Sediment Quality in Lake Huron Tributaries

A Screening-Level Survey

Environmental Conservation Branch
Ontario Region
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Sediment Quality in Canadian Lake Huron Tributaries:

A Screening-Level Survey

D. A. Burniston, J. Kraft, Sean Backus and A. Dove

Ecosystem Health Division, Ontario Region
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Executive Summary

A survey of sediment quality was undertaken in the summer and fall of 2004 in the mouths of tributaries draining to the Upper Channel, Georgian Bay, and Lake Huron. A total of 81 samples were obtained, representing 73 tributaries. Eight (8) samples were field duplicates and given fictitious names.

The sampling program was based on the Guidelines for Collecting and Processing Samples of Stream Bed Sediment for Analysis of Trace Elements and Organic Contaminants, developed by the United States Geological Survey (USGS) for the U.S. National Water-Quality Assessment Program (NAWQA; Shelton and Capel, 1994). A number of sub-samples are combined at each site so that one sample is obtained that is representative of the overall conditions in that tributary.

The samples were analyzed for 26 organochlorine compounds plus seven (7) PCB Aroclors and Total PCBs. Sixteen (16) PAH compounds and 30 metals were analyzed, and the inorganic and organic carbon content as well as grain size distribution of each sample was determined. For many of the tributaries, this study represents the first information related to organic compounds in sediments.

Twenty three (23) organochlorine compounds were not detected in any sample. DDT and metabolites DDE and DDE were the only detected organochlorines, with only a 5.5% occurrence for DDE and a 4.1% occurrence for DDT. Three (3) sites had detectable parent DDT concentrations with one site, found not only above the PEL, but reported as the only isomer with no detectable metabolites. One or more PCB Aroclor was detected at nine sites. Total PCB concentrations exceeded federal TEL guidelines at only two (2) sites while no federal PEL were found.
Polycyclic aromatic hydrocarbons (PAHs) were found more often, with one or more of the 16 PAH compounds detected at 14 sites (i.e., detection frequency of 19%). Exceedences of one or more federal TEL guideline for PAHs occurred at 10% of the sites and PEL exceedences occurred at a further two (2) sites. In general, PAH concentrations were lower than found on the lower great lakes. This is probably do to the lower urbanization found along Lake Huron.

At most sites, the detections of metals are likely related to the natural occurrence of trace elements in stream sediments. For some metals, however, concentrations appear to be elevated to a degree that is considered to be toxic to aquatic biota. These metals include: chromium, mercury, zinc. Nickel has a natural occurrence, in Sudbury which reflects levels of greater than two times the serious effect level. Other metals, including manganese and iron, appeared to be elevated at certain sites but these higher levels might be related to natural sources.

1.0 Introduction and Purpose

The Ecosystem Health Division (EHD) of Environment Canada (EC), Ontario Region, conducted a screening-level survey of sediment quality in Canadian tributaries to Lake Huron during the summer of 2004. The sampling represents the first stages of a track-down program to identify potential sources of contamination to the upper Great Lakes that are not being addressed by other Great Lakes programs. The program constitutes a portion of Environment Canada's commitment towards the Great Lakes Water Quality Agreement (GLWQA).

The purpose of the sampling was to assess sediment quality in deposition zones in each tributary prior to discharge to Lake Huron. One sediment sample, consisting of many subsamples, was taken from each tributary in a manner that is representative of the overall sediment quality in that tributary.

The study was designed to maximize the probability of detecting persistent toxic substances entering the lake, if they exist. The intent of the program is to identify remaining sources of contamination for subsequent follow-up work. It is not the intent at this stage to quantify the loadings of contaminants entering Lake Huron. Instead, the results from this program will be combined with existing water quality, fish, benthic and sediment contaminant information, using a weight-of-evidence approach, to prioritize subsequent track-down efforts.

Previous Great Lake screening studies targeted parameters for the sediment screening identified in their respective Lakewide Management Plan (LaMP) as impairing lake-wide beneficial uses. Since there is no current Lake Huron LaMP to help identify parameters of issue, previously targeted parameters from Lake Erie and Lake Ontario screening studies were used. In addition, a suite of contaminants targeted for virtual elimination in the Canada-U.S. Binational Toxics Strategy (BTS) were considered in order to assess Canada's commitments towards that Strategy. Additional parameters were included for contextual information (such as particle size and total organic carbon) and to improve our understanding of the contaminant status of Lake Huron tributaries (e.g., metals, pesticides, contaminants of emerging concern).

2.0 Methodology

To achieve the study objectives, the sampling program consisted of a survey-level, screening assessment of recently deposited sediment quality near the mouths of tributaries entering Lake Huron. The targeted substances are relatively insoluble in water (i.e., hydrophobic) and are therefore typically found at higher concentrations in sediments than in water. In addition, bed sediments in depositional environments provide a time-integrated sample of particulate matter transported by a stream. Analysis of bed sediments alleviated problems associated with detecting trace levels of substances in water samples. Bed sediment sampling can overcome problems detecting periodic or intermittent sources of contaminants in water from non-point pollution sources.

2.1 Field Program

Tributary Selection

A reconnaissance survey was conducted in May and June 2004 to identify tributaries and select the sampling sites. Sediment deposition zones were sought near the mouths of the tributaries such that they were likely downstream from potential contaminant sources yet sufficiently far upstream not to be influenced by the water body into which it drains. In other words, sites were selected to be outside of the zone of lake influence.

During the reconnaissance survey, the method of access was also identified. Most sites were accessed by wading or were sampled from a bridge crossing. In certain, larger tributaries, sampling sites were accessed by boat. In the majority of cases, the sample site coincided with the most downstream road crossing of the tributary.

Number of Sites

Virtually every tributary, containing sediment, draining the Canadian Lake Huron watersheds was sampled in this program. For many sites, this program has provided its first information about organic contaminants in sediments. The geographic extent of the program was from Sarnia in the south to just east of the St. Marys River on the northern tip of the North Channel at Echo Bay. Tributaries to the North Channel, Georgian Bay and Lake Huron were included in this program. The tributaries sampled during the project are shown in Figure 1 and with their labels (i.e. tributary names) in Appendix B.

A total of 81 samples were obtained, representing 73 tributaries. As mentioned above, a single site sediment sample was generally taken from depositional zones upstream of the tributary mouth.

Of the 81 samples, 8 were blind duplicate samples; that is, they were split samples that were assigned a fictitious name in the field (usually a name of a common bird, unless a more appropriate name was conceived). The blind duplicates were obtained to assess variability due to sample handling and laboratory precision. A list of blind duplicates and the corresponding tributary is provided in Table 1, below.

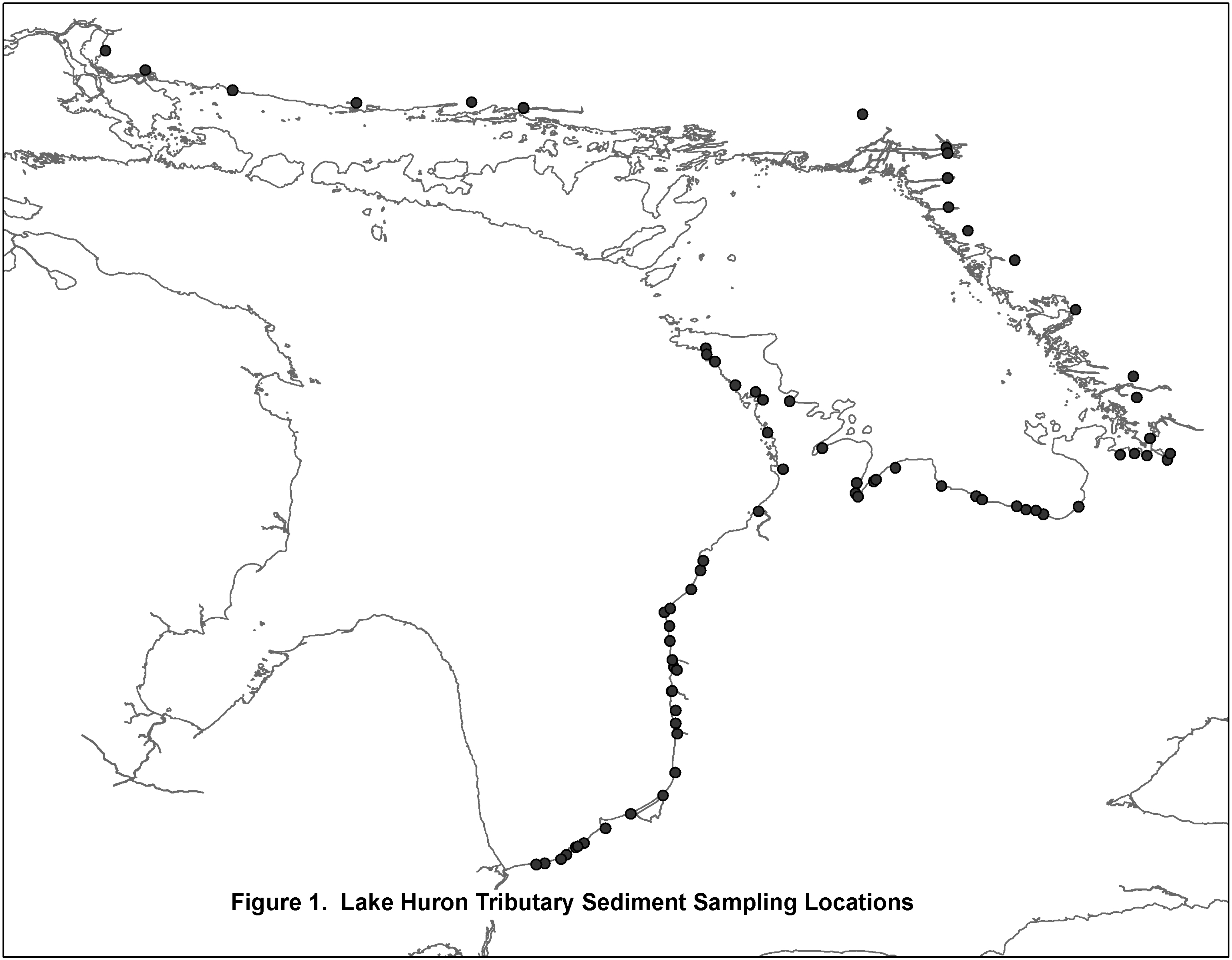

Figure 1. Lake Huron Tributary Sediment Sampling Locations

Table 1. Blind Duplicate Sample Listing

Tributary	Blind Duplicate Sample
Aberarder Creek	Partridge Creek
Nine Mile River	Grouse Creek
Judges Creek	Pintail Creek
Thessalon River	Canvasback Creek
Pickerel River	Old Squaw Creek
Severn River	Teal Creek
Gleason Brook	Shoveller Creek
Sauble River	Scaup Creek

Sampling Methodology

The sampling program was based on the Guidelines for Collecting and Processing Samples of Stream Bed Sediment for Analysis of Trace Elements and Organic Contaminants, developed by the United States Geological Survey (USGS) for the U.S. National Water-Quality Assessment Program (NAWQA; Shelton and Capel, 1994). In the NAWQA program, downstream locations in watersheds are selected to provide a coarse-scale network of sites. At these "integrator" sites, large-scale problems that may not be detected in smaller basins have a reasonable chance of being detected. A number of sub-samples are combined so that one sample is obtained that is representative of the overall conditions in that tributary.

Field Campaign

Sampling was conducted between Aug 31 and November3, 2004. One or more depositional reach was sampled upstream of the mouth in each tributary. Only the very fine-grained surface deposits, to a maximum depth of approximately 1 or 2 cm, depending on the site, were collected. These surface sediments better represent relatively recent rather than historic deposition. Sites were selected to be representative of the variety of locations (i.e., mid-channel, left bank, right bank) and habitat types (pools, different depths of water, and depositional zones behind obstacles such as boulders or sand bars) present at each site. Only wetted depositional zones were sampled.

Where water depths permitted wading and water velocities were slow enough to permit sample retrieval, samples were obtained using a stainless steel spoon and collected in a glass bowl. At sites where the water depth was too great for wading, or water velocities were swift enough to wash the fine particles from the spoons during sample retrieval, an all-stainless steel Wildco Petite Ponar sampler was used.

Upon arrival at each site, the sampling equipment was thoroughly rinsed in the ambient river water. The surface sediments were collected (either by spoon or Ponar, as described above) and combined in a glass bowl. The sediments were sieved through a 2-mm stainless steel sieve to remove the larger size fractions and to assist with homogenization of the sample. The sample was further homogenized by mixing with a spoon for approximately two minutes.

Several sample jars were filled at each site. In general, four jars were used:

- one 125-mL polyethylene container filled with approximately 2 cm of sediment for metals analysis;

- one 125-mL polyethylene container filled with approximately 2 cm of sediment for metals analysis;
- one 125-mL polyethylene container filled approximately ½ full for total organic carbon and grain size analysis;
- one 250-mL glass container with Teflon-lined screw cap filled approximately ¾ full for organochlorine (OC) and polyaromatic hydrocarbon (PAH) analysis, and;
- one 250-mL Teflon or glass container filled approximately ¾ full for archiving purposes.

Blind duplicate samples were obtained at eight sites, including blind duplicate archive samples at each of these.

Sample jars were labeled with permanent marker on both the lids and on laboratory tape affixed to the side of the jars. The recorded information included the site name, date, organization (EHD/OR), and parameters for analysis (e.g. OCs and PAHs, metals, TOC and grain size, Archive). After the appropriate sample jars were filled, the sampling equipment was thoroughly rinsed in the ambient river water.

A field drawing was made and digital photos were taken at each site. A sketch of each tributary reach was made to include its major features, habitat types, approximate dimensions, surrounding land uses, major road crossings, etc. The locations and number of sampling sites were identified on each sketch, and the method of sediment retrieval was noted. A Lowrance Global Map 100 geographic positioning system (GPS) device was used to obtain each location using the position averaging function. The GPS location within the site was included on the sketch.

Samples were kept on ice in portable coolers while in the field. Upon return to the Canada Centre for Inland Waters in Burlington, the samples were decanted then frozen at –10ºC. Samples in glass bottles were frozen on their sides to prevent bottle breakage.

2.2 Laboratory Methods

The samples in polyethylene containers (i.e., those for metals, TOC and grain size analysis) were freeze-dried prior to analysis. Samples were sent to Natural Resources Canada in Ottawa, Ontario. All metals samples, TOC and grain size samples were freeze-dried at these facilities. Once freeze-dried, TOC was analyzed by Leco Cr-412 and grain size fractions were determined using a Lecotrac Particle Size Analyzer LT100.

Metal analysis was performed in their entirety by Caduceon Enterprises Inc. The laboratory performed the metals analysis (including mercury) on freeze-dried sediment samples using aqua regia digestion methods.

