Nitrate and Phosphorous Levels in Selected Surface Water Sites in Southern Ontario – 1964-1994

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1. Objectives

Using existing water quality data from the Ontario Ministry of the Environment, we have attempted to:

1) Show the current and past state of surface water nitrate-N and total phosphorous levels;
2) Recognize trends in nitrate and phosphorous levels over time; and
3) Identify relationships among nutrient levels, watershed uses and management practices.

2. Background

Surface water quality is a concern as it relates directly to drinking water quality and the general status and condition of the environment. Monitoring it over a period of time can often reveal trends in the changing quality and perhaps the practices which may have initiated the change. Over the last 30 years, there has been an awakening to the importance of protecting the environment.

Despite the fact that consuming large amounts of waterborne phosphorous has few, if any, direct adverse affects to human health, it is a nutrient of concern if detected in the environment (CAST 1992). During the 1950's and 1960's, phosphate was used as a cleaning agent in detergent. Family households, institutions and industries were flushing phosphates literally down the drain and into a sewage treatment system that did not have the facility to remove them. This resulted in extremely high levels of phosphates in the streams and lakes into which "treated" water was released. Massive algal "blooms" began to grow and subsequently decay. The foul-smelling decaying process depleted oxygen in the water to a level that suffocated large amounts of fish and other oxygen-relying water creatures. This process is called eutrophication. A well-known Canadian example of eutrophication is lake Erie – in the 1970's, this lake was generally regarded as dead. Fishing industries could no longer find any fish to catch and the smell of decaying algae was overwhelming. It wasn't until the 1970's that measures were taken to put a halt on phosphate pollution. Ontario legislation was introduced to reduce phosphate levels in waterways by limiting and eventually phasing-out phosphate use in detergents. Sewage treatment plants (STP's) were also required to reduce phosphate levels in their effluents. As a result of these efforts, the average phosphorous content of raw Ontario sewage has dropped significantly from around 10 mg/L in 1969 to 5 mg/L in 1974 and has remained below 5 mg/L since then (Bunce 1993). As previously mentioned, human consumption of phosphorous does not appear to be detrimental to human health. Therefore no "acceptable" level of phosphorous has been established for drinking water quality. However, elevated phosphorous levels can have quite an effect on aquatic life. Excessive plant growth due to elevated phosphorous levels can occur in surface waters at concentrations above 0.03 mg/L (MOE, 1984).

Agricultural practices can also contribute to elevated phosphorous levels in surface waters. Plants require phosphorous for growth, so by adding phosphorous in the form of manure or commercial fertilizer, better crop yields can be attained. Phosphorous tends to bind tightly to soils and therefore does not leach into water systems as easily as some nutrients. It can, however enter surface waters through deposited eroded soil (CAST 1992). In the 1960's and 1970's efforts were taken to try to prevent soil erosion. This resulted in a decrease in surface water phosphorous levels in agricultural areas.

Pure nitrogen (N_2), makes up approximately 80% of the atmosphere. Nitrates are naturally formed in the environment by nitrogen-fixing bacteria, as well as in high temperatures such as those found in lightning (Bunce 1993). Nitrogen, like phosphorous, is a required plant nutrient and so is added to soil to improve crop yields. In 1991, Agriculture Canada estimated that 400 million kilograms of nitrate-based inorganic fertilizer were sold annually in Canada. It is possible to add nitrogen-based fertilizer to a field in order to maximize yield without harming the environment – the technologies exist. Before addition of fertilizer, accurate tests need to be conducted to determine nitrogen levels in soil to prevent subsequent nitrogen-overload; realistic yield goals need to be determined; and the appropriate type of nitrogen fertilizer needs to be selected considering application method and timing. This "Nutrient Management" approach makes most efficient use of fertilizer and helps protect the environment. Despite these available technologies and recommended practices, nitrogen is often mismanaged (Peterson and Frye 1989).

Outside of agricultural practices, nitrates can also come from septic systems and, to a much lesser extent, naturally decaying organic matter (CAST 1992). Nitrate is highly soluble and can thus migrate easily through the soil. Here it is able to contaminate a groundwater or a tile drainage system. The Maximum Acceptable Concentration (MAC) for nitrate-nitrogen in Canadian drinking water has been established as 10 mg/L. Generally, Canadian municipal water supplies have nitrate-N levels no higher than 5 mg/L (Health Canada 1987).

3. Procedures

In the mid-1960's, what is now the Ministry of the Environment (MOE) began an intensive program of testing surface water in Ontario. Many sites were established and a range of water quality parameters was examined. In 1994 and 1995, we contacted staff of the Environmental Monitoring and Reporting Branch, Ministry of the Environment and Energy, to begin our study. We requested nitrate and total phosphorous data over a 30-year period for sites representing a variety of typical land uses in southern Ontario. In total, data for 49 sampling sites were examined. We characterized the various watersheds by predominant land use and found that we had sites with one main land use and sites with combinations. To simplify comparisons, this report will just look at the surface waters that drained mainly agricultural, urban, or natural watersheds.

We defined "Agricultural" watersheds as being located in an intensive agricultural area, or in a predominantly agricultural area with some small rural developments. "Urban" watersheds drained one or more urban centers, and/or were located in a predominantly urban area. Lastly, "natural" watersheds were located in a mainly natural areas with little to no intensive agriculture, small rural developments or cottage areas. Land uses may include some logging, and outdoor recreational activities such as hunting, fishing, skiing, boating, etc.. In total, we will be looking at 24 sites: 11 agricultural, eight urban, and five natural.

Predominant Land Use	Stream/River	MOE site number
Agricultural	Bayfield River	8004000602
	Big Creek (1)	4001303302
	Big Creek (2)	16000100102
	Bighead River	3003000202
	Middle Maitland River	8005600902
	Nanticoke Creek	16016400102
	Ruscom River	4001000202
	Scotch River	18207004002
	South Nation River	18207002002
	Sydenham River	3001600302
	Tilbury Creek	4001302602
Urban	Carruthers Creek	6010700102
	Etobicoke Creek	6008000102
	Humber River	6008300102
	Little River	4000100102
	Oakville Creek	6006300102
	Oshawa Creek	6011100102
	Rouge River	6009700202
	Twelve Mile Creek	6001700102

Natural	Albemarble Brook	8013500402
	Madawaska River	18349002002
	Muskoka River	3008501202
	Musquash River	3008500102
	Rocky Saugeen River	8012300602

Yearly averages were calculated for each site – as some sites had multiple samples taken (up to about 280 per year) while others had just a few – and the results were graphed. Though not all sites had samples taken each year, the overall sampling period covered the years from 1964-1994.

