Lake Simcoe Watershed

2013 Environmental Monitoring Report (2007-2011 data)

Lake Simcoe Region
conservation authority

Acknowledgements

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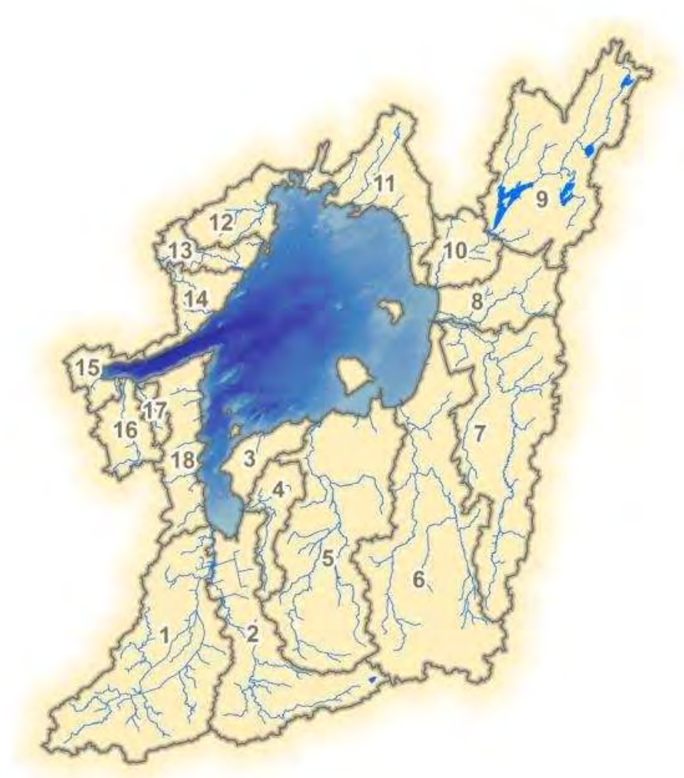
THE LAKE SIMCOE WATERSHED

The Lake Simcoe watershed is a 3,400 km^2 area of land which drains into Lake Simcoe in its centre, which is approximately 722 km^2 in area. The watershed drains 18 subwatersheds (Figure 1-1), which cross 20 municipal boundaries. This includes two regional municipalities (York Region and Durham Region), Simcoe County, and the Cities of Barrie, Orillia, and Kawartha Lakes. The watershed supports a population of over 400,000 people.

The Lake Simcoe watershed contains a number of significant natural features, including the Oak Ridges Moraine, Oro Moraine, and numerous woodland and wetland areas; as well as significant agricultural areas such as the Holland Marsh and other polders.

The Lake Simcoe watershed has been under pressure since the arrival of European settlers in the early 1800s. The initial changes included the removal of natural features to accommodate agriculture and the damming of watercourses in order to power mills. The land use changes have continued since, and now, 200 years later, a significant proportion of the watershed has been changed from its natural state, and its issues include water quality degradation, particularly from phosphorus, which has led to eutrophication; habitat loss and fragmentation; the introduction of invasive species; and climate change. These pressures will continue to intensify as the watershed population grows and natural areas are removed.

The watershed also provides numerous opportunities for recreation, including ice fishing and fishing in the summer, which contribute significantly to the local economy; boating, which is particularly popular given the lake's connection to the Trent-Severn waterway; snowmobiling; windsurfing; swimming; hiking; cycling; and canoeing. These opportunities attract watershed residents as well as many visitors, as the watershed is within an hour's drive of half of the province's population. The lake's ice fishing is well known, and has been known to attract international visitors.



# on map	Subwatershed Name	# on map	Subwatershed Name
1	West Holland River	10	Talbot River
2	East Holland	11	Ramara Creeks
3	Georgina Creeks	12	Oro Creeks North
4	Maskinonge River	13	Hawkestone Creek
5	Black River	14	Oro Creeks South
6	Pefferlaw River	15	Barrie Creeks
7	Beaver River	16	Lovers Creek
8	Whites Creek	17	Hewitts Creek
9	Upper Talbot River	18	Innisfil Creeks

Figure 1-1: The subwatersheds that drain to Lake Simcoe

Tourism and recreation

Tourism and recreation are a significant source of income for many watershed communities. The population of many lakeside communities increases significantly during the summer months, when cottagers return. Boating and fishing are hugely popular activities, and support industries such as boat and ice hut rentals, depending on the season, baitfish dealers, accommodations such as hotels and bed and breakfast establishments, restaurants, marinas, and outfitting businesses. Snowmobiling is another popular activity that supports many of the same industries.