Analysis of organochlorines (OCs), including PCBs and polycyclic aromatic hydrocarbons (PAHs) was awarded to Maxxam Analytics Inc. in Mississauga as the result of a competitive bidding process. Frozen, wet sediment samples were sent to Maxxam in the autumn of 2004. Samples were thawed and OCs were analyzed by gas chromatography/dual column electron capture detector (GC/ECD) after accelerated solvent extraction following the EPA protocol SW846 EPA 3545. Samples for PAH analysis were extracted using a sonication method. The extracts were then concentrated and analyzed by mass spectrometry (GC/MS). Sample results were reported on a dry weight basis.

compounds). Other sub-samples have been contributed to Dr. B. Scott for analysis of haloacetic acids and perfluoroalkanoic acids (including PFOA) and comparison with water samples from selected tributaries. Dioxin, furans, dioxin-like PCBs and polychlorinated napthalene analysis was conducted on 13 samples by the Ontario Ministry of the Environment.

2.3 Data Analysis

The laboratory results were analyzed in a spreadsheet program. Results were compared with the Federal and Provincial sediment quality objectives and with other sites in the program. The frequency of detection and frequency of exceedence of the sediment quality objectives were computed. Mapping of selected compounds was prepared on 1:250,000 basemaps of the Lake Huron basin using ArcView 8.1.

3.0 Results

Throughout this report, references and comparisons are made to the federal and provincial sediment quality guidelines. For clarity and consistency, each guideline is assigned a unique colour. The graphics presented in this report use these colours to indicate exceedences of the guidelines. The following colour coding is also referenced in Appendix B:

Guideline	Colour Code
Federal Sediment Quality Guidelines	
Below Threshold Effect Level (TEL)	Green
Above Federal TEL but below PEL	Yellow
Above Probable Effect Level (PEL)	Orange
Provincial Sediment Quality Guidelines	
Below Lowest Effect Level (LEL)	Green
Above LEL but below SEL	Blue
Above Severe Effect Level (SEL)	Red

3.1 Quality Assurance/Quality Control

All laboratories used for the project were CAEAL accredited for their respective analytical parameters. As mentioned above in the methodology, Maxxam Analytical Inc. performed the organochlorine and polycyclic aromatic hydrocarbon analyses. The Maxxam laboratory QA/QC program consisted of blanks, spiked blanks and duplicate samples (i.e., laboratory replicate runs).

All method blanks were within acceptable limits (below method detection limit) and spikes were within acceptable limits (40-130%) for all parameters.

Paired student t-tests were also performed to assess differences between blind duplicate samples submitted to the laboratory. The majority of the inorganic parameters could be assessed this way, with the exception of parameters that were detected in fewer than three samples. Organic parameters could not be assessed do to there non-detects. There were no significant differences observed between the blind duplicate samples, for any of the parameter assessed, at the 95% confidence level.

3.2 Method Detection Limits

All of the analytical parameters used in the study are hydrophobic, i.e., they have a propensity for solid surfaces such as sediments as opposed to the dissolved phase. Sampling very fine, flocculent surface deposits, serves to maximize the probability of encountering these analytes, if they are present in the environment. Typical laboratory detection limits are therefore sufficient to detect these parameters at ambient concentrations. The laboratory method detection limits are provided in Table 2, below, for both laboratories used in this study. This Table also provides a useful reference of all parameters measured in the study.

Table 2. Analytical Parameters and Laboratory Method Detection Limits
a. Maxxam Analytics Inc. (Organics)

Polychlorinated Biphenyls (PCBs)		Polycyclic Aromatic Hydrocarbons (PAHs)		Organochlorine Pesticides (OCs)	
Parameter	**MDL**	**Parameter**	**MDL**	**Parameter**	**MDL**
Aroclor 1016	0.01 µg/g	Naphthalene	5 µg/kg	Hexachlorobenzene	0.002 µg/g
Aroclor 1221	0.03 µg/g	Acenaphthylene	5 µg/kg	o,p'-DDD	0.002 µg/g
Aroclor 1232	0.01 µg/g	Acenaphthene	10 µg/kg	Endrin aldehyde	0.002 µg/g
Aroclor 1242	0.02 µg/g	Fluorene	5 µg/kg	o,p'-DDT	0.002 µg/g
Aroclor 1248	0.01 µg/g	Phenanthrene	5 µg/kg	Toxaphene	0.08 µg/g
Aroclor 1254	0.01 µg/g	Anthracene	5 µg/kg	o,p'-DDE	0.002 µg/g
Aroclor 1260	0.01 µg/g	Fluoranthene	5 µg/kg	Aldrin	0.002 µg/g
Total PCB	0.01 µg/g	Pyrene	5 µg/kg	α-HCH	0.002 µg/g
		Benz(a)anthracene	10 µg/kg	β-HCH	0.002 µg/g
		Chrysene	10 µg/kg	δ-HCH	0.002 µg/g
		Benzo(b)fluoranthene	10 µg/kg	Lindane	0.002 µg/g
		Benzo(k)fluoranthene	10 µg/kg	α-Chlordane	0.002 µg/g
		Benzo(a)pyrene	5 µg/kg	γ-Chlordane	0.002 µg/g
		Indeno(1,2,3-cd)pyrene	20 µg/kg	p,p'-DDD	0.002 µg/g
		Dibenzo(a,h)anthracene	20 µg/kg	p,p'-DDE	0.002 µg/g
		Benzo(ghi)perylene	20 µg/kg	p,p'-DDT	0.002 µg/g
				Dieldrin	0.002 µg/g
				α-Endosulfan	0.002 µg/g
				β-Endosulfan	0.002 µg/g
				Endosulfan sulfate	0.002 µg/g
				Endrin	0.002 µg/g
				Heptachlor	0.002 µg/g
				Heptachlor epoxide	0.002 µg/g
				Methoxychlor	0.008 µg/g
				Mirex	0.002 µg/g
				Octachlorostyrene	0.002 µg/g

All laboratory method detection limits, for organic analytes are below the federal PEL except for Lindane (PEL sediment quality guideline 0.00138 µg/g). Most of the laboratory detection limits for the organic analytes are below the TEL with the exception of total DDT, total DDE, toxaphene, heptachlor epoxide and acenaphthene.

Table 2 cont. Analytical Parameters and Laboratory Method Detection Limits
b. Caduceon Enterprises (Metals)

Parameters	Units	MDL
Aluminum	%	0.01
Antimony	µg/g	5
Arsenic	µg/g	5
Barium	µg/g	1
Beryllium	µg/g	0.2
Bismuth	µg/g	5
Cadmium	µg/g	0.5
Calcium	%	0.01
Chromium	µg/g	1
Colbalt	µg/g	1
Copper	µg/g	1
Iron	%	0.01
Lead	µg/g	5
Lithium	µg/g	0.5
Magnesium	%	0.01
Manganese	µg/g	0.5
Molybdenum	µg/g	1
Nickel	µg/g	1
Phosphorus	µg/g	3
Potassium	%	0.05
Silver	µg/g	0.1
Sodium	%	0.01
Strontium	µg/g	1
Tin	µg/g	10
Titanium	µg/g	0.5
Vanadium	µg/g	1
Yttrium	µg/g	0.5
Zinc	µg/g	1
Zirconium	µg/g	0.1
Mercury	ng/g	5

All laboratory method detection limits for metals were below federal sediment quality guidelines.

3.3 Laboratory Results

A review of the detection frequency of analytical parameters and exceedences of sediment quality guidelines is provided here. A discussion of the highest observed levels is provided for selected parameters in Section 4. A full listing of the laboratory data for the 73 unique sites is provided in Appendix A. The laboratory data for the blind duplicate samples is not provided but can be obtained from Environment Canada.

3.3.1 Frequency of Detection

In general, organochlorine parameters were not detected, with only a few exceptions. A total of twenty three (23) organochlorine parameters were not detected in any sample. In addition, six (6) of the nine (9) PCB Aroclors analyzed were not detected. Of the sixteen (16) PAHs, all but one (1) were detected in at least one sample. Two (2) metals parameters were not detected in any sample. The parameters that were not detected are listed below in Table 3.

The frequency of detection of the remaining parameters is provided in Table 4, below. Recall that a total of 73 tributaries were sampled. Metals were commonly detected due to their natural presence in sediments. Polycyclic aromatic hydrocarbons were also commonly detected, but this is likely due to anthropogenic sources. Of the organochlorines, the DDT metabolite DDE was the most frequently detected parameter.

Table 3. Parameters Not Detected

Organochlorines
• Hexachlorobenzene • o,p'-DDD • Endrin aldehyde • o,p'-DDT • Toxaphene • o,p'-DDE • Aldrin • α-HCH • β-HCH • δ-HCH • Lindane • α-Chlordane • γ-Chlordane • Dieldrin • α-Endosulfan • β-Endosulfan • Endosulfan sulfate • Endrin • Heptachlor • Heptachlor epoxide • Methoxychlor • Mirex • Octachlorostyrene
PCB Aroclors
• Aroclor 1016 • Aroclor 1221 • Aroclor 1232 • Aroclor 1242 • Aroclor 1248 • Aroclor 1268
Metals
• Bi (Bismuth) • Sb (Antimony)

Table 4. Frequency of Detection by Parameter

Organochlorines	# Detections	Frequency
p,p'-DDE	4	5.5%
p,p'-DDT	3	4.1%
p,p'-DDD	1	1.4%

PCB	# Detections	Frequency
Total PCB	9	12%
Aroclor 1254	7	9.6%
Aroclor 1260	6	8.2%
Aroclor 1262	1	1.4%

PAH	# Detections	Frequency
Pyrene	12	16%
Chrysene	12	16%
Fluoranthene	11	15%
Benzo(b)fluoranthene	11	15%
Benz(a)anthracene	10	14%
Benzo(a)pyrene	10	14%
Anthracene	2	2.7%
Fluorene	2	2.7%
Benzo(k)fluoranthene	2	2.7%
Benzo(ghi)perylene	2	2.7%
Indeno(1,2,3-cd)pyrene	2	2.7%
Acenaphthylene	1	1.4%
Acenaphthene	1	1.4%
Dibenzo(a,h)anthracene	1	1.4%

Metal	# Detections	Frequency
Aluminum	73	100%
Cadmium	73	100%
Calcium	73	100%
Chromium	73	100%
Copper	73	100%
Iron	73	100%
Lithium	73	100%
Magnesium	73	100%
Manganese	73	100%
Nickel	73	100%
Lead	73	100%
Strontium	73	100%
Titanium	73	100%
Vanadium	73	100%
Ytrium	73	100%
Zinc	73	100%
Mercury	73	100%
Sodium	71	97%
Molybdenum	68	93%
Beryllium	43	59%
Silver	18	25%
Arsenic	6	8.2%
Tin	1	1.4%

3.3.2 Comparison of Results with Sediment Quality Guidelines

The sediment quality results were compared to the Canadian Environmental Quality Guidelines (Canadian Council of Ministers of the Environment, 2001). The CCME sediment quality guidelines provide scientific benchmarks, or reference points, for evaluating the potential for observing adverse biological effects in aquatic systems. The guidelines are derived from available toxicological information. A lower value, referred to as the threshold effect level (TEL), represents the concentration below which adverse biological effects are expected to occur rarely. The upper value, referred to as the probable effect level (PEL), represents the level above which adverse effects are expected to occur frequently. Fewer than 25% of adverse effects (in the Biological Effects Database for Sediments) occur below the TEL, and more than 50% of adverse effects occur above the PEL.

Where no federal guidelines were available, the provincial guidelines were used for comparison (Persaud et al., 1992). Provincial Severe Effect Levels for organic compounds and polycyclic aromatic hydrocarbons were calculated individually for each site using the organic carbon concentration in the sediment. However, no SEL exceedences were determined for these compounds in this study.

A special mention should be made of toxaphene. At present the only guideline that is available is an interim sediment quality guideline which the federal government has adopted from the New York State Department of Environmental Conservation (NYSDEC 1994), 0.01μg/g TOC, which has been converted to dry weight. This value is the lowest available guideline from other jurisdictions; in fact it is lower than many laboratory detection limits. This guideline is considerably lower than the 80 μg/kg method detection limit reported for this program. While it is acknowledged that lower detection limits would be more beneficial for screening sediments it is pointed out that toxaphene is not a critical pollutant; and that sediment inventories of the Great Lakes support atmospheric transport as opposed to local sources (Muir et. al. 2005).

Table 5 provides a summary of the numbers of exceedences of the federal guidelines, and exceedences of the provincial guidelines for those parameters for which federal guidelines are not available. A complete list of the sediment quality guidelines relevant to this study is provided in Appendix B.

Table 5. Number of Sites Exceeding Sediment Quality Guidelines

A. Metals	**Federal Guidelines**		**Provincial Guidelines**	
	Exceeds TEL[1] Below PEL	**Exceeds PEL[2]**	**Exceeds LEL[3] Below SEL**	**Exceeds SEL[4]**
Chromium	45	15		
Zinc	11	0		
Lead	7	1		
Nickel			19	1
Manganese			37	5
Iron			11	0
Copper	6	0		
Cadmium	13	0		
Arsenic	3	0		
Mercury	0	1		
B. Organochlorines				
Total – DDE (o,p' + p,p')	3	1		
Total – DDT (o,p' + p,p')	2	1		
PCB Aroclor 1260			5	
Total PCB	2	0		

Table 5 cont. Number of Sites Exceeding Sediment Quality Guidelines

C. Polycyclic Aromatic Hydrocarbons	Exceeds TEL[1] Below PEL	Exceeds PEL[2]	Exceeds LEL[3] Below SEL	Exceeds SEL[4]
Acenaphthylene	1	0		
Acenaphthene	1	0		
Fluorene	2	1		
Phenanthrene	4	2		
Anthracene	1	1		
Fluoranthene	4	1		
Pyrene	6	2		
Benz(a)anthracene	7	2		
Chrysene	7	1		
Benzo(k)fluoranthene			2	
Benzo(a)pyrene	6	1		
Indeno(1,2,3-cd)pyrene	0	0	2	
Dibenzo(a,h)anthracene	0	1		
Benzo(ghi)perylene			2	
Total PAH			2	

Notes: 1 Federal Threshold Effect Level
2 Federal Probable Effect Level
3 Provincial Lowest Effect Level
4 Provincial Severe Effect Level

4.0 Discussion

4.1 DDT and Metabolites

DDT (dichlorodiphenyltrichloroethane) is a chlorinated hydrocarbon that has broad-spectrum pesticide properties. It was used in large quantities in the 1950s and 1960s on crops. The U.S. banned the use of DDT in 1973. The use of DDT in Canada was severely restricted in the early 1970s and discontinued in 1985, with the sale and use of existing stocks permitted until the end of 1990 (CCME, 2001). DDT is still used as an insecticide in other countries.

DDT has two metabolites: DDE (dichlorodiphenyldichloroethylene) and DDD (dichlorodiphenyldichloroethane). Each DDT molecule has several isomeric forms, depending on the configurations of the chlorine atoms on the molecule. For comparison with sediment quality guidelines, the laboratory results were analyzed according to the following:

Total DDT = o-p'- plus p-p'DDT
Total DDE = o-p'- plus p-p'DDE
Total DDD = o-p'- plus p-p'DDD
Total DDT and metabolites = Total DDT + Total DDE + Total DDD

DDT, including its metabolites, was the only detected organochlorine compound in the current study with only 6.8% of samples reaching detectable levels of one or more isomer of DDT or its metabolites. The most commonly detected isomer was p-p'-DDE, with a detection frequency of 5.5%.