4. Results and Discussion:

4.1 Nitrate-N - Figure 1 shows average nitrate-N levels for all 24 sampling sites, arranged by the decade of sampling. This shows that overall levels of nitrates in surface waters have been rising since the 1960's. The most significant jumps were seen between the 1960's and 1970's in agricultural areas and the 1980's and 1990's in urban areas (see Figure 2). The average nitrate levels for the 1960's in agriculture represent only five of the 11 sites (no data were available for the other six sites during this time - see Figure 4). Three of the sites that did not have samples taken in the 1960's have some of the highest numbers through the subsequent three decades. The same applies for the jump in nitrate concentrations between the 1980's and 1990's in the urban areas. The jump could be excessively steep because the only river that collected data during the 1990's had comparatively elevated levels in the preceding years (Figure 5). Although there is a slight increase in nitrate levels in natural watersheds, the increase is minimal (Figure 2). Levels here should be regarded as “background” levels. All averages used for nitrate-N levels in Figure 2 are shown in Table 1. Figure 3 shows a graph of the mean annual nitrate levels (mg/L) in selected streams arranged by land use.

Figure 1 – Nitrate-N levels– all sites – 1964-1994

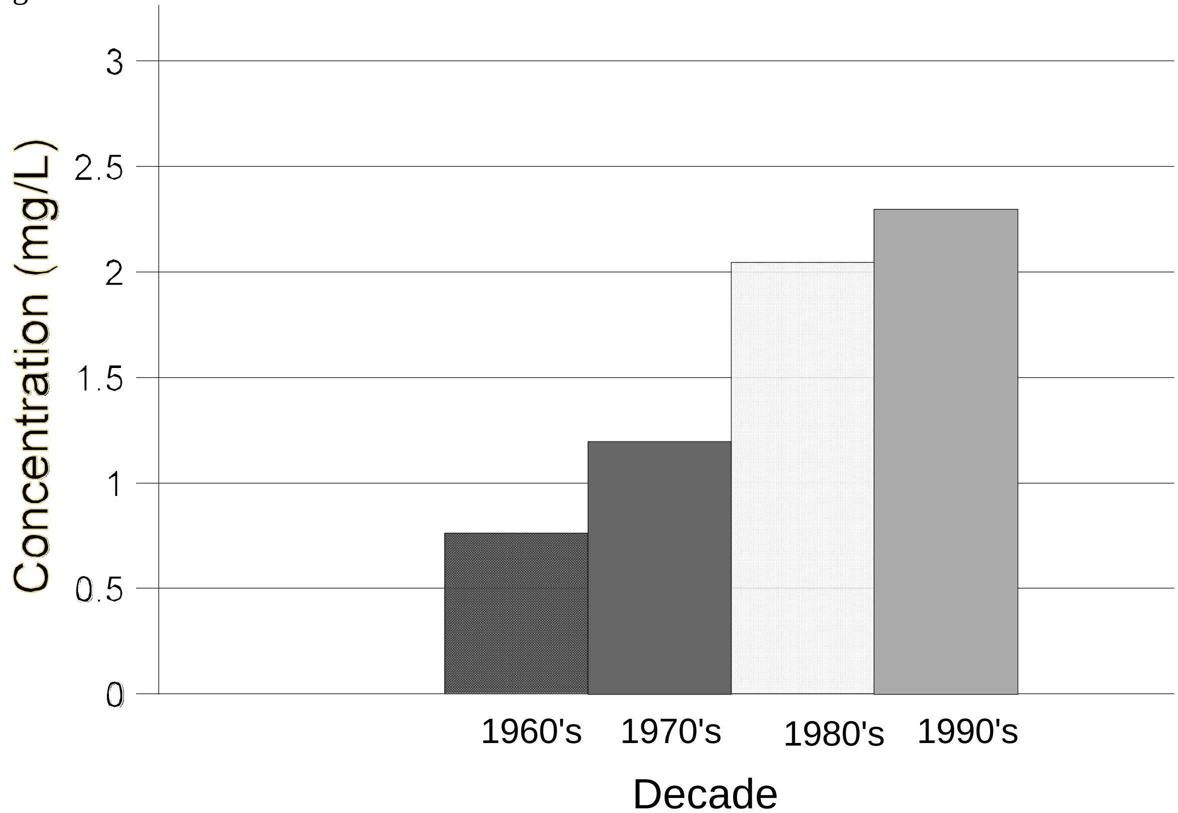

Figure 2 – Nitrate-N Levels in selected watersheds – 1964-1994

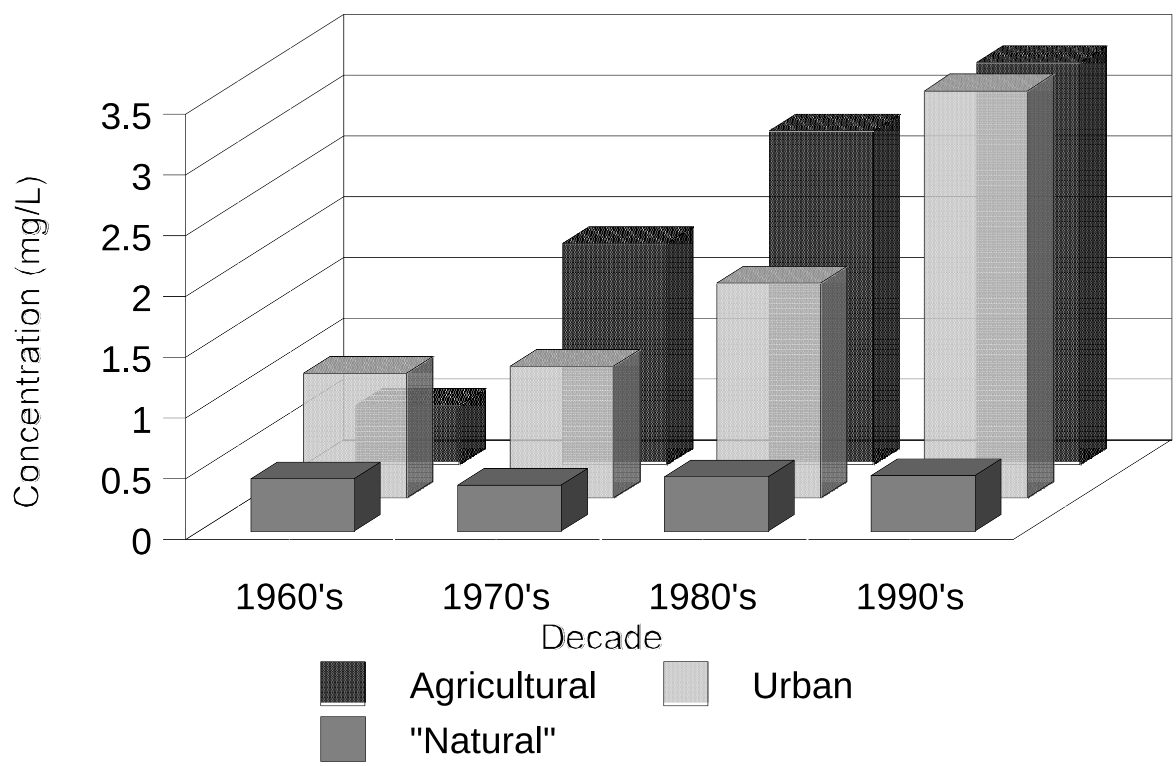

Table 1 Average NO_3-N (mg/L) concentrations in surface water
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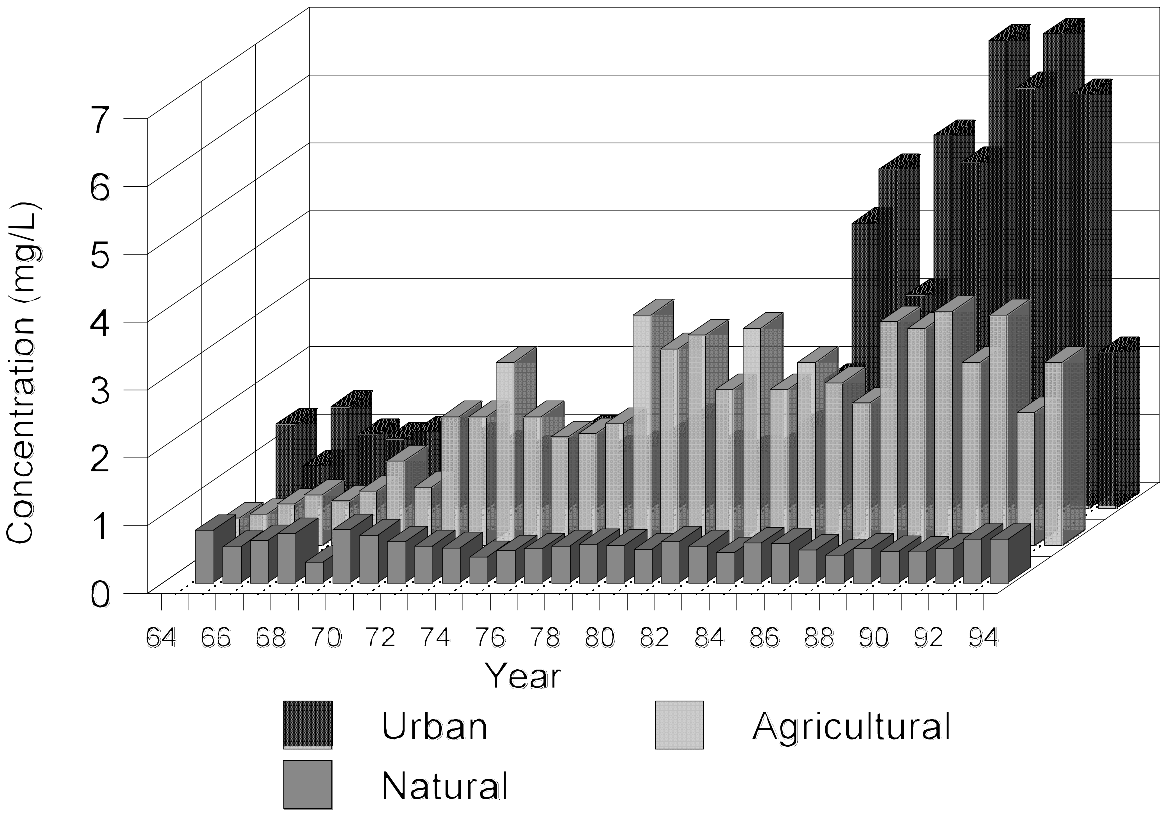
Decade	Agricultural (11 sites)	Urban (8 sites)	Natural (5 sites)	All (24 sites)
60's (1964-1969)	0.49	1.03	0.43	0.76
70's (1970-1979)	1.82	1.08	0.38	1.20
80's (1980-1989)	2.75	1.77	0.45	2.05
90's (1990-1994)	3.31	3.35	0.47	2.30

Figure 3 – Mean annual nitrate-N levels in selected streams arranged by land use



Figures 4, 5, and 6 show the data from the 24 sites grouped into area-type (agriculture, urban and natural) located on a map of southern Ontario. Especially in the agricultural areas (Figure 4), levels vary from site to site and year to year. This variance in levels probably mimics the variance in management practices and environmental conditions at each site (such as soil type, flow rate, rainfall, etc.). Means, minimums, maximums and standard deviation are shown for each site in Table 2. On all but one occasion (in Big Creek (1)), nitrate levels were below the MAC for drinking water. However, seven agricultural, three urban, and one natural site had overall mean levels above 1 mg/L – the level after which excessive plant growth and eutrophication may occur (CAST 1992).