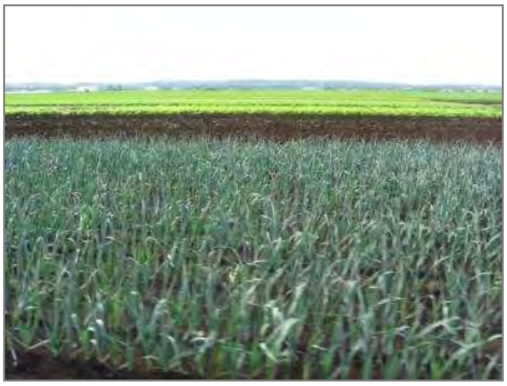
The watershed is also home to 24 conservation areas which are owned and/or managed by the Lake Simcoe Region Conservation Authority. In addition, there are four provincial parks classified as 'Recreation,' which contain amenities such as campgrounds, beaches, hiking trails, and opportunities for winter recreation. These are Bass Lake, Mara, McRae Point, and Sibbald Point Provincial Parks. There are two additional parks, Duclos Point and the Holland Landing Prairie, which are classed as Nature Reserve and do not contain any recreation facilities. These conservation areas and parks are a significant draw for residents of the Greater Toronto Area, who are looking for camping and recreation facilities nearby.

Oak Ridges and Oro Moraines

Sections of two moraines, the Oak Ridges Moraine, and the Oro Moraine, fall within the Lake Simcoe watershed. The Oak Ridges Moraine forms the southern boundary of the watershed, and the Oro Moraine can be found along the northwest boundary.

These moraines are geological landforms that were left behind by a glacial retreat occurring 12,000 - 13,000 years ago. As the ice melted, huge volumes of silts, sands, and gravels that had accumulated along their edges were deposited, leaving a ridge of rolling hills behind.

The moraines are extremely important contributors to the health of Lake Simcoe, as they act as water recharge and discharge systems; their permeable sands and gravels absorbing and collecting rain and melted snow, which then slowly filter into the deep aquifers below the ground. This clean, cool groundwater is then discharged to streams and wetlands along the base of the moraine, supporting numerous sensitive species, and is also used as a source of drinking water for many private landowners and watershed communities. The moraines contribute flow to the headwaters of a number of Lake Simcoe's tributary rivers, have relatively high levels of natural cover, and support a number of sensitive species.



Polders

Polders are wetlands that have been drained for agricultural use. Because they are low-lying, excess water accumulates, and must be pumped off and discharged to watercourses. This water contains phosphorus, sediment, and other contaminants, and has an impact on water quality in the receiving tributaries and in the lake. There are five polders in the watershed, the Keswick, Colbar, Bradford, Deerhurst, and Holland Marshes, occupying approximately 37 km^2, with the Holland Marsh being the largest of these at 28 km^2.

Issues in the watershed

There are numerous issues of concern regarding the health of the Lake Simcoe watershed; many of which stem from changing land uses. The removal of natural cover to accommodate land uses such as agriculture, urban development, golf courses and other recreation facilities, transportation and utility corridors, and aggregate operations can have significant impacts on watershed health, impacting water quality and quantity, and the health of terrestrial and aquatic communities.

Along with land use change has come inputs of nutrients and other contaminants to the watershed’s watercourses and, ultimately, to the lake itself. Inputs of high levels of the nutrient phosphorus have caused many of the issues we have been addressing in the watershed for the past few decades. This phosphorus has caused a process referred to as eutrophication in the lake and in some of its tributary rivers. Generally speaking, high levels of phosphorus have caused the excessive growth of aquatic plants and algae near the mouths of a number of tributaries, and in several areas of the lake, such as Cook’s and Kempenfelt Bays and other areas along the shoreline. As these plants die off they are decomposed by bacteria, a process which consumes dissolved oxygen in the water, rendering it unavailable for use by fish and other aquatic organisms. While some species are more tolerant of low oxygen levels, sensitive species, particularly lake trout and lake whitefish, are unable to tolerate these conditions, and for many years their populations have been sustained by stocking efforts, with little to no natural reproduction occurring. Phosphorus reduction efforts have been undertaken by the LSRCA and its partners under the Lake Simcoe Environmental Management Strategy since the early 1980s, and eventually reductions in phosphorus loads were realized. Coincident with these reductions was an increase in dissolved oxygen levels, and fisheries monitoring work began to show evidence of natural reproduction in lake trout and whitefish populations in the mid-2000s. This is certainly a positive step, although stocking will still be required to sustain populations, as the amount of natural reproduction occurring is still very low. In 2008, the province of Ontario released the Lake Simcoe Protection Act, which provided a legislative framework for protecting the Lake Simcoe watershed. The corresponding Lake Simcoe Protection Plan was released the following June, which directs efforts for protecting and restoring the watershed. In this Plan, the Ontario Ministry of the Environment (MOE) has set an aggressive phosphorus loading target of 44 tonnes/year; the average was approximately 86 tonnes per year in the most recent period of record (2005-2009). It is thought that the target level would correspond to a dissolved oxygen level of 7 mg/L, which is the minimum required to sustain healthy populations of lake trout.