DDT exceeded sediment quality guidelines in three (3) tributaries with one (1) of these tributaries exceeding the federal probable effect level (4.77 ng/g). While four (4) tributaries had federal sediment quality guideline exceedences for total DDE, only one was above the probable effect level (6.75 ng/g).

Analysis of the ratio of parent DDT to the metabolites DDE and DDD indicates that recent sources of the pesticide may be contributing to the observed concentrations. In the five (5) tributaries where DDT or metabolite isomers were detected, the ratios ranged from 0-11*. Two (2) sites had only metabolites detected (ratio 0) which indicates an old source where all of the parent compound, DDT, has broken down. Two further sites had ratios less than one which indicates that the source, while not fresh is more recent. The Seguin River had only the parent compound, DDT, detected at levels above the PEL. This indicates that the source may not only be fresh but may also be new, that is has not been ongoing.

Tributary	Ratio of Parent DDT: Metabolites	Total DDT & Metabolite Concentration (ng/g)
Seguin River	11*	11
Pretty River	0	10
Black Ash Creek	0.5	9
Beaver River	0.67	5
Perch Creek	0	2

*Metabolite concentrations were below detection limits, therefore 0.5 MDL (1.0) was used for calculation.

4.2 PCBs

Polychlorinated biphenyls, or PCBs, were commonly used in electrical equipment such as transformers and capacitors due to their chemical stability. The manufacture of PCBs was halted in 1977 in the United States. PCBs were not produced in Canada but approximately 40 000 t of PCBS were imported and used commercially prior to the 1980s. Like many other organochlorine compounds, PCBs are persistent, bioaccumulative and toxic. They are the cause of the majority of the fish consumption advisories in each of the Great Lakes and they are considered a priority pollutant by many authorities. The Great Lakes Water Quality Agreement calls for the virtual elimination of discharges of PCBs.

In the current study, PCBs were analyzed in the laboratory as Aroclors, the trade name that describes the complex mixture of PCB congeners under which some PCBs were manufactured. This method is much less expensive than the more elaborate congener analyses although it is also less precise and less accurate. The detection limit for Aroclor analysis was 10 ng/g, which is below the sediment quality guidelines and sufficient for the purposes of detecting PCBs in sediments.

Only three of the nine PCB Aroclors were detected in this study. Aroclor 1262 was detected at only one site. Aroclor 1254 was detected at 7 sites, and Aroclor 1260 was detected at 6 sites. Total PCBs were detected at 9 tributaries. In the majority of these (9 sites), the concentration was below the Federal TEL of 34.1 ng/g. The TEL was exceeded at two (2) sites, Gibson River (60ng/g) and the Seguin River (50 ng/g) both draining into Georgian Bay. There were no sites with PCB quantities above the PEL (277 ng/g).

4.3 PAHs

Polycyclic aromatic hydrocarbons are produced during the incomplete combustion of organic substances, most commonly the combustion of fossil fuels. As an indicator of human industrial activities, PAH contamination is relatively widespread.

PAHs were commonly detected in the current survey. One or more PAH compound was found in 19% of the tributaries. A listing is provided below of the three (3) tributaries with concentrations of total PAH (i.e., the sum of the 16 PAH compounds investigated here) greater than 1,000 μg/kg.

The Magnetewan River had the third highest level of PAH concentrations in any of the tributaries in Lake Huron and the lower great lakes combined. It is targeted as a confirmation/follow-up site. Reasons for elevated levels at this site is unclear, while there is recreational boat activity the population is very low.

Tributary	Total PAH concentration (μg/kg)
Magnetewan River	60,710
Seguin River	5,977
Wye River	1,491

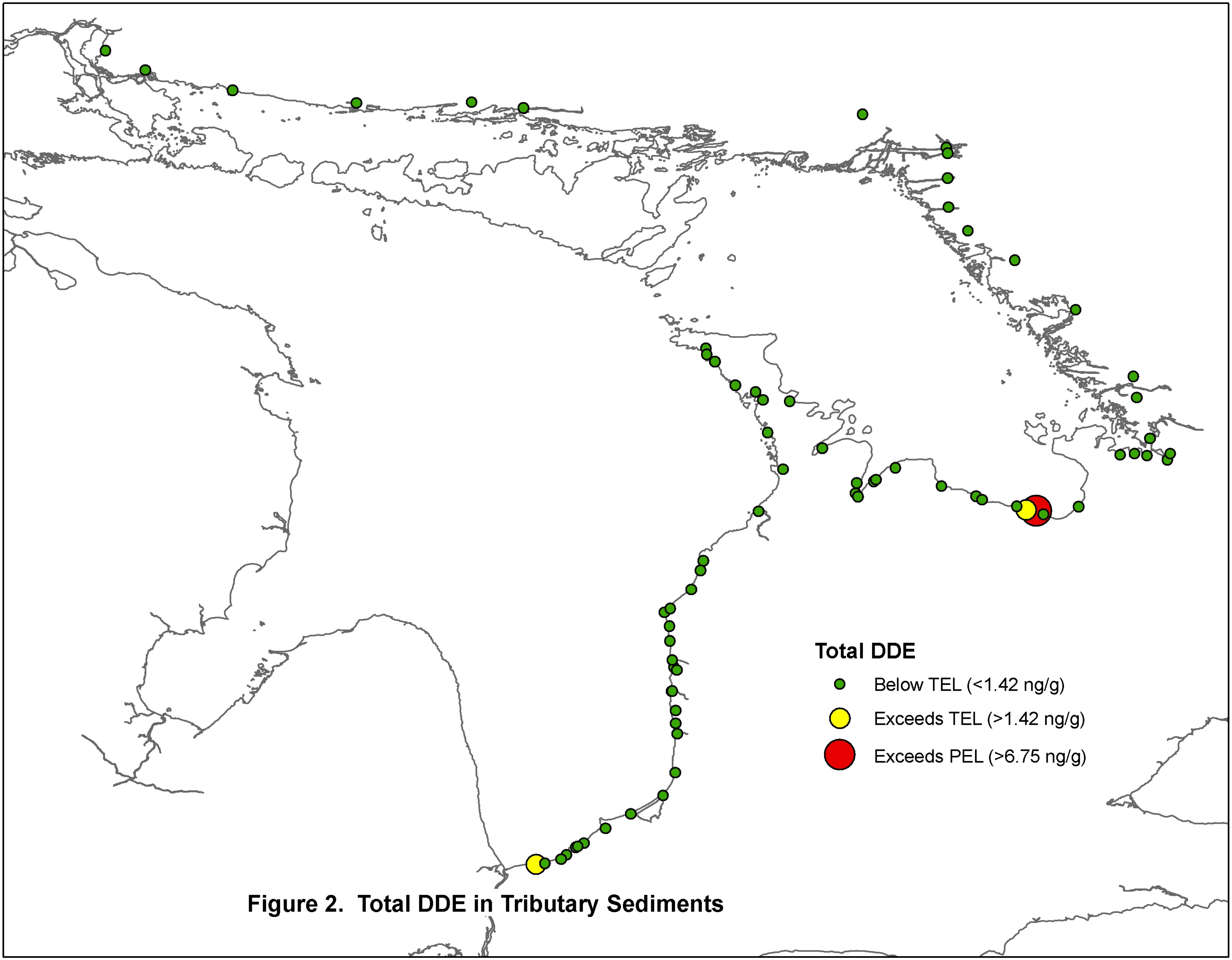

Figure 2. Total DDE in Tributary Sediments

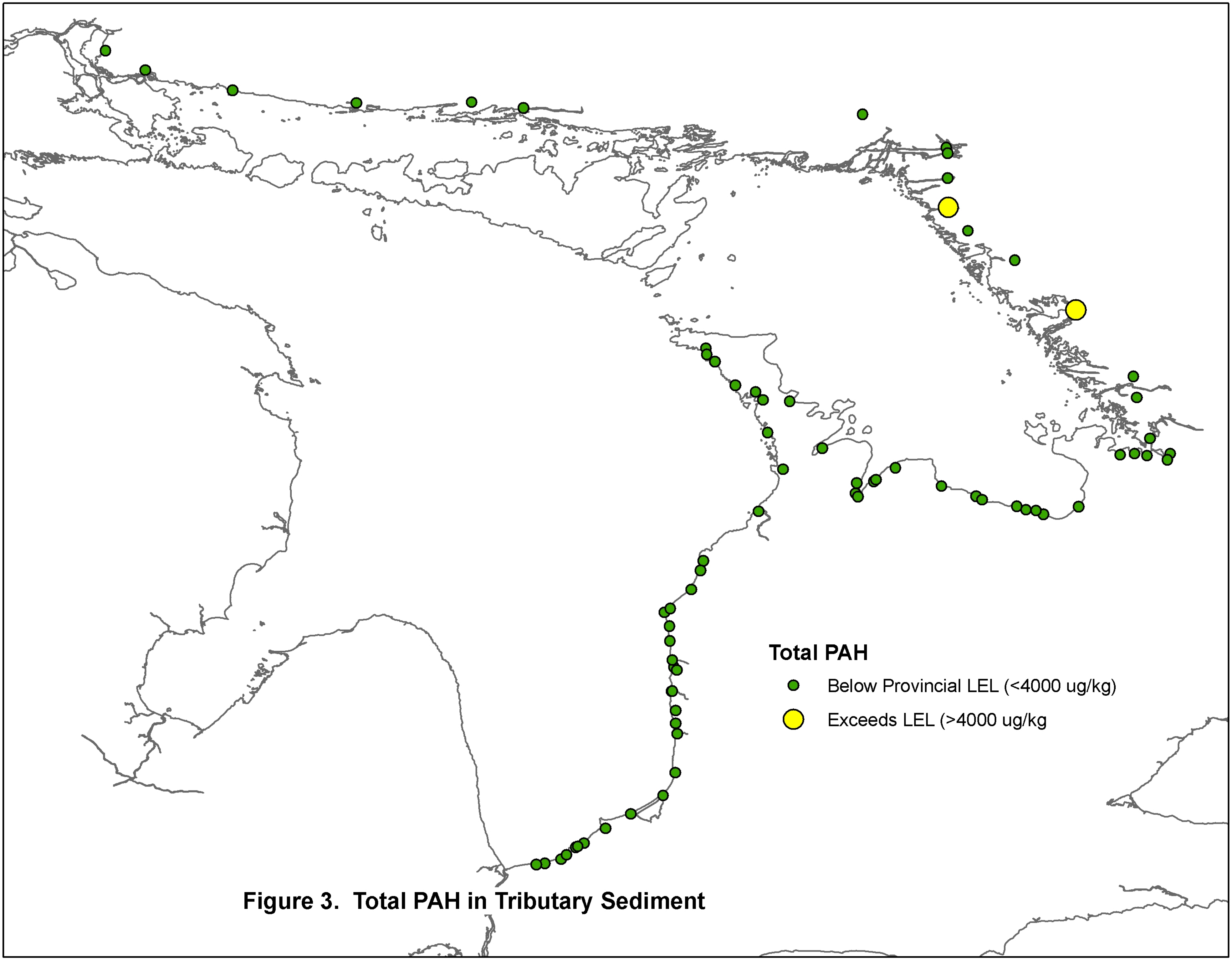

Figure 3. Total PAH in Tributary Sediment

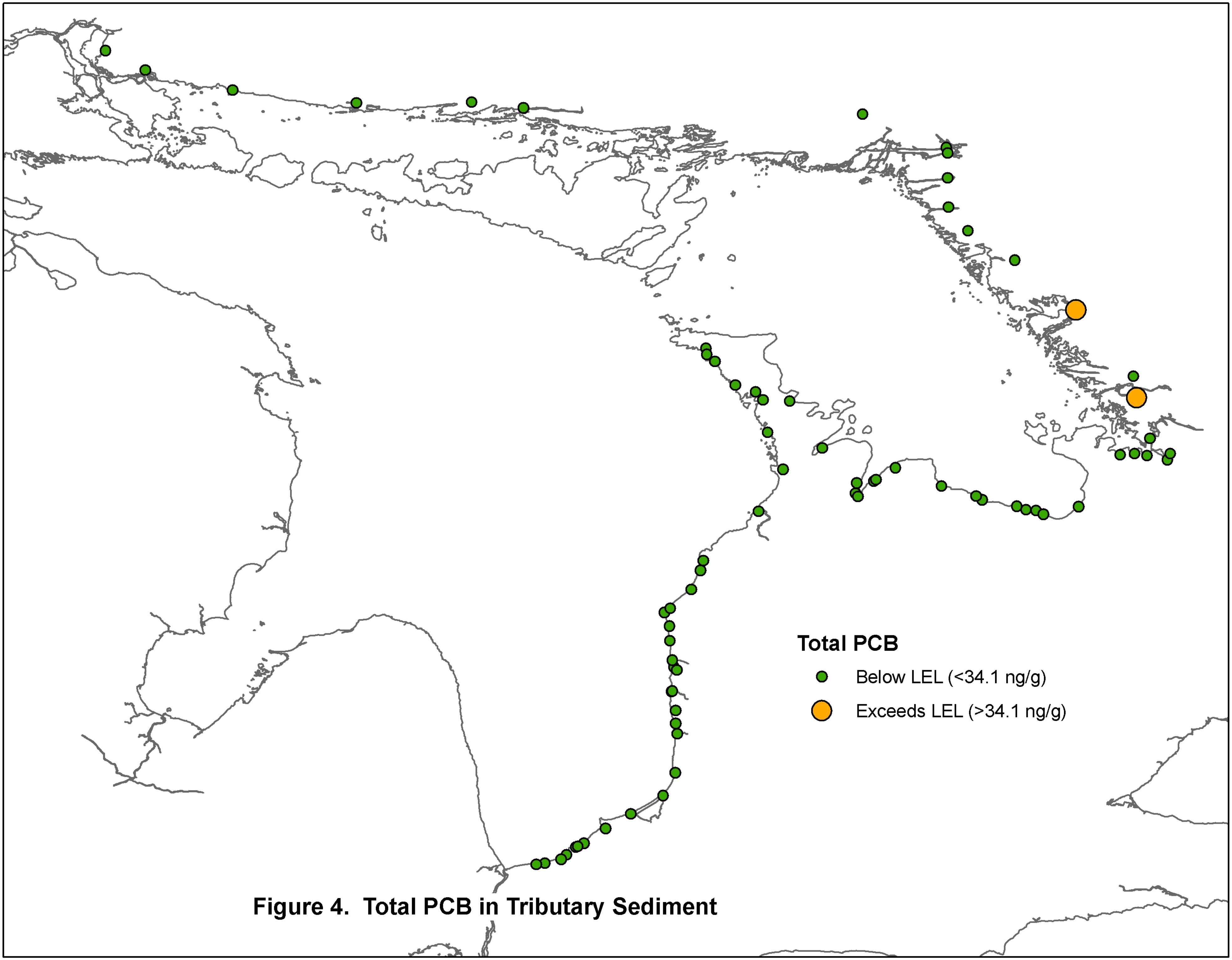

Figure 4. Total PCB in Tributary Sediment

4.4 Metals

4.4.1 Arsenic

Arsenic (As) is a metalloid and a nonessential trace element. Its release from anthropogenic sources is mainly from gold and base metal production facilities, with smaller releases from the use of arsenical pesticides, wood preservatives, coal-fired power generation and disposal of domestic and industrial wastes (Environment Canada, 1993).