Figure 4 – Average Nitrate-N levels (mg/L) by year– Agricultural watersheds

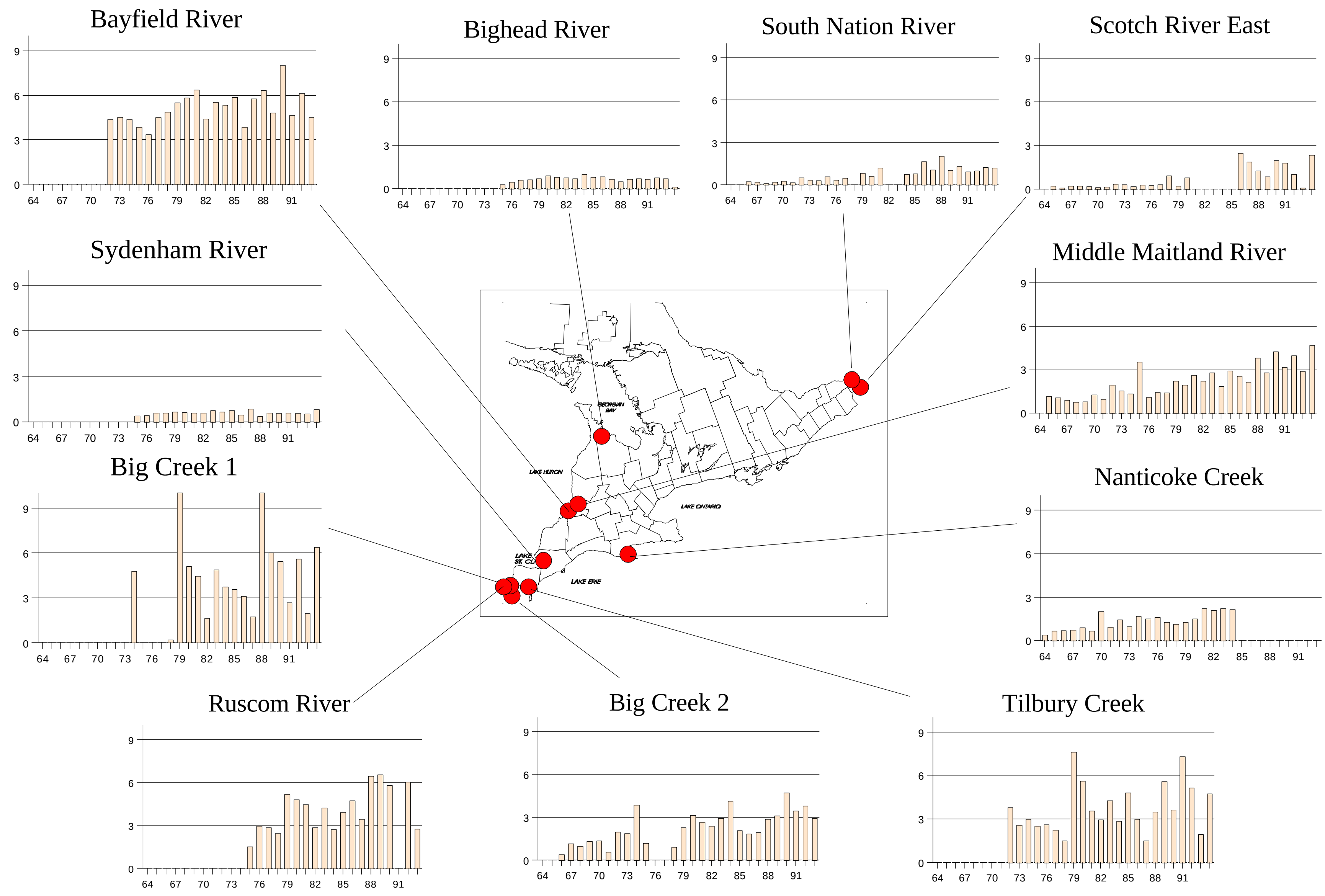


Figure 5 – Average Nitrate-N levels (mg/L) by year– Urban watersheds

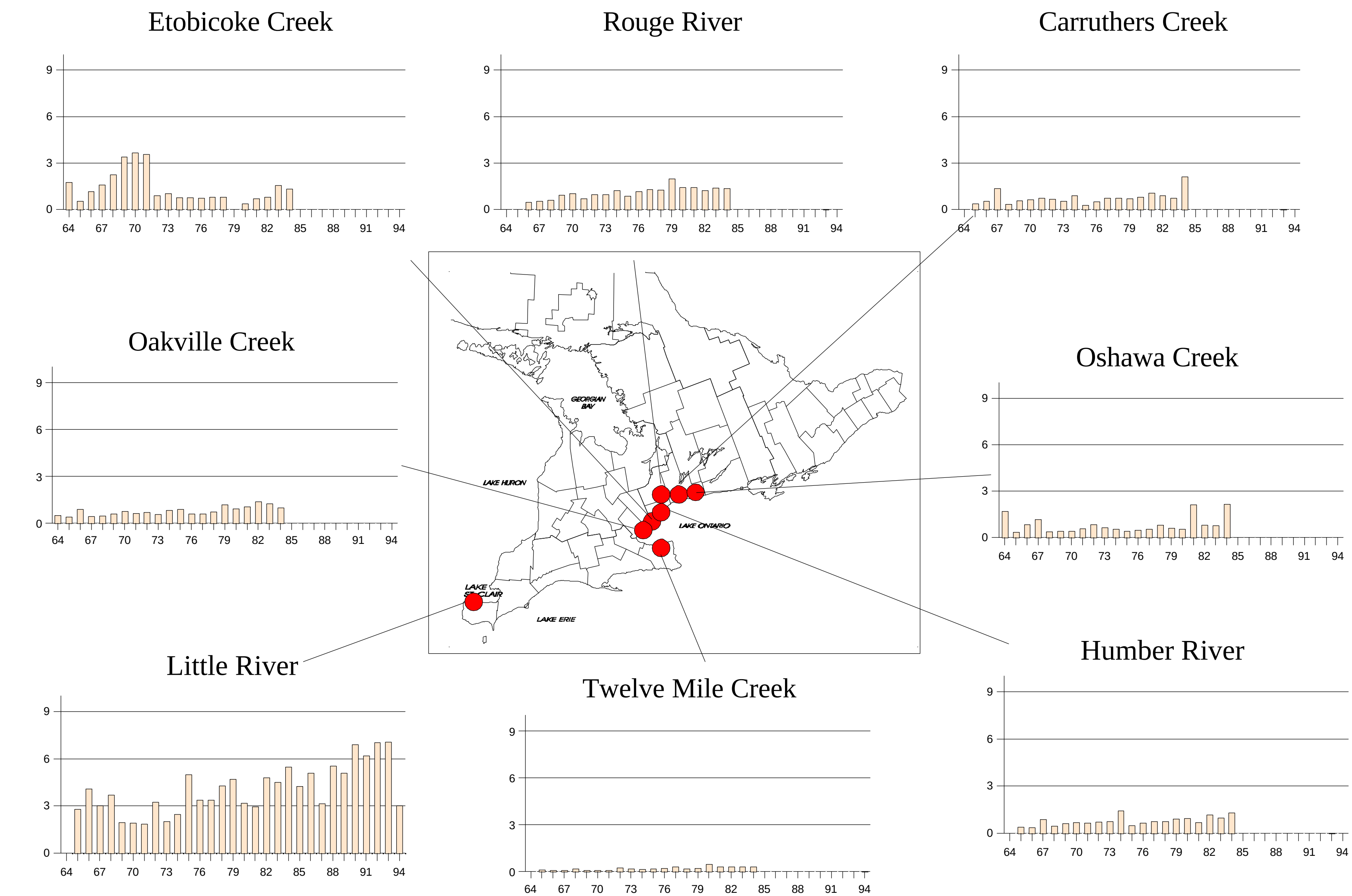


Figure 6 – Average Nitrate-N levels (mg/L) by year – Natural Watersheds

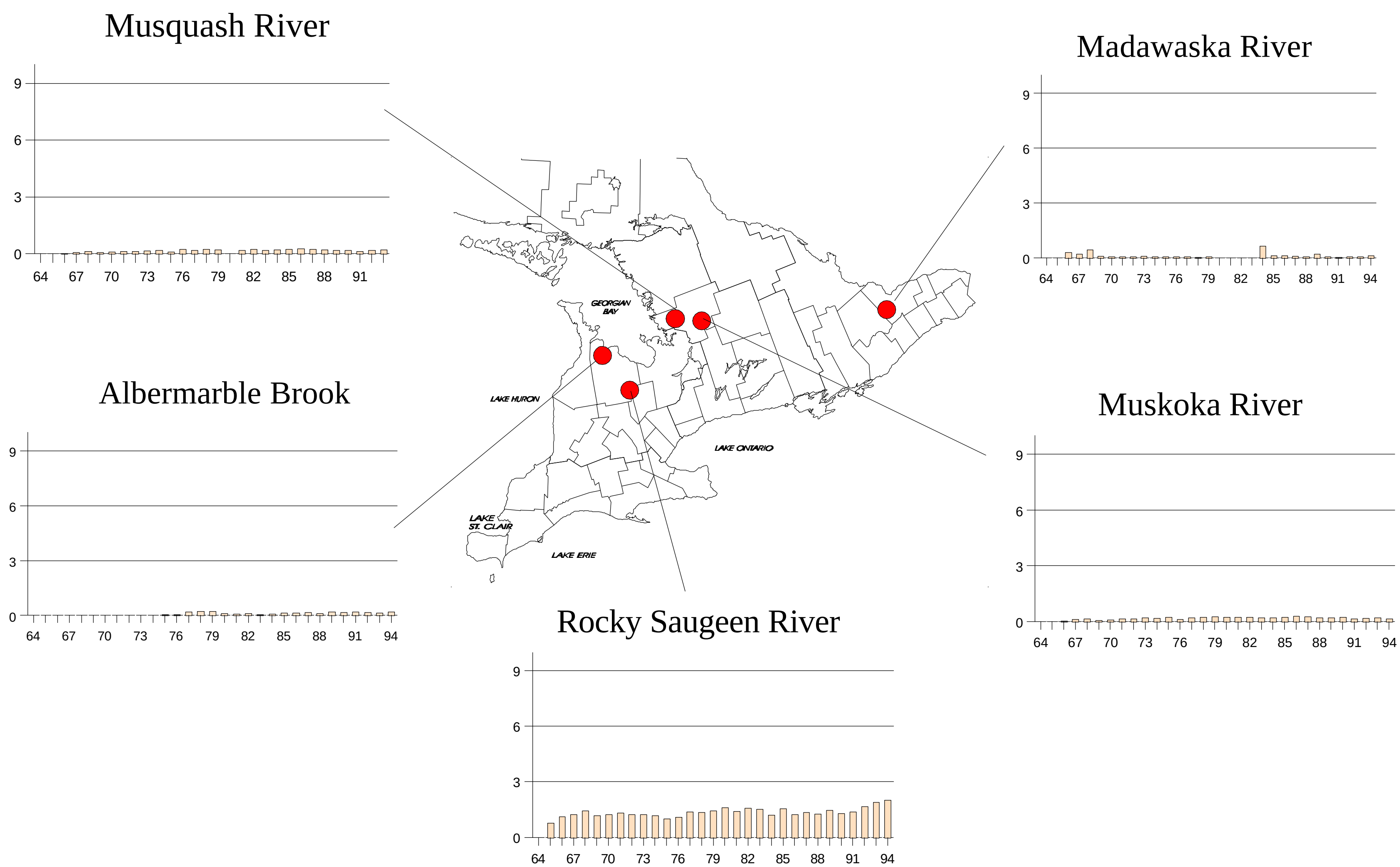


Table 2 – NO_3-N (mg/L) concentrations and calculations for each site

Watershed Type	Name	Count	Mean	Yearly Average Minimum	Yearly Average Maximum	Standard Deviation
Agricultural	Bayfield River	241	5.12	3.33	8.00	3.42
	Big Creek (1)	176	4.51	0.18	10.25	5.17
	Big Creek (2)	307	2.29	0.38	4.71	2.79
	Bighead River	339	0.66	0.28	1.00	0.39
	Middle Maitland River	386	2.20	0.75	4.68	2.34
	Nanticoke Creek	222	1.34	0.40	2.23	1.36
	Ruscom River	195	4.09	1.50	6.53	4.06
	Scotch River East	155	0.69	0.06	2.44	1.07
	South Nation River	208	0.73	0.07	2.04	0.76
	Sydenham River	166	0.58	0.33	0.83	0.57
	Tilbury Creek	241	3.74	1.47	7.62	3.90
Urban	Carruthers Creek	243	0.71	0.26	2.09	1.44
	Etobicoke Creek	261	1.42	0.36	3.63	1.78
	Humber River	351	0.74	0.00	1.42	0.86
	Little River	320	4.06	1.86	7.04	3.26
	Oakville Creek	319	0.77	0.38	1.38	0.74
	Oshawa Creek	235	0.81	0.33	2.16	1.20
	Rouge River	182	1.04	0.47	1.97	0.99
	Twelve Mile Creek	439	0.19	0.07	0.48	0.29
Natural	Albermarble Brook	199	0.13	0.03	0.21	0.17
	Madawaska River	180	0.12	0.21	0.63	0.40
	Muskoka River	236	0.05	0.05	0.28	0.08
	Musquash River	306	0.16	0.00	0.27	0.10
	Rocky Saugeen River	322	1.35	0.77	2.00	0.49

4.2 Total Phosphorous - Figure 7 shows the average total phosphorous levels for all 24 sampling sites, arranged by the decade of sampling. This shows declining amounts of phosphorous in surface water over the 30-year period of observation. Figure 8 shows average total phosphorus levels in agricultural, urban and natural watersheds arranged by decade. It appears that efforts made in agricultural areas during the 1960's and 1970's to reduce soil erosion – a process which transports phosphorous into waterways – may have contributed to a reduction in phosphorus levels in surface water during that period. By far, the most significant reduction in total phosphorous levels was seen in urban watersheds . The 1960's saw extremely high levels of phosphorous. After the enaction of phosphorous abatement legislation in the early 1970's, levels dropped. In fact, phosphorous levels in urban watersheds during the 1990's are almost comparable to levels in natural waterways. All averages used to show total phosphorous levels in Figure 8 are shown in Table 3. Figure 9 shows a graph of the mean annual total phosphorous levels (mg/L) over the 30-year time frame in selected streams, arranged by land use.