Actions being undertaken

The Lake Simcoe Region Conservation Authority and its partners continue to work to improve conditions in the watershed. This work includes:

- The development of Subwatershed Plans, which highlight subwatershed conditions, assess the current management framework, and identify actions that should be undertaken to improve subwatershed conditions
- Undertaking stewardship works throughout the watershed through our Landowner Environmental Assistance Program (LEAP)
- Completing works under the Source Water Protection program, including the development of a Source Protection Plan for this area
- Working with landowners and developers to minimize the impacts of their undertakings on the health of the watershed
- Assessing the effectiveness of stormwater controls in the watershed's urban areas, and recommending stormwater retrofits, where possible
- Providing education programs and materials to inform watershed residents of what is happening in their watershed, and actions that they can take to reduce their impact on the environment

Some of the most important activities that the LSRCA undertakes are through our monitoring program. Through this program, LSRCA staff monitor the watershed's tributary streams and rivers, as well as conditions in the lake. This monitoring work supports a number of the LSRCA's other programs, including subwatershed planning, helping to identify potential areas for undertaking stewardship works, assessing the effectiveness of on-the-ground projects that have been completed, verifying the effectiveness of new technologies and practices, and helping to pinpoint areas of concern in the watershed.

Tributary monitoring includes:

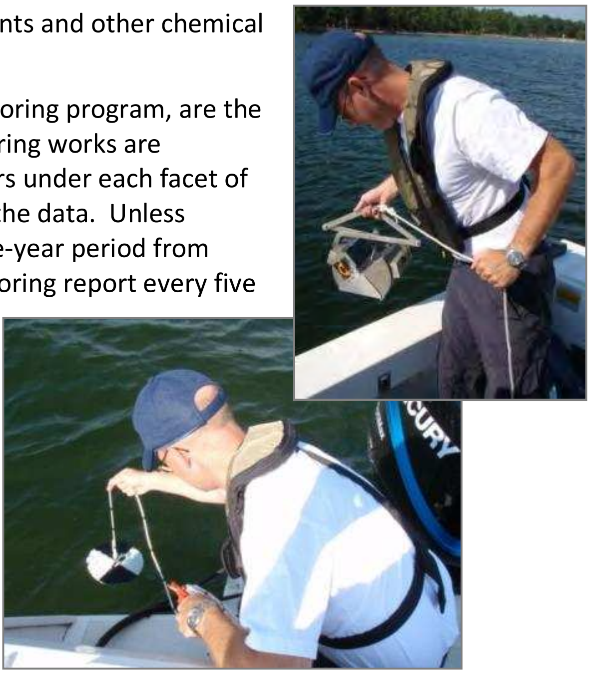
- collecting samples to assess the quality of ground and surface water
- measuring surface water flows and ground water levels
- sampling the fish and benthic invertebrate (aquatic insects, molluscs, crustaceans, and worms) communities
- deploying dataloggers to measure the temperature of stream water
- collecting single-celled algae, called diatoms, to assess stream conditions

Tributary monitoring activities, including benthic invertebrate sampling (left), water quality sampling (centre), and electrofishing (right)

Our nearshore sampling program which, as its name implies, occurs in the nearshore area of the lake, entails:

- Surveying the composition and extent of aquatic plant communities, and noting changes over time
- Assessing the benthic invertebrate community, including noting the levels of invasive species such as zebra and quagga mussels
- Sampling water and sediment to test for a range of nutrients and other chemical parameters

These monitoring works, and the results found through the monitoring program, are the focus of the following report. This report identifies which monitoring works are undertaken where, what the results were for some key parameters under each facet of the monitoring program, and if there are any trends identified in the data. Unless otherwise indicated, the reporting period for this report is the five-year period from 2007-2011. It is anticipated that the LSRCA will complete a monitoring report every five years.