In the current study, arsenic was found to exceed sediment quality criteria infrequently. Of the 73 unique sites, concentrations were above the federal TEL at 4 sites, and above the PEL at none. (see Table 5). At some of these sites, the exceedences may be due to naturally elevated As levels. In the National Geochemical Reconnaissance (NGR) program of the Geological Survey of Canada, the mean concentration of As in stream sediments was determined to be 10.7 μg/g (P.W.B. Friske, 1996 in CCME 2001), which is greater than the federal TEL of 5.9 μg/g.

4.4.2 Cadmium

Cadmium (Cd) is a non-essential trace element that is produced commercially from base-metal smelters and refineries, especially zinc refining. It is used in batteries, coatings, pigments, stabilizers and alloys (Hoskin, 1991 in Environment Canada, 1994a). Natural, background levels of Cd may be greater than the TEL, as the NGR program determined the mean concentration of Cd in stream sediments to be 0.63 μg/g (P.W.B. Friske, 1996 in CCME 2001) as compared with the federal TEL of 0.6 μg/g. In an assessment of the NGR data, Painter et al. (1994) found that 95% of the data were below 1.3 μg/g.

Cadmium concentrations in the current study were generally below the federal TEL (0.6 μg/g) with only 13 (thirteen) sites exceeding the TEL. All sites were below the federal PEL (3.5)

4.4.3 Chromium

Chromium (Cr) is an essential trace element that can be toxic to organisms at elevated levels (CCME 2001). It is not mined in Canada, but its import contributes to the production of pigments, metal finishing, leather tanning and wood preservatives (Nriagu 1988 in Environment Canada 1994b).

Chromium was found at concentrations above sediment quality guidelines at more than 82 per cent of the sites. At forty five sites chromium levels exceeded the federal TEL (37.3 µg/g) while an additional fifteen sites exceeded the federal PEL (90 µg/g). A table of the PEL exceedences is listed below.

Tributary	Cr (µg/g)
Shawanaga River	155
Serpent River	130
French River	125
Severn River	123
Sucker Creek	122
Seguin River	121
Crane River	111
Gibson River	105
Magnetawan River	104
Pickerel River	104
Wye River	103
Coldwater River	98
Moon River	95
Desbarats River	94
Spanish River	94

4.4.4 Copper

Copper (Cu) is an essential trace element whose anthropogenic sources are mainly from mining and smelting operations. Naturally elevated Cu concentrations may contribute to the Cu content in streambed sediments. In an analysis of the NGR sediment database, Painter et al. (1994) found that 95% of Cu concentrations were below 76 µg/g. In the current study, 6 sites showed concentrations above the TEL of 35.7 µg/g while no sites exceeded the PEL of 197 µg/g.

Tributary	Cu (µg/g)
Wanapitei River	102
Seguin River	95
Severn River	70
Desbarats River	45
French River	40
Key River	39

4.4.5 Mercury

Mercury (Hg) is a nonessential trace element that is toxic, persistent and bioaccumulative. Fish consumption advisories are in effect for mercury in much of the Great Lakes ecosystem. Current uses of mercury include some batteries, dental fillings, thermometers and switches, cathode tubes and household cleaners. Sources of mercury to the environment include mining and smelting, wastewater, fossil fuel combustion and waste incineration.

Sediment from most tributaries contained relatively low concentrations of mercury. Only one site exceeded any federal guidelines, that being the Seguin River in Parry Sound which at a concentration of 3.13 μg/g, exceeded the federal PEL (0.486 μg/g) by more than 6 times. Local, natural mercury deposits can impact environmental concentrations. The 95th percentile for mercury in the NGR database was determined to be 190 ng/g (Painter et al., 1994). Levels above this are therefore unlikely to be of natural origin.

4.4.6 Nickel

Nickel (Ni) is a trace element whose primary anthropogenic sources include primary base metal production and fossil fuel combustion (Environment Canada, 1994c). There is no federal sediment quality guideline for Ni, therefore sediment concentrations were compared with the provincial guidelines. The Lowest Effect Level (LEL) of 16 μg/g was exceeded at 19 sites. However, exceedences of the LEL can occur naturally. Analysis of the NGR database of stream and lake sediment metals concentrations showed that the 95th percentile for Ni concentration was 60 μg/g (Painter et al., 1994). Levels greater than this are more likely to indicate anthropogenic impacts. In the current study, the Severe Effect Guideline (SEL) of 75 μg/g was exceeded at one site, the Wanapitei River at a concentration of 192 μg/g. High concentrations of nickel in the Wanapitei River, located in Sudbury, Ontario has been well documented in the past. Hutchinson et al reported that in 1975 water levels were 42 mg/L while sediments were 224 μg/g wet wt. The consistency of the levels of nickel in the river as well as the documented high natural levels which exceed 100 ppm (Painter er al, 1994) suggests that the levels in the sediment may be attributed to natural sources. Sudbury is home of one of the worlds largest sulfitic nickel deposits, the form of nickel which supplies the world with 90% of its nickel.

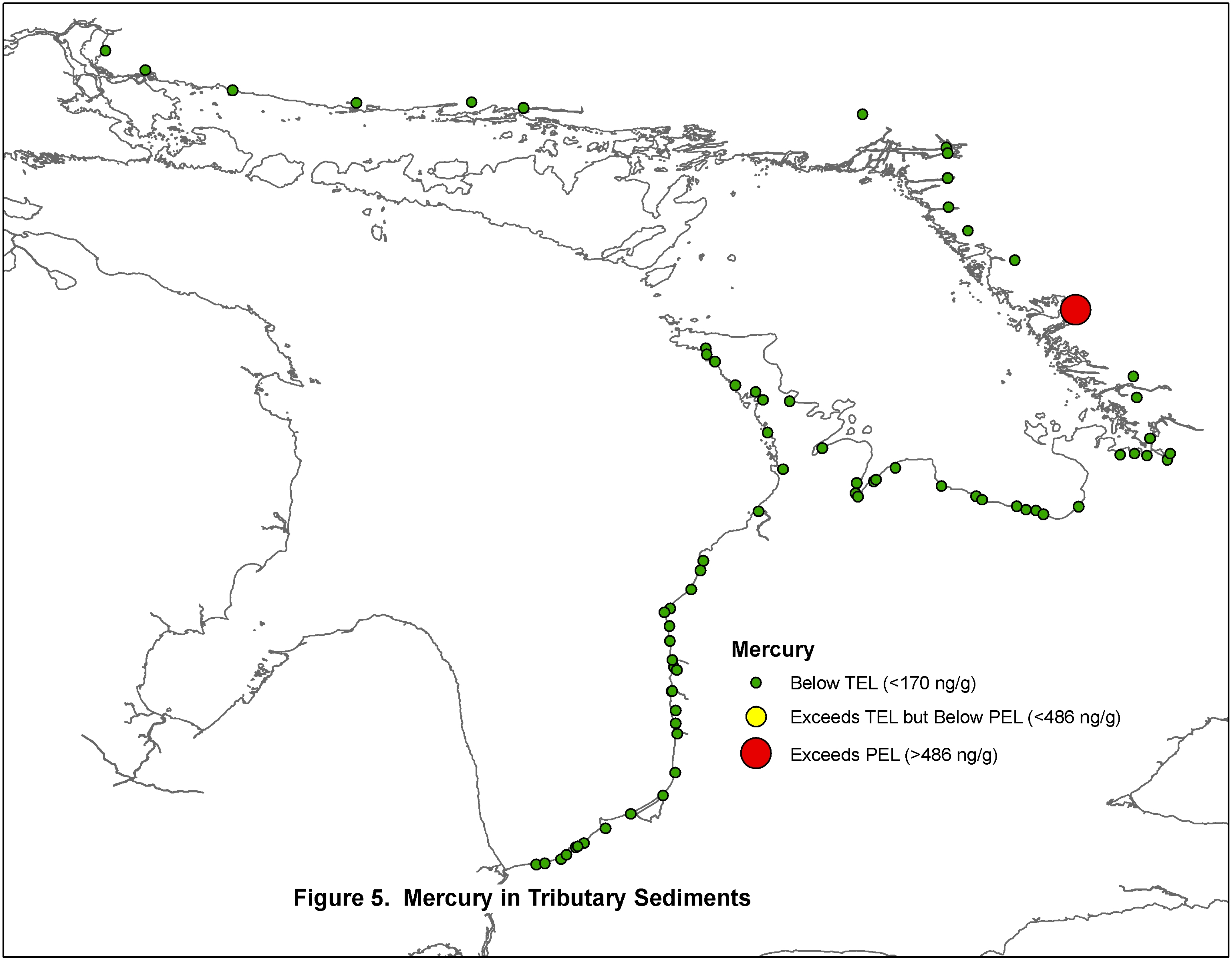

Figure 5. Mercury in Tributary Sediments

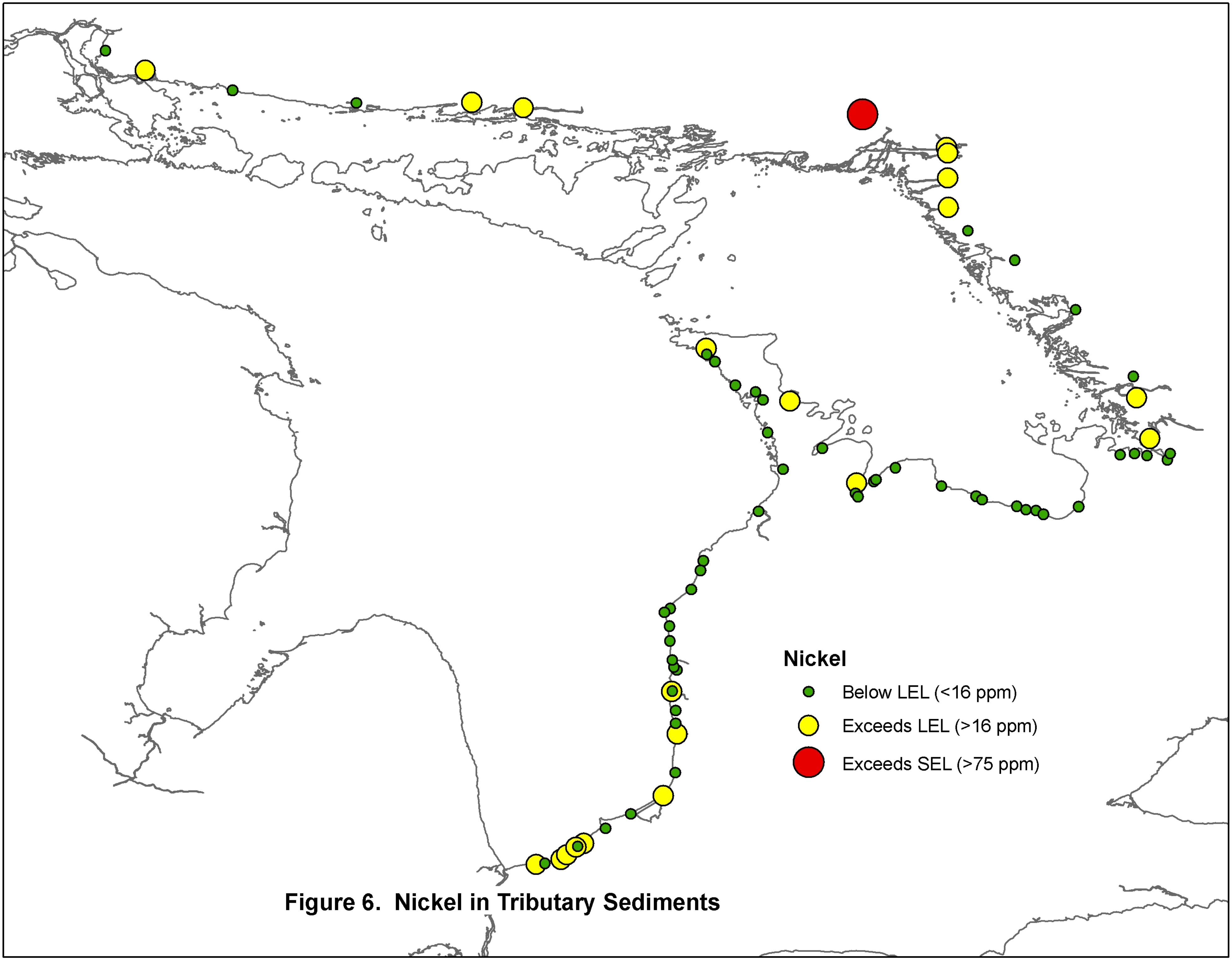

Figure 6. Nickel in Tributary Sediments

4.4.7 Lead

Lead (Pb) is a nonessential trace element. Its past use as an additive in gasoline has resulted in its widespread distribution in the environment above background levels. Currently, sources of lead to the environment include lead processing activities, batteries, and industrial and municipal effluents. Lead concentrations exceeded the federal TEL of 35 µg/g at 8 sites and the PEL of 91.3 µg/g at one site. The 95th percentile of stream and lake sediment Pb concentration in the NGR database was 25 µg/g (Painter et al., 1994), therefore even TEL exceedences are likely to be due to anthropogenic influences. The guideline exceedences are listed below.

Tributary	Pb (µg/g)
Severn River	108
Pickerel River	85
Seguin River	54
Sideroad Creek	52
Key River	44
French River	40
Gibson River	38
Shawanaga River	36
Spring Creek	108

4.4.8 Zinc

Zinc (Zn) is an essential trace element that is considered toxic to aquatic biota at elevated concentrations (CCME, 2001). Anthropogenic zinc sources are primarily related to metals processing, with smaller releases from fossil fuel burning and ancillary sources such as fertilizers, rubber goods and pharmaceuticals.

In the current study, the federal TEL of 124 µg/g was exceeded at 11 sites. There were no PEL (315 µg/g) exceedences. The 95th percentile zinc sediment concentration in the NGR database was 191 µg/g, therefore TEL exceedences may not be due to anthropogenic sources. The five highest concentrations of zinc for the Canadian Lake Huron Tributaries are listed below.

