake Simcoe	**B-Li -08**		Oct 3	Oct 3	Oct 3	Oct 3	Oct 3	Oct 3	Oct 3	Oct 3
Lake Simcoe	**E-50**					1				
Lake Simcoe	**B-Li -05A**		Oct 3	Oct 3	Oct 3	Oct 3	Oct 3	Oct 3	Oct 3	Oct 3

Table A-3 (cont.). Date of sample collection in fall 2023. Each date corresponds to one sample.

Site type	Site ID	Surface water					Sediment			
		PFAS	PHC + BTEX	SVOC/PAH	Phenols	Metals	OCP + PCB	PHC + BTEX	PAH	Metals
Lake Simcoe	**HR-6**		Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2
Lake Simcoe	**HR-2**		Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2
Lake Simcoe	**EH-1**		Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2
Lake Simcoe	**WH-3**		Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2	Oct 2

Table A-4. Date of sample collection in spring 2024. Each date corresponds to one sample.

Site type	Site ID	Water					Sediment			
		OCP + PCB	PHC + BTEX	SVOC/PAH	Phenols	Metals	OCP + PCB	PHC + BTEX	PAH	Metals
Polder	**WH-2**	Mar 19		Mar 19		Mar 19	Mar 19	Mar 19	Mar 19	Mar 19
Polder	**WH-9**			Mar 19		Mar 19	Mar 19	Mar 19	Mar 19	Mar 19
Polder	**WH-1**			Mar 19		Mar 19	Mar 19	Mar 19	Mar 19	Mar 19
Polder	**WH-8**			Mar 19		Mar 19	Mar 19	Mar 19	Mar 19	Mar 19
Polder	**WH-7**			Mar 19		Mar 19	Mar 19	Mar 19	Mar 19	Mar 19
Polder	**WH-4**			Mar 19		Mar 19	Mar 19	Mar 19	Mar 19	Mar 19
Polder	**WH-5**			Mar 19		Mar 19	Mar 19	Mar 19	Mar 19	Mar 19
Polder	**HM-Canal1**			Mar 19		Mar 19	Mar 19	Mar 19	Mar 19	Mar 19
Polder	**WH-6**			Mar 19		Mar 19	Mar 19	Mar 19	Mar 19	Mar 19
Polder	**HM-Canal2**			Mar 19		Mar 19	Mar 19	Mar 19	Mar 19	Mar 19
Polder	**TS-7**	Mar 19		Mar 19		Mar 19	Mar 19	Mar 19	Mar 19	Mar 19
Polder	**WH-10**			Mar 19		Mar 19	Mar 19	Mar 19	Mar 19	Mar 19
Tributary	**TS-22**			Mar 19		Mar 19		Mar 19	Mar 19	Mar 19
Tributary	**TS-23**			Mar 19		Mar 19		Mar 19	Mar 19	Mar 19
Tributary	**STJOHNS**			Mar 19		Mar 19		Mar 19	Mar 19	Mar 19
Tributary	**TS-9**			Mar 19		Mar 19		Mar 19	Mar 19	Mar 19
Tributary	**TS-8**			Mar 19		Mar 19		Mar 19	Mar 19	Mar 19
Tributary	**AUTO**			Mar 19		Mar 19		Mar 19	Mar 19	Mar 19
Tributary	**TS-33**			Mar 20		Mar 20		Mar 20	Mar 20	Mar 20
Tributary	**TS-32**			Mar 20		Mar 20		Mar 20	Mar 20	Mar 20
Tributary	**TS-31**			Mar 20		Mar 20		Mar 20	Mar 20	Mar 20
Tributary	**TS-4**			Mar 20		Mar 20		Mar 20	Mar 20	Mar 20
Tributary	**TS-30**			Mar 20		Mar 20		Mar 20	Mar 20	Mar 20
Tributary	**TS-29**			Mar 20		Mar 20		Mar 20	Mar 20	Mar 20
Tributary	**TS-28**			Mar 20		Mar 20		Mar 20	Mar 20	Mar 20
Tributary	**TS-2**			Mar 20		Mar 20		Mar 20	Mar 20	Mar 20

Table A-4 (cont.). Date of sample collection in spring 2024. Each date corresponds to one sample.

Site type	Site ID	Water					Sediment			
		OCP + PCB	PHC + BTEX	SVOC/PAH	Phenols	Metals	OCP + PCB	PHC + BTEX	PAH	Metals
Tributary	**TS-25/BLU**			Mar 20	N/A	Mar 20		Mar 20	Mar 20	Mar 20
Tributary	**TS-27**		Mar 20	Mar 20	Mar 20	Mar 20		Mar 20	Mar 20	Mar 20
Tributary	**TS-26**		Mar 20	Mar 20	Mar 20	Mar 20		Mar 20	Mar 20	Mar 20
Tributary	**TS-24**		Mar 20	Mar 20	Mar 20	Mar 20		Mar 20	Mar 20	Mar 20
Tributary	**UXB**			Mar 20		Mar 20		Mar 20	Mar 20	Mar 20
Tributary	**TS-10/MASK**	Mar 20	Mar 20	Mar 20	Mar 20	Mar 20	Mar 20	Mar 20	Mar 20	Mar 20
Lake Simcoe	**K-38**	Apr 16	Apr 16	Apr 16	Apr 16	Apr 16	Apr 16	Apr 16	Apr 16	Apr 16
Lake Simcoe	**K-42**			Apr 16		Apr 16		Apr 16	Apr 16	Apr 16
Lake Simcoe	**C-6**			Apr 16		Apr 16		Apr 16	Apr 16	Apr 16
Lake Simcoe	**N-32**			Apr 16		Apr 16		Apr 16	Apr 16	Apr 16
Lake Simcoe	**S-15**			Apr 16		Apr 16		Apr 16	Apr 16	Apr 16
Lake Simcoe	**K-45**			Apr 16		Apr 16		Apr 16	Apr 16	Apr 16