Conducting sampling on the lake – collecting samples using a Petite Ponar Grab (top) and using a Secchi disc to determine water clarity (bottom)

METHODS

This section of the LSRCA Monitoring Report 2013 provides a description of the components of the monitoring program, explaining how and when monitoring is undertaken and why that particular component is monitored. The LSRCA monitoring program includes monitoring of the quality and quantity of surface and groundwater, the status of the aquatic communities within the watercourses of the Lake Simcoe watershed (which include fish, benthic invertebrates, and diatoms, as well as the spread of invasive aquatic species and the location of species of concern), and the physical and biological components of the Lake Simcoe-nearshore environment,.

The information collected from the monitoring program is used to establish the current status of a particular parameter, track both short and long term trends, identify and locate stressors and where possible predict future changes.

TRIBUTARY WATER QUALITY

The chemical, physical and microbiological characteristics of natural water make up an integrated index we define as “water quality”. Water quality is a function of both natural processes and anthropogenic impacts. For example, natural processes such as weathering of minerals and various kinds of erosion are two actions that can affect the quality of groundwater and surface water. There are several different types of anthropogenic influences, such as point sources and non-point sources of pollution. Point sources of pollution are direct inputs of contaminants to the surface water or groundwater system and include municipal and industrial wastewater discharges, ruptured underground storage tanks, and landfills. Non-point sources include, but are not exclusive to, agricultural drainage, urban runoff, land clearing, construction activity, and land application of waste that typically travel to waterways through surface runoff and infiltration. Contaminants delivered by point and non-point sources can travel in suspension and/or solution and are characterized by routine sampling of surface waters in the Lake Simcoe watershed.

Surface Water

Description (how and when):

Samples are routinely collected from 25 monitoring stations throughout the Lake Simcoe watershed (some of the numbered sites on Figure 2-1 contain more than one sampling station) as part of two monitoring programs, the LSPP (Lake Simcoe Protection Plan) program and the PWQMN (Provincial Water Quality Monitoring Network) program. The stations represent most of the subwatersheds of Lake Simcoe (except Oro Creeks South and Georgina Creeks). The water quality stations are at major tributaries and representative creeks, but there are also stations at the Art Janse Pumping Station of the Holland Marsh and at Atherley Narrows, the outflow of Lake Simcoe. From approximately the same stream bank location on each sampling event, a simple grab sample is collected using a reaching pole or drop bucket and the sample is contained in a new polyethylene container pre-rinsed with the stream water. Samples are kept on ice in a cooler for transportation and are sent to the laboratory expediently to make sure samples are analyzed within perishability limits. The stations are numbered in Figure 2-1, and their corresponding station names are shown in Table 2-1 below.

Samples from both programs are analyzed in the Laboratory Services Branch of the Ministry of Environment, and are assessed using the Provincial Water Quality Objectives (PWQO) (Ministry of Environment, 1994). Samples collected under the LSPP program are analyzed for eight key chemical parameters and are collected year round, every two weeks during the spring, summer, and fall and every three weeks in the winter months. Sampling dates are shifted or added to coincide with storm/rain events especially during the spring freshet. Samples under the PWQMN program are collected eight times a year on a monthly basis during the ice-free period and analyzed for 32 chemical parameters. The key chemical parameters include nutrients (such as phosphorus), total suspended solids, chloride, and a suite of metals (iron for example). Physical parameters including pH, temperature, dissolved oxygen, and conductivity are measured instantaneously at each site using a YSI sonde.