Figure 7 — Total phosphorous levels– all sites – 1964-1994

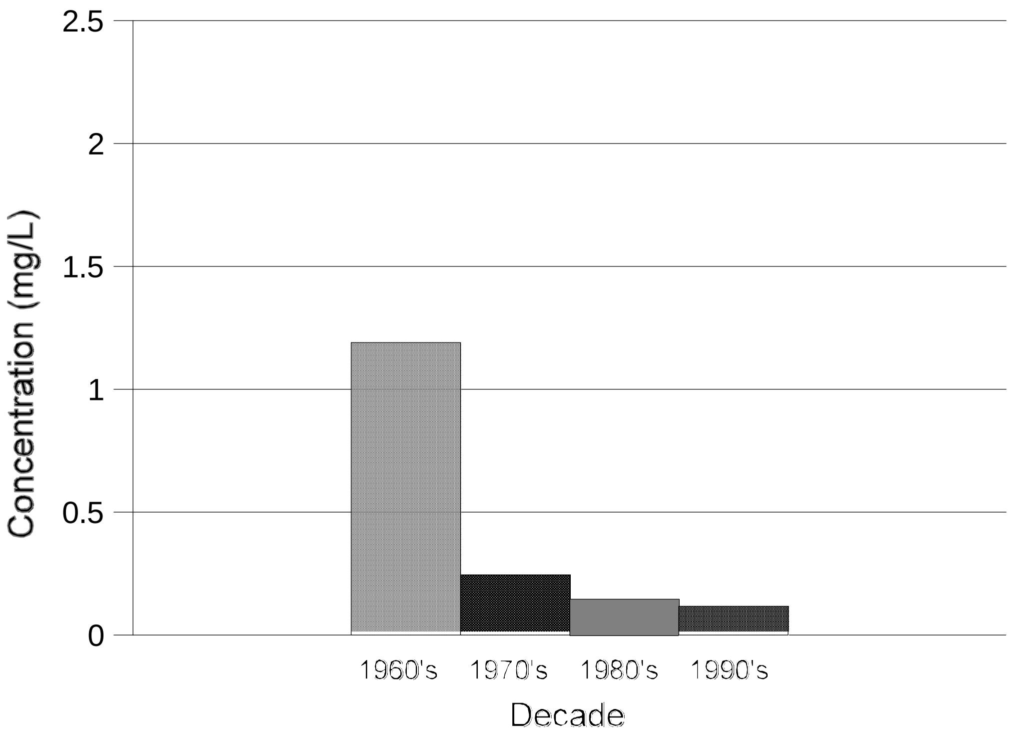


Figure 8 -- Average total phosphorous levels in selected watersheds – 1964-1994

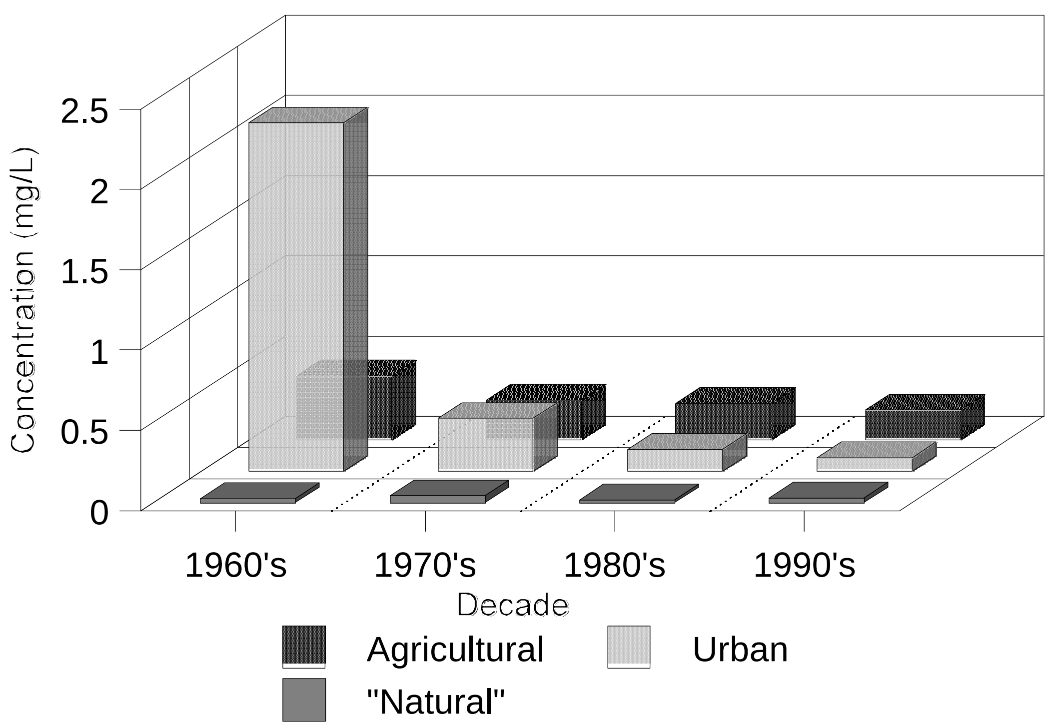
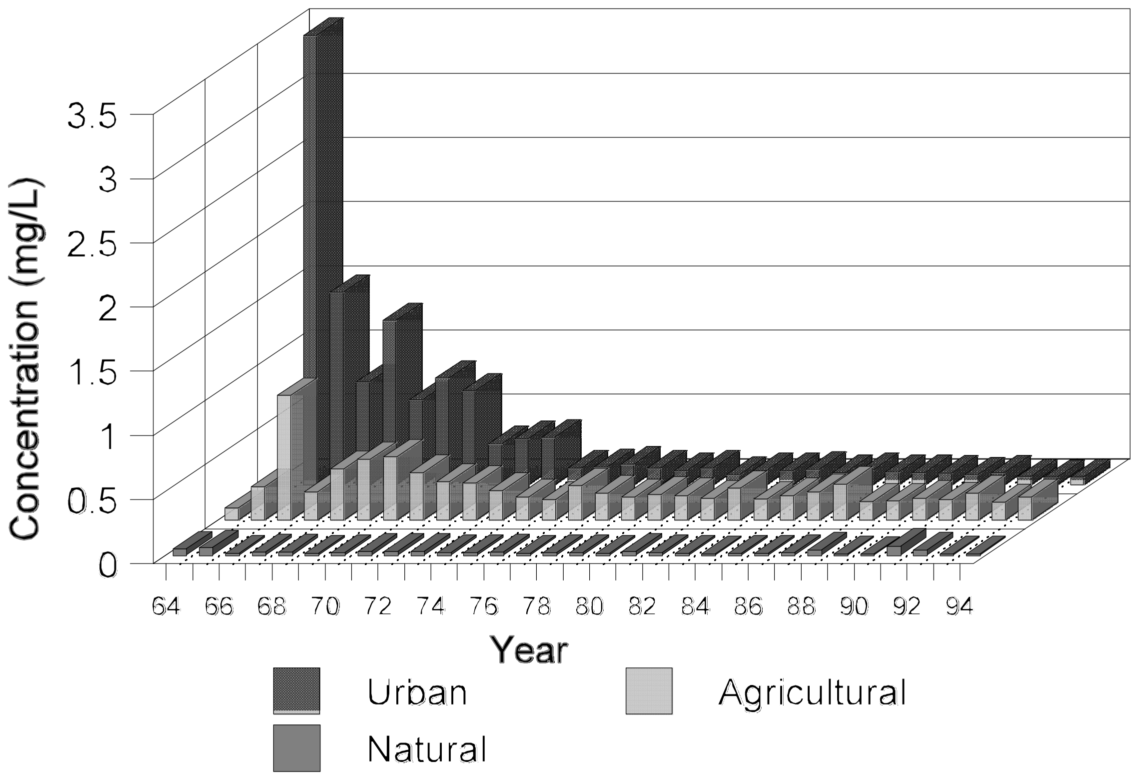


Table 3 – Average Total-Phosphorous (mg/L) concentrations in surface water

Decade	Agricultural (11 sites)	Urban (8 sites)	Natural (5 sites)	All (24 sites)
60's (1964-1969)	0.40	2.17	0.02	1.24
70's (1970-1979)	0.24	0.33	0.04	0.26
80's (1980-1989)	0.23	0.14	0.02	0.15
90's (1990-1994)	0.19	0.09	0.03	0.12

Figure 9 — Mean annual total phosphorous levels in selected streams arranged by land use



Figures 10, 11 and 12 show each of the 24 sites grouped into their area-type (agriculture, urban and natural) located on a map of southern Ontario. Although the overall trend for phosphorous levels has been for levels to decline, it can be seen in the agricultural areas that some sites' levels increased periodically throughout the later decades. Site minimums, maximums, means and standard deviations are shown for the three different areas in Table 4. Note that a high number of sites (ten agricultural, seven urban, and one natural) have total phosphorous levels above the 0.03 mg/L maximum guideline.