Tributary	Zn (µg/g)
Severn River	260
Willow Creek	231
Key River	214
Pickerel River	188
Gibson River	170

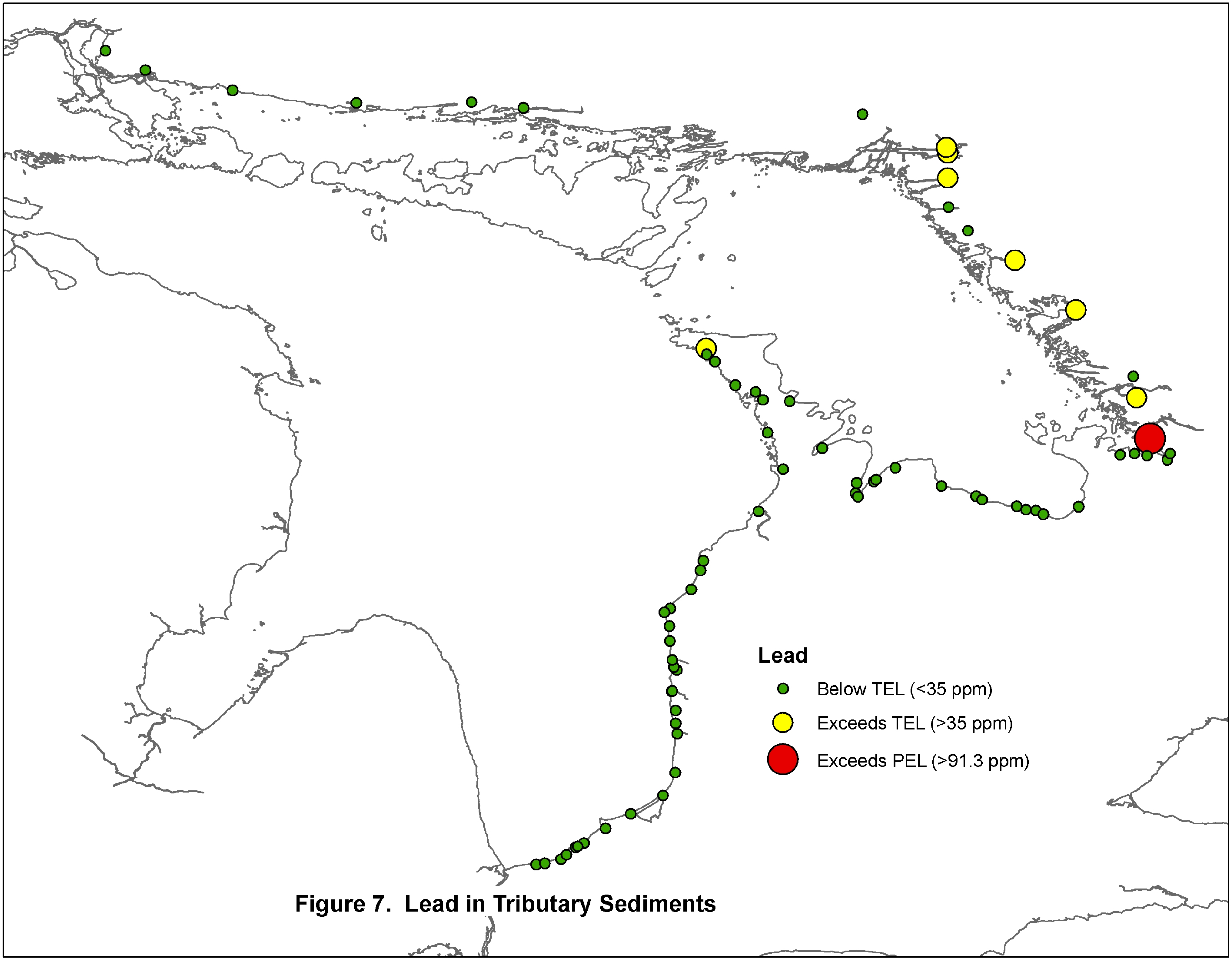

Figure 7. Lead in Tributary Sediments

4.4.9 Manganese and Iron

Concentrations of the essential metals manganese and iron were compared with provincial sediment quality guidelines as no federal guidelines are available. Manganese concentrations exceeded the LEL of 460 µg/g at 37 sites and the SEL of 1100 µg/g at a further five sites. The five SEL exceedences are listed below. These exceedences generally did not appear to be related to industrial impacts in the majority of cases. Indeed, Mn exceedences also occurred in relatively "clean" tributaries that were expected to represent background or unimpacted conditions (e.g. Forestville Creek). The median Mn concentration in the Ontario Geological Survey stream sediment database (Fortescue, 1984) is calculated to be 850 µg/g, and the 95th percentile of concentrations was 2150 µg/g. It might therefore be interpreted that stream sediment concentrations in this range may be attributed to natural sources. Indeed, the application of the Ontario Sediment Quality Guidelines should take the background levels of metals into account prior to any management action (Persaud et al., 1992).

Tributary	Mn (µg/g)
Gleason Brook	2570
Spring Creek	1990
Indian Creek	1740
Severn River	1330
Keefer Creek	1260

For iron (Fe), background levels may also be high due to natural sources. The Ontario Geological Survey stream sediment data (Fortescue, 1984) shows that the median Fe concentration is 3.1% and that the 95th percentile of Fe concentrations is 5.5%. These values are comparable to the LEL of 2% and the SEL of 4%. In the current study, 11 sites exceeded the LEL. Several of these included sites at which contamination from anthropogenic sources would not be expected. Similar to Mn, the natural or background concentration of Fe would need to be determined in order to interpret sediment quality guideline exceedences.

5.0 Next Steps

This sampling represents the first stage of a track-down program to identify potential sources of contamination to the upper Great Lakes that are not being addressed by other Great Lakes programs. The program constitutes a portion of Environment Canada's commitment towards the Great Lakes Water Quality Agreement (GLWQA).

By committing to the track-down program, the federal and provincial partners have agreed to conduct follow-up work at locations where ambient data indicate potentially significant sources of persistent, bioaccumulative and toxic substances (PBTs) may exist. The program has, to date, focused on potential PCB sources. Three pilot projects have been initiated/conducted in Lake Ontario tributaries and another two in Lake Erie tributaries where PCB contamination is suspected based on available ambient information. Based on the experiences in these projects, the project partners have developed a decision framework guide for potential future track-down projects; in particular, it provides guidelines for the initiation and termination of such projects and provides recommendations with respect to appropriate project design and sampling methodologies.

The parties have determined that potential projects must be prioritized based on the available information. The degree of contamination is determined for various media, and a prioritization is then made. These recommendations will require full disclosure and the sharing of ambient information between the project partners. To that end, steps have already been taken to ensure that information is freely shared in a manner that permits a broad prioritization based on the most current and reliable information.

By virtue of this document the information from the current study is being shared with other environmental authorities and partners in Ontario. Confirmatory and, where warranted, follow-up studies to investigate observed exceedences of the federal PEL have already been carried out in two tributaries, the Magnetawan River, the Seguin River by Environment Canada. Based on these sampling results, determinations will be made by the appropriate agencies about how to proceed.

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Appendices

Appendix A and B Notes

Note: The following Organochlorine and metal compounds were not detected in any sample and are not included in the preceding table of laboratory results:

Aldrin
α-Chlordane
γ-Chlordane
o,p'-DDE
o,p'-DDD
o,p'-DDT
Dieldrin
α- Endosulphan
β-endosulphan
Endosulphan sulfate
Endrin
Endrin aldehyde
α-HCH
β-HCH
δ-HCH
Heptachlor
Heptachlor epoxide
Hexachlorobenzene
Lindane
Methoxychlor
Mirex
Octachlorostyrene
Toxaphene
Naphthalene
PCB Aroclor 1016
PCB Aroclor 1221
PCB Aroclor 1232
PCB Aroclor 1242
PCB Aroclor 1248
PCB Aroclor 1268
Antimony
Bismuth

Appendix A and B Notes

Note: An explanation of Short-Forms and Chemical Compound Names

HCB	Hexachlorobenzene
OCS	Octachlorostyrene
α-HCH	Alpha-hexachlorocyclohexane (previously a-BHC)
β-HCH	Beta-hexachlorocyclohexane (previously b-BHC)
δ-HCH	Delta-hexachlorocyclohexane (previously d-BHC)
Lindane	Gamma-hexachlorocyclohexane
Total Chlordane	Sum of alpha- and gamma-Chlordane
o,p'-DDD	Isomer of Dichlorodiphenyldichloroethane
p,p'-DDD	Isomer of Dichlorodiphenyldichloroethane
o,p'-DDE	Isomer of Dichlorodiphenyldichloroethylene
p,p'-DDE	Isomer of Dichlorodiphenyldichloroethylene
o,p'-DDT	Isomer of Dichlorodiphenyltrichloroethane
p,p'-DDT	Isomer of Dichlorodiphenyltrichloroethane
Total DDD	Sum of o,p'- and p,p'-DDD
Total DDE	Sum of o,p'- and p,p'-DDE
Total DDT	Sum of o,p'- and p,p'-DDT
DDT & Metabolites	Sum of Total DDD, Total DDE and Total DDT
Total PCB	Sum of 9 PCB Aroclors
Total PAH	Sum of 16 PAH Compounds

Ag	Silver
Al	Aluminum
As	Arsenic
Ba	Barium
Be	Beryllium
Bi	Bismuth
Ca	Calcium
Cd	Cadmium
Co	Cobalt
Cr	Chromium
Cu	Copper
Fe	Iron
K	Potassium
Li	Lithium
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
Na	Sodium
Nb	Niobium
Ni	Nickel
Pb	Lead
Sb	Antimony
Sn	Tin
Sr	Strontium
Ti	Titanium
V	Vanadium
W	µg/g
Y	Yttrium
Zn	Zinc
Hg	Mercury
LOI	Loss on Ignition
TOC	Total organic carbon
TIC	Total inorganic carbon

Note: An explanation of Sediment Quality Guideline Short-

Federal TEL:	Threshold Effect Level
Federal PEL:	Probable Effect Level
Provincial LEL:	Lowest Effect Level
Provincial SEL:	Severe Effect Level

Grain size classification:

Sand	63 um-2 mm
Silt	2 um- 63 um
Clay	<2 um

Exceedences of (any) sediment quality guideline is shown in bold (Appendix A)

Appendix A. Laboratory Results

Tributary	Sampling Date	Latitude	Longitude	Moisture	p,p'-DDD	p,p'-DDE	p,p'-DDT	Total DDD	Total DDE	Total DDT
	dd-mmm-yy	dec.deg	dec.deg	%	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g
Aberarder Creek	13-Sep-04	43.09566173	-82.12244554	43	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Andrews Creek	31-Aug-04	44.25352153	-81.6008777	35	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Ausable River	25-Oct-04	43.31169185	-81.75689017	46	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Ausable River Cut	25-Oct-04	43.2349164	-81.89197359	30	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Bar River	05-Oct-04	46.42566062	-84.08799178	36	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Batteaux River	18-Oct-04	44.48831075	-80.16721961	57	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Bayfield River	15-Sep-04	43.56929624	-81.69829423	49	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Beaver River	19-Oct-04	44.56412351	-80.44925706	50	<0.002	**0.003**	**0.002**	<0.002	**0.003**	**0.002**
Bighead River	20-Oct-04	44.60457268	-80.59231732	56	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Black Ash Creek	19-Oct-04	44.50561153	-80.23834413	39	0.002	**0.004**	**0.003**	0.002	**0.004**	**0.003**
Bonnie Doon Creek	14-Sep-04	43.06338319	-82.15985104	46	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Bothwells Creek	20-Oct-04	44.62478351	-80.87631067	52	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Boundary Creek	15-Sep-04	43.84923465	-81.7108769	45	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Clarks Creek	16-Sep-04	44.07783346	-81.75235644	38	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Coldwater River	18-Oct-04	44.71586934	-79.64760767	52	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cow Creek	14-Sep-04	43.028182	-82.25137283	45	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Crane River	21-Sep-04	45.12581563	-81.54034389	86	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Desbarats River	05-Oct-04	46.34397476	-83.92353378	74	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Eighteen Mile River	16-Sep-04	44.02022178	-81.72969682	38	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Errol Creek	14-Sep-04	43.04496173	-82.18440346	45	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
French River	06-Oct-04	46.02108496	-80.57311883	69	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Gibson River	08-Oct-04	44.97615469	-79.77701266	76	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Gleason Brook	21-Oct-04	44.76400168	-81.09145087	69	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Goderich Harbour	15-Sep-04	43.74707576	-81.72183716	52	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Gully Creek	15-Sep-04	43.61400745	-81.70532466	27	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Hickory Creek	13-Sep-04	43.11321258	-82.08816768	41	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Highland Creek	13-Sep-04	43.09916967	-82.11427942	37	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Hog River	18-Oct-04	44.74069598	-79.78439462	66	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Indian Brook	19-Oct-04	44.54798992	-80.42408271	55	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Indian Creek	21-Oct-04	44.61840021	-80.94691242	59	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Judges Creek	21-Sep-04	44.95975309	-81.22703003	59	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Keefer Creek	20-Oct-04	44.63225652	-80.86791922	34	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Kerrys Creek	31-Aug-04	43.95899218	-81.72829074	32	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Key River	07-Oct-04	45.89404786	-80.56708888	63	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Little Sauble River	20-Sep-04	44.29337327	-81.58993546	41	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Magnetawan River	07-Oct-04	45.77181217	-80.56483554	44	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Maitland River	25-Oct-04	43.75007086	-81.7179524	70	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Mississagi River	05-Oct-04	46.20695913	-83.04041251	49	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Moon River	08-Oct-04	45.06497457	-79.79027134	51	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Naftels Creek	15-Sep-04	43.66644476	-81.70511736	68	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Naiscoot River	07-Oct-04	45.67262234	-80.48209278	44	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Nine Mile River	16-Sep-04	43.87871845	-81.71859235	37	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
North River	18-Oct-04	44.74037587	-79.63589028	41	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Nottawasaga River	26-Oct-04	44.52053584	-80.01914792	58	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Old Woman River	22-Sep-04	44.96551842	-81.33948988	31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Penetangore River	20-Sep-04	44.17370467	-81.63881498	41	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Perch Creek	14-Sep-04	43.02438006	-82.28863411	54	<0.002	**0.002**	<0.002	<0.002	**0.002**	<0.002
Pickerel River	06-Oct-04	45.99690808	-80.56815246	60	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Pine River	16-Sep-04	44.09365017	-81.72703788	39	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Pottawatomi River	21-Oct-04	44.57445514	-80.95250973	61	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Pretty River	19-Oct-04	44.5031752	-80.19764875	68	<0.002	**0.01**	<0.002	<0.002	**0.01**	<0.002
Sauble River	03-Nov-04	44.67643348	-81.25662994	30	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002