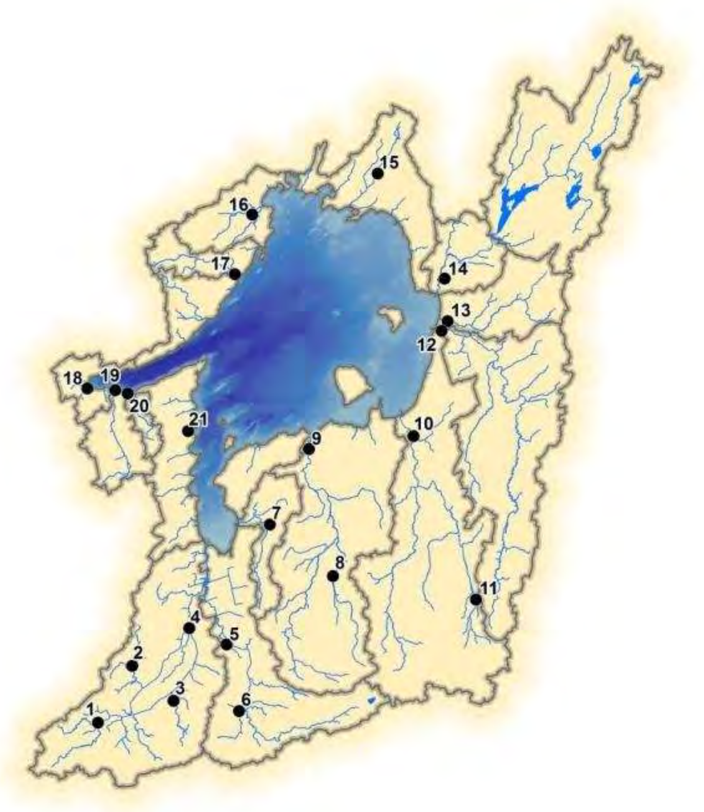


Figure 2-1: Location of surface water quality sampling stations.

Importance of component:

Water quality sampling of the tributaries provides information required for calculating nutrient and chloride loads from tributaries to Lake Simcoe. The program also provides long-term data for trend monitoring, assessment of phosphorus reduction efforts, research initiatives, comparison to provincial and federal water quality guidelines, and to track the environmental conditions of subwatersheds. These efforts support the water quality and phosphorus loading objectives of the Lake Simcoe Protection Act and Plan and the Phosphorus Reduction Strategy.

Table 2-1: Water quality monitoring station names corresponding to numbers in Figure 2-1. The monitoring program undertaken at each site is also noted

# on map	Station Name (program)	# on map	Station Name (program)
1	Upper Schomberg (LSPP/PWQMN)	**12**	Beaver (LSPP/PWQMN)
2	North Schomberg (LSPP)	**13**	Whites (LSPP)
3	Kettleby (LSPP)	**14**	Talbot (LSPP)
4	West Holland (LSPP)	**15**	Ramara (LSPP)
5	East Holland (LSPP/PWQMN)	**16**	Bluffs (LSPP)
6	Tannery (PWQMN)	**17**	Hawkestone (LSPP/PWQMN)
7	Maskinonge (LSPP/PWQMN)	**18**	Hotchkiss (LSPP)
8	Mount Albert (PWQMN)	**19**	Lovers (LSPP/PWQMN)
9	Black (LSPP/PWQMN)	**20**	Hewitt’s (LSPP)
10	Pefferlaw (LSPP/PWQMN)	**21**	Leonards (LSPP)
11	Uxbridge (PWQMN)		

Groundwater

Description (how and when):

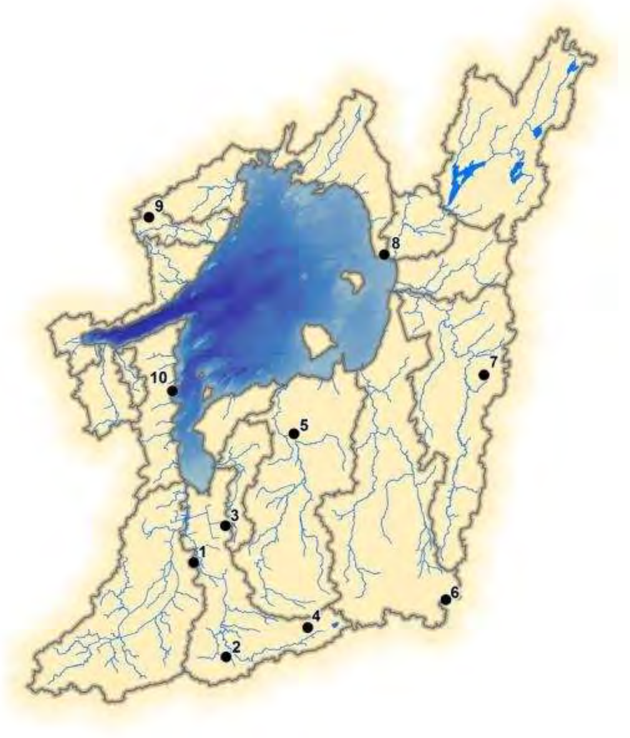


Figure 2-2: Location of groundwater quality monitoring stations.