Figure 10 — Average total phosphorous levels (mg/L) by year — Agricultural Watersheds

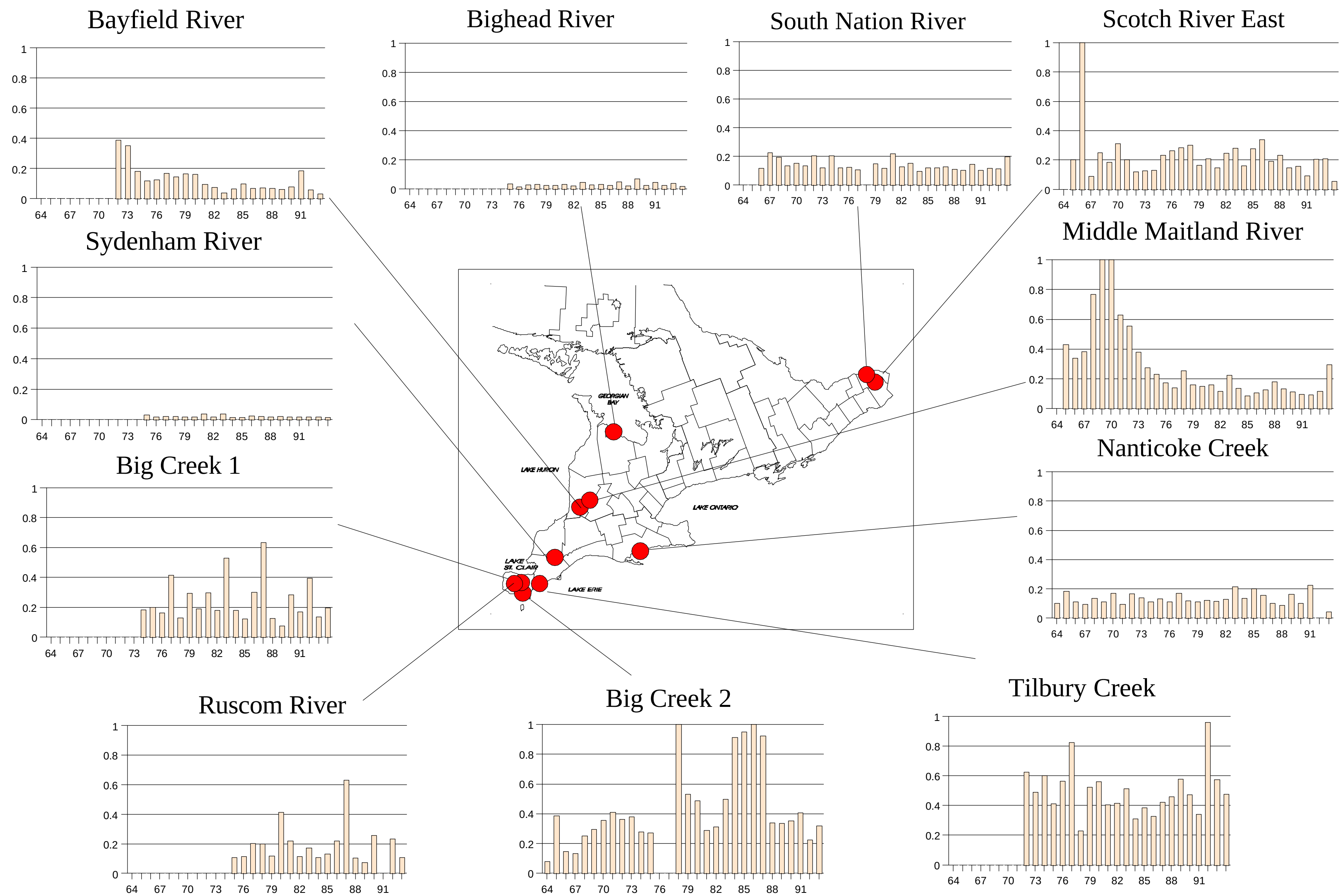


Figure 11 — Average total phosphorous levels (mg/L) by year — Urban Watersheds

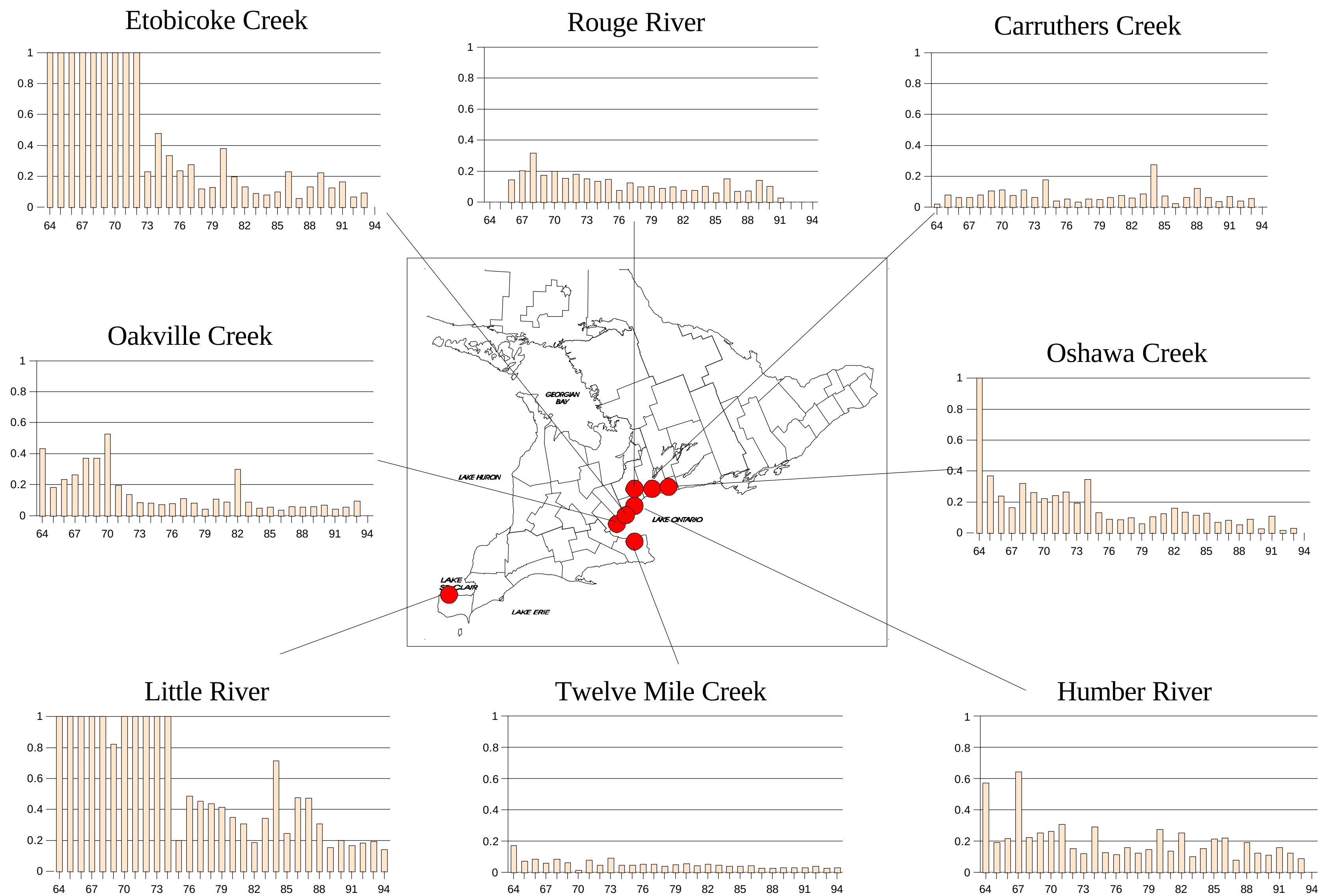


Figure 12 — Average total phosphorous levels (mg/L) by year – Natural Watersheds

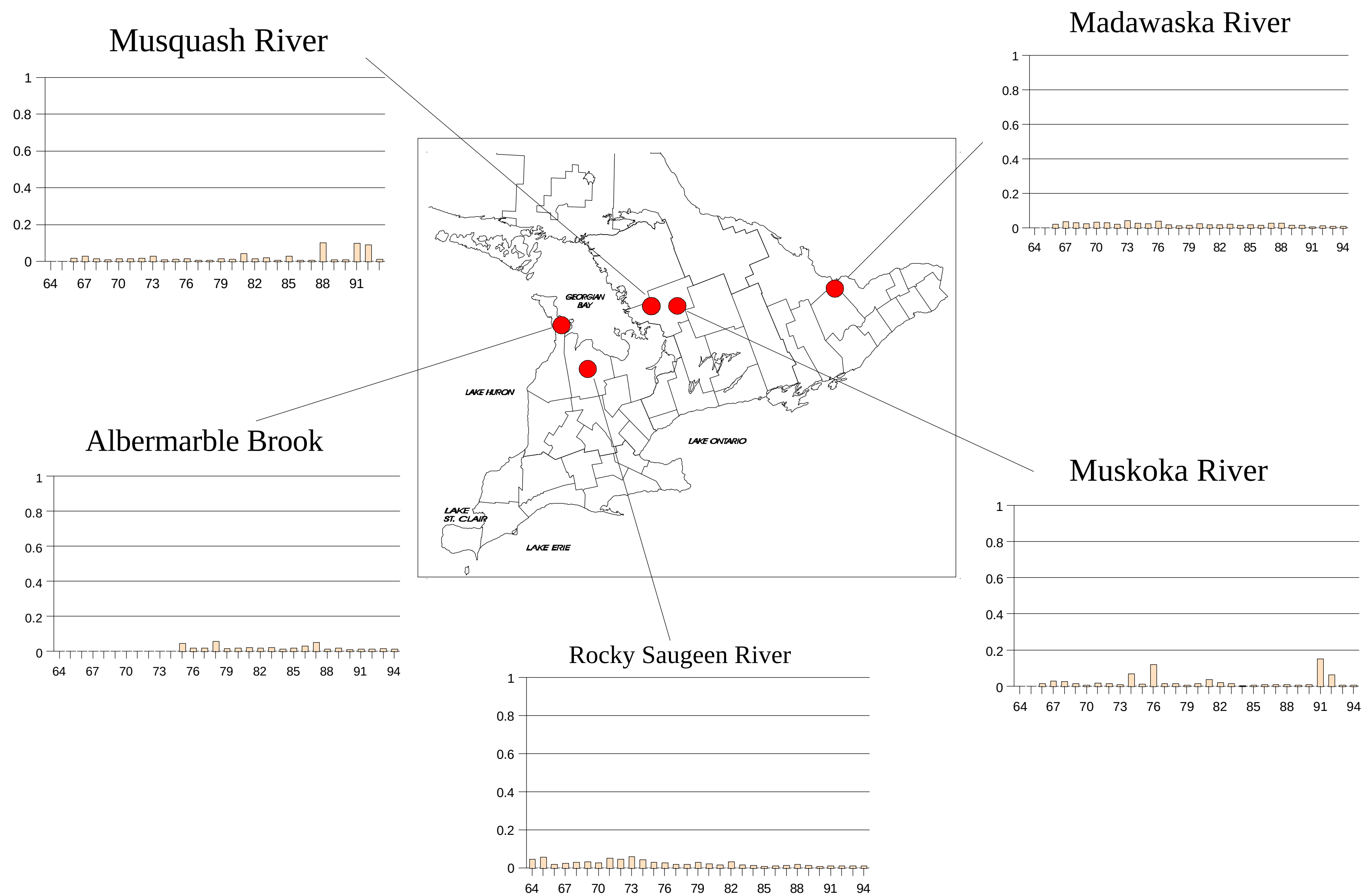


Table 4 – Total Phosphorous concentrations (mg/L) and calculations

Watershed type	Name	Count	Mean	Yearly Average Minimum	Yearly Average Maximum	Standard Deviation
Agricultural	Bayfield River	240	0.119	0.031	0.386	0.18
	Big Creek (1)	588	0.218	0.076	0.634	0.42
	Big Creek (2)	316	0.425	1.288	0.078	0.39
	Bighead River	342	0.034	0.014	0.069	0.07
	Middle Maitland River	386	0.374	0.085	1.249	0.54
	Nanticoke Creek	298	0.134	0.042	0.224	0.11
	Ruscom River	195	0.194	0.072	0.629	0.35
	Scotch River East	197	0.400	0.054	3.930	2.36
	South Nation River	238	0.138	0.101	0.218	0.10
	Sydenham River	166	0.021	0.015	0.038	0.02
	Tilbury Creek	242	0.501	0.229	0.959	0.58
Urban	Carruthers Creek	364	0.079	0.020	0.275	0.16
	Etobicoke Creek	426	1.068	0.058	15.800	2.50
	Humber River	533	0.197	0.075	0.640	0.50
	Little River	331	1.829	0.140	28.800	5.63
	Oakville Creek	440	0.162	0.035	0.525	0.26
	Oshawa Creek	350	0.155	0.016	1.690	0.19
	Rouge River	258	0.126	0.024	0.315	0.14
	Twelve Mile Creek	1078	0.042	0.024	0.170	0.04
Natural	Albemarble Brook	199	0.022	0.008	0.056	0.03
	Madawaska River	230	0.022	0.007	0.083	0.02
	Muskoka River	238	0.022	0.003	0.150	0.08
	Musquash River	306	0.024	0.004	0.102	0.10
	Rocky Saugeen River	320	0.023	0.008	0.059	0.03

5.0 References

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