Appendix A. Laboratory Results

Tributary	Sampling Date	Latitude	Longitude	Moisture	p,p'-DDD	p,p'-DDE	p,p'-DDT	Total DDD	Total DDE	Total DDT
	dd-mmm-yy	dec.deg	dec.deg	%	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g
Saugeen River	25-Oct-04	44.49936944	-81.35839092	40	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Seguin River	07-Oct-04	45.34210082	-80.03182072	49	<0.002	<0.002	**0.011**	<0.002	<0.002	**0.011**
Serpent River	05-Oct-04	46.20923586	-82.55771033	68	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Severn River	08-Oct-04	44.80459297	-79.72103962	73	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Shashawandah Creek	14-Sep-04	43.17432816	-81.99842153	36	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Shawanaga River	07-Oct-04	45.54999539	-80.28645752	72	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Sideroad Creek	21-Sep-04	45.18107751	-81.57774938	88	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Silver Creek	19-Oct-04	44.52225169	-80.27786777	61	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Spanish River	06-Oct-04	46.18585275	-82.34164176	52	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Spring Creek	21-Sep-04	45.02679018	-81.45452756	83	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
St. Joseph Creek	14-Sep-04	43.40698964	-81.70727155	39	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Stokes River	22-Sep-04	44.99874703	-81.36959455	52	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Sturgeon River	18-Oct-04	44.73295521	-79.73354117	46	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Sucker Creek	22-Sep-04	44.83001435	-81.31911966	72	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Sydenham River	20-Oct-04	44.56141348	-80.94328003	45	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Thessalon River	05-Oct-04	46.25993575	-83.55678865	41	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Wanapitei River	06-Oct-04	46.15980019	-80.92328837	45	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Waterton Creek	20-Oct-04	44.68149661	-80.78459059	53	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Willow Creek	21-Sep-04	45.15649151	-81.57399982	82	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Wye River	18-Oct-04	44.73641916	-79.8456495	59	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Youngs Creek	15-Sep-04	43.83569334	-81.69952907	48	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002

Appendix A. Laboratory Results

Tributary	DDT & Metabolites	Aroclor 1262	Aroclor 1254	Aroclor 1260	Total PCB	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene
	ug/g	ug/g	ug/g	ug/g	ug/g	ug/kg	ug/kg	ug/kg	ug/kg
Aberarder Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Andrews Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Ausable River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	36
Ausable River Cut	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Bar River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Batteaux River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	**42**	<5
Bayfield River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Beaver River	**0.005**	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Bighead River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Black Ash Creek	**0.009**	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Bonnie Doon Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Bothwells Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Boundary Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Clarks Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Coldwater River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Cow Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	**87**
Crane River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Desbarats River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Eighteen Mile River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Errol Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
French River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Gibson River	<0.002	<0.01	0.04	0.02	**0.06**	<5	<10	<5	<5
Gleason Brook	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Goderich Harbour	<0.002	<0.01	0.01	0.007	0.02	<5	<10	<5	**63**
Gully Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Hickory Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Highland Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Hog River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Indian Brook	<0.002	<0.01	0.007	0.003	0.01	<5	<10	<5	<5
Indian Creek	<0.002	<0.01	0.02	**0.02**	0.03	<5	<10	<5	<5
Judges Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Keefer Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Kerrys Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Key River	<0.002	<0.01	0.01	**0.01**	0.02	<5	<10	<5	<5
Little Sauble River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Magnetawan River	<0.002	<0.01	<0.01	<0.01	<0.01	**87**	**111**	**302**	**2200**
Maitland River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Mississagi River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Moon River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Naftels Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Naiscoot River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Nine Mile River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
North River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	**54**
Nottawasaga River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Old Woman River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Penetangore River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Perch Creek	**0.002**	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Pickerel River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Pine River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Pottawatomi River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Pretty River	**0.01**	<0.01	<0.01	**0.02**	0.02	<5	<10	<5	<5
Sauble River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5

Appendix A. Laboratory Results

Tributary	DDT & Metabolites	Aroclor 1262	Aroclor 1254	Aroclor 1260	Total PCB	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene
	ug/g	ug/g	ug/g	ug/g	ug/g	ug/kg	ug/kg	ug/kg	ug/kg
Saugeen River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Seguin River	**0.011**	<0.01	0.05	<0.01	0.05	<5	<10	55	**689**
Serpent River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Severn River	<0.002	0.03	<0.01	<0.01	0.03	<5	<10	<5	<5
Shashawandah Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Shawanaga River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Sideroad Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Silver Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Spanish River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Spring Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
St. Joseph Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Stokes River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Sturgeon River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Sucker Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Sydenham River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Thessalon River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Wanapitei River	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Waterton Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Willow Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5
Wye River	<0.002	<0.01	0.01	<0.01	0.01	<5	<10	<5	**433**
Youngs Creek	<0.002	<0.01	<0.01	<0.01	<0.01	<5	<10	<5	<5

Appendix A. Laboratory Results

Tributary	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(a)pyrene
	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg
Aberarder Creek	<5	<5	<5	<10	<10	<10	<10	<5
Andrews Creek	<5	<5	<5	<10	<10	<10	<10	<5
Ausable River	<5	88	**80**	<10	52	<10	<10	28
Ausable River Cut	<5	<5	<5	<10	<10	<10	<10	<5
Bar River	<5	<5	<5	<10	<10	<10	<10	<5
Batteaux River	<5	<5	<5	<10	<10	<10	<10	<5
Bayfield River	<5	<5	<5	<10	<10	<10	<10	<5
Beaver River	<5	<5	<5	<10	<10	<10	<10	<5
Bighead River	<5	<5	<5	<10	<10	<10	<10	<5
Black Ash Creek	<5	<5	<5	<10	<10	<10	<10	<5
Bonnie Doon Creek	<5	<5	<5	<10	<10	<10	<10	<5
Bothwells Creek	<5	<5	<5	<10	<10	<10	<10	<5
Boundary Creek	<5	<5	<5	<10	<10	<10	<10	<5
Clarks Creek	<5	<5	<5	<10	<10	<10	<10	<5
Coldwater River	<5	<5	<5	<10	<10	<10	<10	<5
Cow Creek	<5	**174**	**152**	**101**	**101**	<10	<10	58
Crane River	<5	<5	<5	<10	<10	<10	<10	<5
Desbarats River	<5	<5	<5	<10	<10	<10	<10	<5
Eighteen Mile River	<5	<5	<5	<10	<10	<10	<10	<5
Errol Creek	<5	<5	32	<10	<10	<10	<10	<5
French River	<5	<5	<5	<10	<10	<10	<10	<5
Gibson River	<5	<5	<5	<10	<10	<10	<10	<5
Gleason Brook	<5	<5	<5	<10	<10	<10	<10	<5
Goderich Harbour	<5	**113**	**109**	**76**	**84**	50	<10	59
Gully Creek	<5	<5	<5	<10	<10	<10	<10	<5
Hickory Creek	<5	<5	<5	<10	<10	<10	<10	<5
Highland Creek	<5	<5	<5	<10	<10	<10	<10	<5
Hog River	<5	<5	<5	<10	<10	<10	<10	<5
Indian Brook	<5	<5	<5	<10	<10	<10	<10	<5
Indian Creek	<5	<5	<5	<10	<10	<10	<10	<5
Judges Creek	<5	<5	<5	<10	<10	<10	<10	<5
Keefer Creek	<5	<5	<5	<10	<10	<10	<10	<5
Kerrys Creek	<5	<5	<5	<10	<10	<10	<10	<5
Key River	<5	48	48	**54**	54	<10	<10	<5
Little Sauble River	<5	<5	<5	<10	<10	<10	<10	<5
Magnetawan River	**1140**	**18500**	**14100**	**8000**	**7690**	1790	**2050**	**2980**
Maitland River	<5	<5	<5	<10	<10	<10	<10	<5
Mississagi River	<5	<5	<5	<10	<10	<10	<10	<5
Moon River	<5	<5	<5	<10	<10	<10	<10	<5
Naftels Creek	<5	<5	<5	<10	<10	<10	<10	<5
Naiscoot River	<5	<5	<5	<10	<10	<10	<10	<5
Nine Mile River	<5	<5	<5	<10	<10	<10	<10	<5
North River	<5	41	41	<10	<10	<10	<10	<5
Nottawasaga River	<5	<5	<5	<10	<10	<10	<10	<5
Old Woman River	<5	<5	<5	<10	<10	<10	<10	<5
Penetangore River	<5	<5	<5	<10	<10	<10	<10	<5
Perch Creek	<5	<5	<5	<10	54	<10	<10	27
Pickerel River	<5	<5	<5	<10	<10	<10	<10	<5
Pine River	<5	<5	<5	<10	<10	<10	<10	<5
Pottawatomi River	<5	<5	<5	**59**	**64**	<10	<10	35
Pretty River	<5	<5	<5	<10	<10	<10	<10	<5
Sauble River	<5	<5	<5	<10	<10	<10	<10	<5

Appendix A. Laboratory Results

Tributary	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(a)pyrene
	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg
Saugeen River	<5	<5	<5	<10	<10	<10	<10	<5
Seguin River	**181**	**1250**	**1030**	524	**575**	307	**311**	**496**
Serpent River	<5	<5	<5	<10	<10	<10	<10	<5
Severn River	<5	<5	<5	<10	<10	<10	<10	<5
Shashawandah Creek	<5	<5	<5	<10	<10	<10	<10	<5
Shawanaga River	<5	<5	<5	<10	<10	<10	<10	<5
Sideroad Creek	<5	<5	<5	<10	<10	<10	<10	<5
Silver Creek	<5	<5	<5	<10	<10	<10	<10	<5
Spanish River	<5	**96**	**76**	**56**	**66**	<10	<10	<5
Spring Creek	<5	<5	<5	<10	<10	<10	<10	<5
St. Joseph Creek	<5	<5	<5	<10	<10	<10	<10	<5
Stokes River	<5	<5	<5	<10	<10	<10	<10	<5
Sturgeon River	<5	**67**	**63**	**60**	**71**	<10	<10	**37**
Sucker Creek	<5	<5	<5	<10	<10	<10	<10	<5
Sydenham River	<5	<5	<5	<10	<10	<10	<10	<5
Thessalon River	<5	<5	<5	<10	<10	<10	<10	<5
Wanapitei River	<5	<5	<5	<10	<10	<10	<10	<5
Waterton Creek	<5	<5	<5	<10	<10	<10	<10	<5
Willow Creek	<5	<5	<5	<10	<10	<10	<10	<5
Wye River	<5	**442**	**298**	**63**	**135**	77	<10	**43**
Youngs Creek	<5	<5	<5	<10	<10	<10	<10	<5

Appendix A. Laboratory Results

Tributary	Indeno(1,2,3-cd)pyrene	Dibenzo(a,h)anthracene	Benzo(ghi)perylene	Total PAH	Ag	Al	As	Ba	Be	Ca	Cd	Co
	ug/kg	ug/kg	ug/kg	ug/kg	µg/g	pct	µg/g	µg/g	µg/g	pct	µg/g	µg/g
Aberarder Creek	<20	<20	<20	<20	<0.1	0.98	<5	57	0.30	9.34	<0.5	7
Andrews Creek	<20	<20	<20	<20	NA	0.924	2	28	0.33	12.40	0.1	4
Ausable River	<20	<20	<20	284	<0.1	1.20	<5	65	0.40	7.96	<0.5	7
Ausable River Cut	<20	<20	<20	<20	<0.1	0.52	<5	29	<0.2	7.17	<0.5	4
Bar River	<20	<20	<20	<20	<0.1	0.54	<5	47	0.20	0.27	<0.5	5
Batteaux River	<20	<20	<20	<20	0.1	0.45	<5	55	<0.2	16.10	<0.5	2
Bayfield River	<20	<20	<20	<20	<0.1	1.39	<5	103	0.40	11.10	<0.5	6
Beaver River	<20	<20	<20	731	<0.1	0.54	<5	32	<0.2	11.30	<0.5	4
Bighead River	<20	<20	<20	<20	<0.1	0.59	<5	30	<0.2	11.40	<0.5	4
Black Ash Creek	<20	<20	<20	<20	0.2	0.26	<5	17	<0.2	15.30	<0.5	<1
Bonnie Doon Creek	<20	<20	<20	<20	<0.1	0.96	<5	62	0.40	8.82	<0.5	7
Bothwells Creek	<20	<20	<20	<20	<0.1	0.57	<5	25	<0.2	12.40	<0.5	4
Boundary Creek	<20	<20	<20	<20	<0.1	0.86	<5	53	0.30	6.56	<0.5	5
Clarks Creek	<20	<20	<20	<20	<0.1	0.53	<5	35	<0.2	9.25	<0.5	3
Coldwater River	<20	<20	<20	<20	<0.1	0.73	<5	106	0.20	4.02	<0.5	5
Cow Creek	<20	<20	<20	673	<0.1	0.57	<5	47	0.20	6.13	<0.5	4
Crane River	<20	<20	<20	<20	0.1	0.38	<5	32	<0.2	12.90	**0.7**	2
Desbarats River	<20	<20	<20	<20	<0.1	1.55	5.0	137	0.70	0.50	**0.9**	13
Eighteen Mile River	<20	<20	<20	<20	<0.1	0.84	<5	52	0.20	9.88	<0.5	5
Errol Creek	<20	<20	<20	32	<0.1	2.34	**7.0**	115	1.00	4.41	0.6	12
French River	<20	<20	<20	<20	<0.1	1.22	<5	117	0.40	0.56	**1.2**	15
Gibson River	<20	<20	<20	<20	<0.1	1.05	<5	181	0.40	0.93	**1.5**	13
Gleason Brook	<20	<20	<20	<20	0.1	0.65	<5	61	0.20	9.11	<0.5	7
Goderich Harbour	<20	<20	<20	554	<0.1	1.19	<5	64	0.40	11.60	<0.5	6
Gully Creek	<20	<20	<20	<20	<0.1	0.40	<5	31	<0.2	9.74	<0.5	2
Hickory Creek	<20	<20	<20	<20	<0.1	0.84	<5	58	0.30	8.40	<0.5	7
Highland Creek	<20	<20	<20	<20	<0.1	0.72	<5	52	0.30	8.39	<0.5	6
Hog River	<20	<20	<20	<20	<0.1	0.98	<5	155	0.30	6.18	<0.5	6
Indian Brook	<20	<20	<20	<20	0.1	0.34	<5	35	0.00	14.80	<0.5	2
Indian Creek	<20	<20	<20	<20	<0.1	1.10	<5	42	0.50	9.16	<0.5	8
Judges Creek	<20	<20	<20	<20	<0.1	1.16	<5	45	0.40	5.84	<0.5	10
Keefer Creek	<20	<20	<20	<20	0.1	0.47	<5	33	<0.2	10.80	<0.5	4
Kerrys Creek	<20	<20	<20	<20	NA	1.60	3.0	90	0.58	13.60	0.1	6
Key River	<20	<20	<20	204	<0.1	1.51	5.0	144	0.70	0.53	**1.2**	18
Little Sauble River	<20	<20	<20	<20	<0.1	0.60	<5	34	<0.2	10.90	<0.5	3
Magnetawan River	**781**	**264**	**715**	**60710**	<0.1	1.08	**6.0**	116	0.40	0.42	**0.7**	13
Maitland River	<20	<20	<20	<20	0.3	0.77	<5	97	<0.2	16.30	<0.5	3
Mississagi River	<20	<20	<20	<20	<0.1	0.79	<5	54	0.20	0.39	<0.5	6
Moon River	<20	<20	<20	<20	<0.1	0.67	<5	57	0.20	0.37	<0.5	4
Naftels Creek	<20	<20	<20	<20	<0.1	0.94	<5	74	0.30	7.45	<0.5	5
Naiscoot River	<20	<20	<20	<20	<0.1	0.64	<5	56	0.20	0.40	<0.5	8
Nine Mile River	<20	<20	<20	<20	0.2	0.46	<5	51	<0.2	13.60	<0.5	2
North River	<20	<20	<20	136	<0.1	0.71	<5	85	0.20	3.89	<0.5	7
Nottawasaga River	<20	<20	<20	<20	<0.1	0.76	<5	94	<0.2	10.20	<0.5	4
Old Woman River	<20	<20	<20	<20	<0.1	0.31	<5	15	<0.2	4.31	<0.5	2
Penetangore River	<20	<20	<20	<20	<0.1	0.69	<5	40	0.20	8.85	<0.5	4
Perch Creek	<20	<20	<20	81	0.3	1.35	<5	81	0.50	9.99	0.5	8
Pickerel River	<20	<20	<20	<20	<0.1	1.38	<5	215	1.00	0.50	**1.1**	16
Pine River	<20	<20	<20	<20	<0.1	0.79	<5	49	0.20	11.10	<0.5	5
Pottawatomi River	<20	<20	<20	158	<0.1	0.50	<5	38	<0.2	8.71	<0.5	4
Pretty River	<20	<20	<20	<20	0.2	0.56	<5	57	<0.2	17.00	<0.5	3
Sauble River	<20	<20	<20	<20	0.2	0.33	<5	25	<0.2	11.40	<0.5	1

Appendix A. Laboratory Results

Tributary	Indeno(1,2,3-cd)pyrene	Dibenzo(a,h)anthracene	Benzo(ghi)perylene	Total PAH	Ag	Al	As	Ba	Be	Ca	Cd	Co
	ug/kg	ug/kg	ug/kg	ug/kg	µg/g	pct	µg/g	µg/g	µg/g	pct	µg/g	µg/g
Saugeen River	<20	<20	<20	<20	0.1	0.37	<5	22	<0.2	11.30	<0.5	2
Seguin River	**268**	<20	291	**5977**	4.6	0.65	<5	61	0.20	0.84	0.6	5
Serpent River	<20	<20	<20	<20	<0.1	1.17	<5	69	0.40	0.45	0.6	17
Severn River	<20	<20	<20	<20	<0.1	1.45	**8.0**	191	0.50	2.14	**1.3**	13
Shashawandah Creek	<20	<20	<20	<20	<0.1	0.62	<5	44	0.20	6.80	<0.5	5
Shawanaga River	<20	<20	<20	<20	<0.1	0.81	<5	62	0.40	0.65	**0.9**	10
Sideroad Creek	<20	<20	<20	<20	0.1	0.40	<5	35	<0.2	6.56	**2.1**	5
Silver Creek	<20	<20	<20	<20	<0.1	0.54	<5	34	<0.2	12.10	<0.5	3
Spanish River	<20	<20	<20	294	<0.1	0.70	<5	60	0.30	0.43	0.6	12
Spring Creek	<20	<20	<20	<20	0.3	0.41	<5	63	<0.2	7.68	**0.9**	4
St. Joseph Creek	<20	<20	<20	<20	<0.1	0.97	<5	61	0.30	10.60	<0.5	6
Stokes River	<20	<20	<20	<20	<0.1	0.57	<5	30	<0.2	4.55	<0.5	5
Sturgeon River	<20	<20	<20	298	<0.1	0.57	<5	72	<0.2	2.88	<0.5	4
Sucker Creek	<20	<20	<20	<20	0.2	0.25	<5	36	<0.2	11.60	<0.5	2
Sydenham River	<20	<20	<20	<20	<0.1	0.28	<5	23	<0.2	10.20	<0.5	2
Thessalon River	<20	<20	<20	<20	<0.1	0.73	<5	43	0.20	0.35	<0.5	7
Wanapitei River	<20	<20	<20	<20	<0.1	1.09	<5	89	0.30	0.34	**0.7**	27
Waterton Creek	<20	<20	<20	<20	<0.1	0.77	<5	33	0.30	6.27	<0.5	7
Willow Creek	<20	<20	<20	<20	0.1	0.55	<5	30	<0.2	6.53	**2.6**	5
Wye River	<20	<20	<20	1491	<0.1	0.66	<5	79	<0.2	4.05	<0.5	4
Youngs Creek	<20	<20	<20	<20	0.1	1.10	<5	63	0.30	10.20	<0.5	5

Appendix A. Laboratory Results

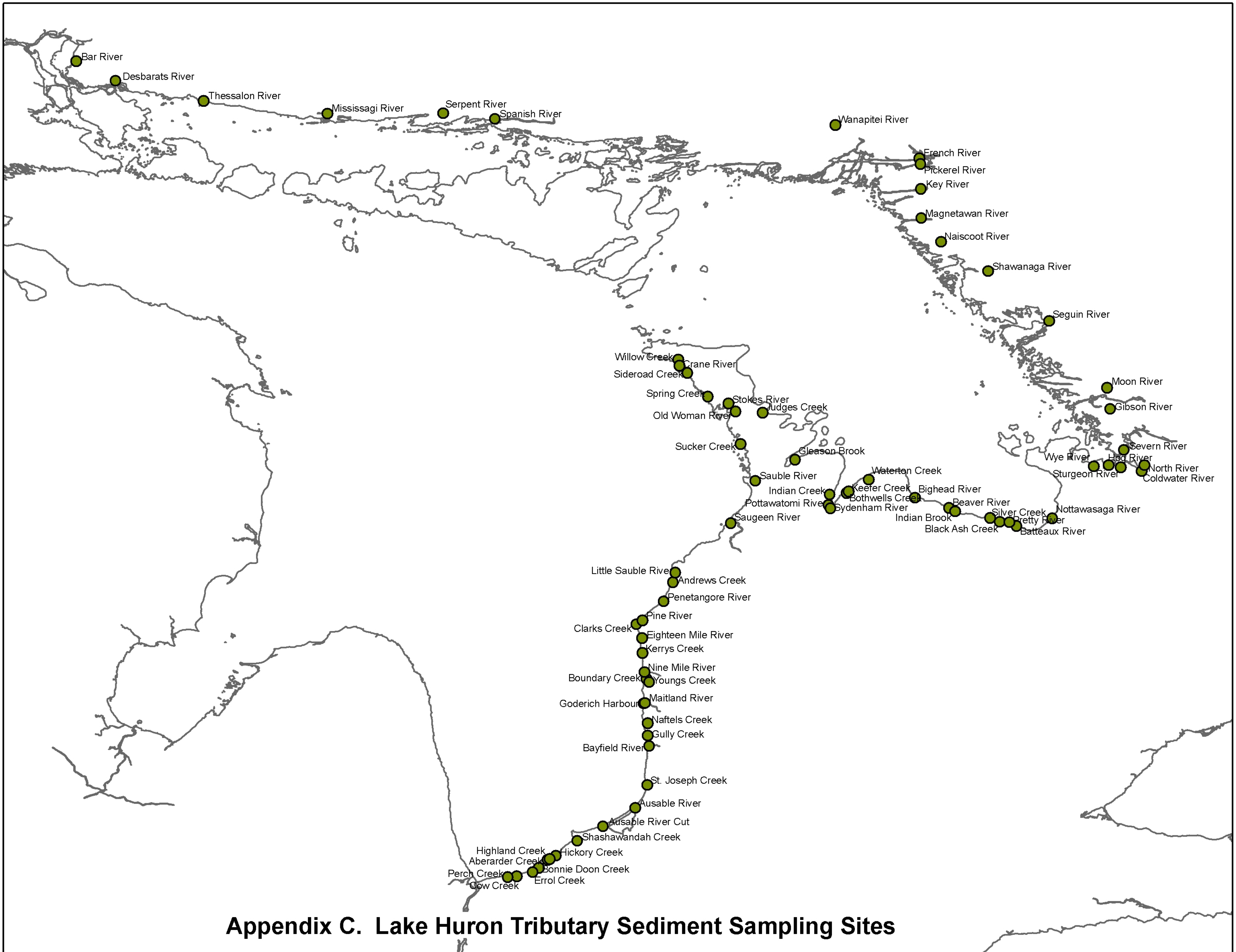
Tributary	Cr	Cu	Fe	Hg	K	Li	Mg	Mn	Mo	Na	Ni	Pb	Sn	Sr	Ti	V	Y	Zn
	µg/g	µg/g	pct	ng/g	pct	µg/g	pct	µg/g	µg/g	pct	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
Aberarder Creek	**41**	**17**	1.44	27	0.220	52.8	1.74	**486**	3	0.04	**18**	13	<10	82	231	22	7	50
Andrews Creek	24	9	1.05	15	0.134	8	4.60	318	<0.5	<0.05	8.3	4.7	NA	127	NA	24	NA	22
Ausable River	**52**	**26**	1.55	48	0.270	50.6	1.66	381	2	0.04	**18**	18	<10	78	319	27	7	66
Ausable River Cut	**35**	10	0.93	17	0.100	31	1.01	316	2	0.03	10	8	<10	68	203	14	5	28
Bar River	**58**	10	0.98	17	0.090	9.9	0.287	185	<1	0.01	11	5	<10	10	372	19	5	32
Batteaux River	**35**	8	0.86	12	0.100	51.5	0.677	**556**	2	0.03	6	10	<10	190	174	10	6	21
Bayfield River	**35**	**18**	1.69	39	0.270	59.1	1.68	**457**	2	0.04	**17**	16	<10	173	318	27	9	55
Beaver River	**54**	14	1.23	16	0.120	43.3	1.14	**963**	2	0.02	9	14	<10	138	163	14	7	44
Bighead River	**39**	**18**	1.35	12	0.150	47.6	1.25	**569**	2	0.03	10	11	<10	155	147	13	8	30
Black Ash Creek	**30**	6	0.62	9	0.070	46.1	0.719	223	2	0.03	4	10	<10	217	102	5	4	17
Bonnie Doon Creek	**52**	**19**	1.60	27	0.230	50.2	1.53	423	4	0.04	**20**	14	<10	85	224	23	7	72
Bothwells Creek	**65**	13	1.29	12	0.150	48.4	1.02	**690**	2	0.03	10	10	<10	141	161	13	8	25
Boundary Creek	**60**	12	1.24	29	0.180	36.7	1.5	417	2	0.03	12	9	<10	64	350	23	6	35
Clarks Creek	**70**	11	0.93	21	0.130	37.6	1.65	302	2	0.03	9	8	<10	137	264	16	5	30
Coldwater River	**98**	11	1.40	23	0.150	22.7	0.666	**662**	1	0.04	10	13	<10	76	601	23	9	49
Cow Creek	**85**	**18**	1.07	36	0.130	29.9	1.06	268	2	0.04	12	13	<10	54	167	16	4	81
Crane River	**111**	12	0.90	70	0.080	41.6	1.53	267	3	0.04	13	26	<10	62	188	11	3	69
Desbarats River	**94**	**45**	**2.91**	56	0.220	28.9	0.634	373	2	0.04	**30**	20	<10	23	765	42	12	**168**
Eighteen Mile River	**80**	13	1.20	25	0.190	46.2	1.81	279	2	0.03	13	10	<10	138	314	21	6	28
Errol Creek	**43**	**32**	**2.90**	56	0.420	67	1.35	400	5	0.04	**37**	21	<10	57	266	45	13	**130**
French River	**125**	**40**	1.92	68	0.140	22.3	0.516	**570**	2	0.03	**56**	**40**	<10	22	665	32	11	**152**
Gibson River	**105**	**26**	**2.00**	57	0.220	19.3	0.536	**907**	2	0.03	16	**38**	<10	61	1380	34	13	**170**
Gleason Brook	**38**	**30**	**2.43**	43	0.140	44.8	1.64	**2570**	2	0.01	12	17	<10	78	117	18	10	63
Goderich Harbour	**35**	**24**	1.79	40	0.290	61.7	1.79	408	3	0.04	**19**	24	<10	218	325	26	7	94
Gully Creek	**35**	8	0.67	16	0.090	36.2	1.73	204	2	0.03	6	8	<10	87	240	13	4	17
Hickory Creek	**53**	**18**	1.56	24	0.190	46.8	1.44	**546**	4	0.04	**19**	15	<10	81	195	21	7	49
Highland Creek	**44**	15	1.25	22	0.170	43.2	1.64	410	3	0.04	14	11	<10	73	210	19	6	38
Hog River	**74**	13	1.79	17	0.210	33.5	0.925	**947**	2	0.04	12	9	<10	164	798	32	12	48
Indian Brook	**49**	10	0.88	7	0.090	47.9	0.985	**670**	2	0.02	6	10	<10	162	162	10	5	17
Indian Creek	23	13	**2.42**	13	0.340	62.6	1.68	**1740**	2	0.02	**19**	11	<10	86	175	24	9	51
Judges Creek	**42**	**24**	**2.22**	32	0.230	47.4	1.12	**893**	2	0.01	**23**	11	<10	71	259	25	9	62
Keefer Creek	**36**	16	1.40	11	0.110	42.4	1.32	**1260**	2	0.03	8	9	<10	126	150	13	8	44
Kerrys Creek	**35**	11	1.30	23	0.483	19.9	4.26	307	<0.5	<.05	15.7	4.9	NA	151	NA	35	NA	28
Key River	**85**	**39**	**3.49**	65	0.200	31.7	0.625	**634**	1	0.03	**42**	**44**	<10	22	869	42	19	**214**
Little Sauble River	**38**	11	1.10	22	0.150	45.7	1.86	370	2	0.03	10	9	<10	126	218	17	6	25
Magnetawan River	**104**	**29**	**2.52**	41	0.140	21.7	0.49	**1070**	1	0.03	**28**	27	<10	29	701	33	11	**140**
Maitland River	**53**	12	1.14	30	0.160	58.2	1.31	**584**	2	0.04	9	16	<10	707	192	15	5	44
Mississagi River	**90**	15	1.76	20	0.060	14.3	3.67	194	1	0.03	15	9	<10	14	705	30	6	46
Moon River	**95**	12	**2.04**	16	0.100	12.6	2.82	296	1	0.03	9	15	<10	16	765	26	9	51
Naftels Creek	**84**	16	1.31	55	0.160	39	1.64	**611**	2	0.03	13	14	<10	60	256	21	7	55
Naiscoot River	**88**	7	1.31	10	0.080	13.3	0.368	312	<1	0.03	14	5	<10	17	706	25	7	51
Nine Mile River	**39**	10	0.76	15	0.110	47.8	1.77	287	2	0.03	7	9	<10	299	190	12	4	20
North River	**44**	12	1.28	17	0.140	22	0.545	249	1	0.03	10	8	<10	70	659	24	10	42
Nottawasaga River	**51**	12	1.56	20	0.150	40.7	0.695	**747**	2	0.04	9	12	<10	140	422	20	8	56
Old Woman River	**53**	6	0.70	21	0.050	17.9	1.28	272	1	0.03	6	5	<10	40	201	11	3	22
Penetangore River	**39**	13	1.06	29	0.140	38	1.76	308	2	0.03	9	10	<10	248	277	18	7	45
Perch Creek	**57**	**29**	1.87	42	0.340	62.3	1.62	**473**	3	0.06	**23**	24	<10	104	256	29	7	**122**
Pickerel River	**104**	**28**	**3.70**	49	0.210	29.3	0.528	**1040**	2	0.03	**43**	**85**	<10	18	1150	41	16	**188**
Pine River	**39**	14	1.19	32	0.220	50.4	1.91	278	2	0.03	12	10	<10	165	320	21	6	30
Pottawatomi River	**87**	14	1.32	24	0.130	35.3	0.978	**626**	2	0.02	10	16	<10	100	175	14	6	51
Pretty River	**36**	13	1.05	17	0.130	58.6	0.871	**590**	2	0.02	9	13	<10	177	150	10	6	35
Sauble River	**53**	11	0.88	39	0.070	37.3	1.91	**467**	2	0.03	5	14	<10	73	168	12	4	55

Appendix A. Laboratory Results

Tributary	Cr	Cu	Fe	Hg	K	Li	Mg	Mn	Mo	Na	Ni	Pb	Sn	Sr	Ti	V	Y	Zn
	µg/g	µg/g	pct	ng/g	pct	µg/g	pct	µg/g	µg/g	pct	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
Saugeen River	**27**	8	0.77	17	0.080	38.7	1.97	343	2	0.02	5	9	<10	169	160	11	5	23
Seguin River	**121**	**95**	1.77	**313**	0.110	12.8	0.441	218	2	0.07	15	**54**	10	22	952	40	11	**132**
Serpent River	**130**	**26**	**2.19**	32	0.140	23.5	0.50	277	2	0.03	**28**	25	<10	16	714	35	29	93
Severn River	**123**	**70**	**3.03**	105	0.170	29.3	0.568	**1330**	2	0.05	**23**	**108**	<10	54	939	48	15	**260**
Shashawandah Creek	**50**	13	1.31	21	0.130	34.6	1.21	365	2	0.03	13	11	<10	61	194	17	14	38
Shawanaga River	**155**	12	1.24	51	0.070	13.3	0.315	213	2	0.04	14	**36**	<10	143	524	22	12	73
Sideroad Creek	**90**	**24**	1.09	166	0.080	24.7	1.78	**731**	2	0.04	**18**	**52**	<10	29	124	13	5	**134**
Silver Creek	**53**	13	1.17	22	0.120	45	0.926	**496**	2	0.02	9	10	<10	136	140	12	7	30
Spanish River	**94**	**27**	1.76	20	0.090	15	0.427	**898**	1	0.02	**68**	14	<10	15	612	28	6	68
Spring Creek	**88**	15	1.55	116	0.070	28.6	1.8	**1990**	2	0.03	11	27	<10	51	126	17	5	80
St. Joseph Creek	**38**	16	1.44	21	0.240	53.8	1.82	383	2	0.04	15	12	<10	129	320	24	7	39
Stokes River	**88**	11	1.21	30	0.100	24.3	1.45	363	2	0.04	11	11	<10	35	307	17	5	39
Sturgeon River	**63**	12	1.49	15	0.110	18.2	0.78	**546**	1	0.06	8	6	<10	51	615	30	11	33
Sucker Creek	**122**	12	0.83	45	0.070	37	2.13	**850**	3	0.03	8	15	<10	72	133	10	5	40
Sydenham River	**37**	10	0.84	18	0.070	34.3	1.3	**527**	2	0.03	5	11	<10	101	125	9	5	22
Thessalon River	**68**	16	1.44	14	0.070	12.3	0.384	284	<1	0.03	15	8	<10	13	541	28	5	47
Wanapitei River	**86**	**102**	1.89	23	0.110	19.3	0.507	**467**	1	0.02	**192**	11	<10	17	680	30	6	76
Waterton Creek	**53**	**19**	1.59	21	0.150	36.3	0.986	**826**	2	0.01	12	9	<10	72	144	17	11	37
Willow Creek	**89**	16	1.12	147	0.050	26.7	1.87	**990**	2	0.04	13	23	<10	31	157	15	6	**231**
Wye River	**103**	**18**	1.42	23	0.130	21.9	0.495	417	2	0.05	12	15	<10	66	562	23	8	57
Youngs Creek	**51**	16	1.33	28	0.250	52.9	1.77	299	2	0.03	14	12	<10	101	345	25	7	42

Appendix B: Physical Parameters

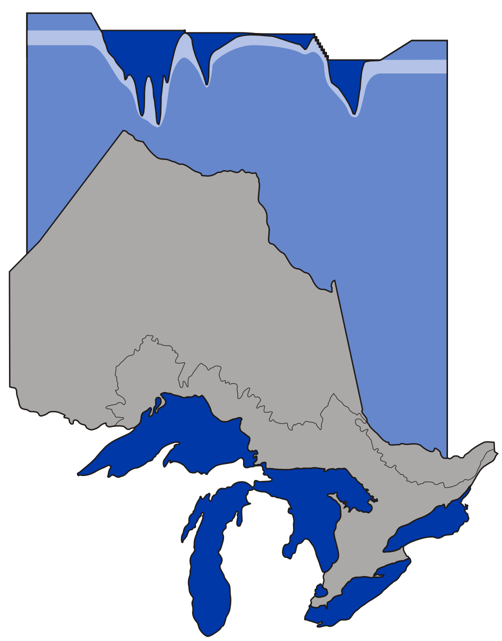
Sample No.	Total Carbon (+- 0.1%)	Inorganic Carbon (+- 0.1%)	Organic Carbon (+- 0.2%)	Loss on Ignition %	wt. % Sand-Silt-Clay of <2mm		
					% Sand	% Silt (63-2um)	% Clay (<2um)
Aberarder Creek	5.8	4.5	1.3	3.3	23.98	69.89	6.13
Andrews Creek	6.1	5.6	0.6	1.5	70.81	28.37	0.82
Ausable River	5.6	4.0	1.6	4.0	30.21	61.77	8.02
Ausable River Diversion Cut	3.4	2.8	0.6	1.3	76.85	21.27	1.88
Bar River	1.1	0.1	1.1	2.3	70.52	26.75	2.73
Batteaux River	7.6	6.1	1.5	4.1	34.67	64.02	1.31
Bayfield River	7.0	5.2	1.8	5.1	8.56	87.30	4.14
Beaver River	6.3	4.8	1.5	3.1	67.72	32.14	0.14
Bighead River	6.4	4.8	1.6	3.6	27.01	72.68	0.32
Black Ash Creek	6.5	5.6	0.9	1.8	89.44	10.56	0.00
Bonnie Doon Creek	5.5	4.0	1.4	3.2	38.15	55.87	5.98
Bothwells Creek	6.3	5.0	1.3	3.3	48.97	50.50	0.53
Boundary Creek	4.9	3.0	1.9	4.8	48.82	48.70	2.49
Clark Creek	5.4	4.4	1.0	2.6	56.87	40.76	2.37
Coldwater River	4.1	1.4	2.8	5.8	48.10	51.90	0.00
Cow Creek	4.3	2.4	1.9	4.1	72.97	26.33	0.70
Crane River	17.3	7.1	10.2	27.4	63.99	34.70	1.31
Desbarats River	5.5	0.0	5.5	12.1	7.76	78.57	13.68
Eighteen Mile River	5.9	5.0	0.9	2.9	31.66	63.66	4.68
Errol Creek	4.0	1.8	2.2	7.3	1.21	79.05	19.74
French River	4.2	0.1	4.1	8.6	34.30	61.03	4.67
Gibson River	11.9	0.5	11.5	24.2	44.13	55.87	0.00
Gleason Brook	9.7	4.8	5.0	12.3	16.10	81.83	2.07
Goderich Harbour	6.8	5.4	1.4	3.9	21.47	62.01	16.52
Gully Creek	5.3	4.8	0.5	1.3	63.59	34.47	1.94
Hickory Creek	5.4	3.8	1.6	3.5	36.54	59.31	4.15
Highland Creek	5.2	4.0	1.2	2.9	43.20	52.93	3.87
Hog Creek	4.7	2.2	2.4	6.1	26.91	72.39	0.71
Indian Brook	7.0	5.7	1.3	3.0	58.50	41.50	0.00
Indian Creek	6.3	4.5	1.8	4.7	6.54	90.35	3.11
Judges Creek	4.8	2.4	2.4	5.8	4.14	91.58	4.28
Keefer Creek	5.5	4.4	1.0	2.5	65.50	34.33	0.17
Kerrys Creek	6.4	5.6	0.8	2.2	18.60	72.73	8.67
Key River	3.8	0.0	3.8	8.5	3.14	91.15	5.71
Little Sauble River	6.1	5.2	0.8	1.9	29.48	65.31	5.21
Magnetawan River	2.5	0.1	2.4	4.8	40.71	59.29	0.00
Maitland River	10.1	7.0	3.1	8.7	29.00	66.92	4.08
Mississaugi River	2.1	0.0	2.1	4.6	44.17	55.83	0.00
Moon River	2.2	0.0	2.2	4.9	69.47	30.53	0.00
Naftels Creek	9.7	4.2	5.4	12.9	31.92	63.21	4.87
Naiscoot River	1.2	0.0	1.2	2.8	85.15	14.85	0.00
Nine Mile River	7.7	6.8	1.0	2.7	47.98	50.27	1.74
North River	2.7	1.3	1.4	3.2	60.77	37.52	1.71
Nottawasaga River	5.8	3.6	2.2	5.5	47.86	51.33	0.81
Old Womans River	2.6	1.9	0.7	1.7	82.88	17.12	0.00
Penetangore River	5.9	4.4	1.4	3.6	39.35	59.97	0.68
Perch Creek	6.9	4.6	2.3	6.1	12.58	79.39	8.03
Pickerel River	2.3	0.0	2.3	5.8	73.68	26.32	0.00
Pine River	6.4	5.6	0.8	2.6	21.38	69.70	8.92
Pottawatomi River	6.1	3.6	2.5	5.9	50.52	49.48	0.00
Pretty River	8.4	6.6	1.8	4.8	16.70	82.54	0.75
Sauble River	9.5	6.1	3.4	8.7	55.38	43.39	1.23
Saugeen River	7.0	5.9	1.1	3.0	49.37	50.63	0.00
Seguin River	2.5	0.2	2.3	4.2	79.16	20.84	0.00
Serpent River	4.3	0.0	4.2	9.1	34.31	59.77	5.91
Severn River	10.1	0.7	9.5	22.7	34.63	60.20	5.16
Shashawandah Creek	4.0	2.8	1.2	2.8	61.13	35.87	3.00
Shawanaga River	5.8	0.1	5.7	NA	65.74	33.81	0.45
Sideroad Creek	25.7	7.3	18.4	52.8	14.20	83.92	1.88
Silver Creek	7.5	5.1	2.5	5.9	41.60	58.40	0.00
Spanish River	2.1	0.2	1.9	4.3	41.21	58.79	0.00
Spring Creek	23.5	6.3	17.2	39.0	21.39	76.20	2.40
St. Joseph Creek	5.9	5.2	0.8	2.7	13.48	77.98	8.54
Stokes River	4.2	2.2	2.0	4.6	77.47	22.41	0.11
Sturgeon River	3.3	1.0	2.3	4.8	51.71	48.29	0.00
Sucker Creek	13.9	7.8	6.1	16.3	65.35	33.90	0.75
Sydenham River	5.6	4.4	1.2	2.9	66.64	33.36	0.00
Thessalon River	1.3	0.0	1.3	3.0	56.24	42.94	0.82
Wanapitei River	1.5	0.0	1.5	3.7	20.39	78.28	1.33
Waterton Creek	4.0	2.3	1.7	4.4	49.13	50.29	0.58
Willow Creek	16.5	5.1	11.4	28.4	41.99	56.58	1.43
Wye River	4.2	1.3	2.9	5.8	69.04	30.96	0.00
Young Creek	6.7	5.2	1.5	4.3	15.99	78.81	5.19



Appendix C. Lake Huron Tributary Sediment Sampling Sites

Appendix D: Summary of Federal and Ontario Sediment Quality Guidelines

Compound	Unit	Federal TEL	Federal PEL	Provincial LEL	Provincial SEL
Hexachlorobenzene	ug/g			0.02	24
Endrin aldehyde	ug/g	0.00267	0.0624		
Toxaphene	ug/g	0.0001			
Aldrin	ug/g			0.002	8
a-BHC	ug/g			0.006	10
b-BHC	ug/g			0.005	21
Lindane	ug/g	0.00094	0.00138	0.003	1
Total Chlordane	ug/g	0.0045	0.00887	0.007	6
p,p'-DDD	ug/g			0.008	6
p,p'-DDE	ug/g			0.005	19
Total DDD	ug/g	0.00354	0.00851		
Total DDE	ug/g	0.00142	0.00675		
Total DDT	ug/g	0.00119	0.00477	0.008	71
DDT & Metabolites	ug/g			0.007	12
Dieldrin	ug/g	0.00285	0.00667	0.002	91
Endrin	ug/g	0.00267	0.0624	0.003	130
Heptachlor epoxide	ug/g	0.0006	0.00274	0.005	5
Mirex	ug/g			0.007	130
Aroclor 1016	ug/g			0.007	53
Aroclor 1248	ug/g			0.03	150
Aroclor 1254	ug/g	0.06	0.34	0.06	34
Aroclor 1260	ug/g			0.005	24
Total PCB	ug/g	0.0341	0.277	0.07	530
Naphthalene	ug/kg	34.6	391		
Acenaphthylene	ug/kg	5.87	128		
Acenaphthene	ug/kg	6.71	88.9		
Fluorene	ug/kg	21.2	144	190	
Phenanthrene	ug/kg	41.9	515	560	
Anthracene	ug/kg	46.9	245	220	
Fluoranthene	ug/kg	111	2355	750	
Pyrene	ug/kg	53	875	490	
Benz(a)anthracene	ug/kg	31.7	385	320	
Chrysene	ug/kg	57.1	862	340	
Benzo(k)fluoranthene	ug/kg			240	
Benzo(a)pyrene	ug/kg	31.9	782	370	
Indeno(1,2,3-cd)pyrene	ug/kg			200	
Dibenzo(a,h)anthracene	ug/kg	6.22	135	60	
Benzo(ghi)perylene	ug/kg			170	
Total PAH	ug/kg			4,000	
As (Arsenic)	µg/g	5.9	17	6	33
Cd	µg/g	0.6	3.5	0.6	10
Cr	µg/g	37.3	90	26	110
Cu	µg/g	35.7	197	16	110
Fe	pct			2	4
Mn	µg/g			460	1100
Ni	µg/g			16	75
Pb	µg/g	35	91.3	31	250
Zn	µg/g	123	315	120	820
Mercury	ng/g	170	486	200	2000



Environmental Conservation Branch
Ontario Region

P.O. Box 5050
867 Lakeshore Road
Burlington, Ontario
Canada, L7R 4A6

Direction conservation de l'environnement
Région de l'Ontario

Case postale 5050
867, chemin Lakeshore
Burlington, Ontario
Canada L7R 4A6

Environment Canada
Environnement Canada

Canada