Samples are collected during the spring and fall from 13 monitoring wells at 10 locations throughout the Lake Simcoe watershed as part of the Provincial Groundwater Monitoring Network (PGMN) (monitoring well locations are numbered in Figure 2-2, with corresponding Well ID numbers and location names shown below in Table 2-2). Three aquifer depths are sampled at site 5 on the map, and two are sampled at site 9. Samples are collected manually using high density polyethylene tubing with a footvalve or using low density polyethylene tubing and a 12 volt stainless steel groundwater pump. Prior to the start of sampling the water Levelogger is removed and a static water level and a calculation is performed to determine the volume of water within the well casing. The well is pumped for a minimum of an hour or until three casing volumes have been removed to ensure that the sample being taken is representative of water from the aquifer and not stagnant water from the well. A probe (i.e. YSI sonde) is used to measure the chemical parameters such as pH, temperature, dissolved oxygen, and conductivity from the discharged water. Once the parameter measurements and the static water level within the casing have stabilized, the sample is taken. All samples are unfiltered except for the metals samples which are filtered through a 0.45 micron in-line filter that is attached to the end of the sampling tube. Samples are kept on ice in a cooler for transportation and are sent to the laboratory expediently to ensure that the samples are analyzed within their perishability limits.

Samples collected in the spring are analysed by Maxxam Analytics and samples collected in the fall are analysed by the Laboratory Services Branch of the Ministry of the Environment. The laboratories analyze the samples for the key chemical parameters including phosphorus, nitrogen, total suspended solids, chloride, dissolved organic carbon and dissolved inorganic carbon, and a suite of metals (iron for example).

Importance of component:

Sampling of water quality in groundwater monitoring wells provides long-term data for trend analysis, comparison to other monitoring wells across the province that are a part of the PGMN program, and to track the environmental conditions of the aquifers studied.

# on map	Well ID #	Location Name (depth)	# on map	Well ID #	Location Name (depth)
1	W0000063-3	Holland Landing (shallow)	**6**	W0000032-1	Durham Forest (deep)
2	W0000283-1	Aurora (intermediate)		W0000039-1	Durham Forest (intermediate)
3	W0000025-1	Queensville (shallow)	**7**	W0000062-1	Cannington (shallow)
4	W0000071-1	Ballantrae (deep)	**8**	W0000408-1	Ramara (shallow)
5	W0000298-2	Baldwin (shallow)	**9**	W0000408-1	Oro-Medonte (deep)
	W0000298-3	Baldwin (intermediate)		W0000408-1	Oro-Medonte (shallow)
	W0000298-4	Baldwin (deep)	**10***	W0000408-1	Innisfil (shallow)

*Well decommissioned in 2010

Table 2-2: Provincial Groundwater Quality Monitoring Network Well ID numbers, station names, and sampling depths, as shown in Figure 2-2. Sampling depths correspond to the depth of the well screen below the surface. In general, shallow wells have a total depth less than 10 m, intermediate wells have a total depth between 10 and 30 m, and deep wells have a total depth greater than 30 m.

TRIBUTARY WATER QUANTITY

Water quantity monitoring includes the evaluation of precipitation, stream flow, baseflow, and groundwater. These parameters are very useful when examining issues such as contaminant and nutrient loading to the lake, water availability for different kinds of consumption, as well as anthropogenic impacts on water resources. Water quantity can be impacted by land use practices such as paving, clearing of land, groundwater withdrawals, and alteration of river channels. Such changes in land use can lead to decreased infiltration rates, affecting groundwater recharge and increasing runoff rates, which increases the chances of downstream flooding. Groundwater withdrawal for urban, industrial, or agricultural uses can also impact baseflow of local streams.

Surface Water

Description (how and when):

There are currently 17 hydrometric gauges within the Lake Simcoe watershed. Seven of these are maintained by Water Survey of Canada, nine are maintained by LSRCA, and one is operated by a partnership between Parks Canada Trent Severn Waterway Authority and the LSRCA.

At each gauge, water level (stage) is recorded continuously using either a float recorder or constant flow bubbler and data logger combination. Data is accessed remotely in near real time or downloaded at regular intervals using a personal computer. The continuous stage record is converted to continuous discharge (volume of water per unit time) using stage-discharge relationships calculated for each site. To establish the stage-discharge relationships, routine discrete measurements are performed using the standard mid-section method and a velocity meter or with an Acoustic Doppler Channel Profiler (ADCP). These are plotted against corresponding stage readings from staff gauges installed at each hydrometric gauge using Kisters WISKI hydrologic software.

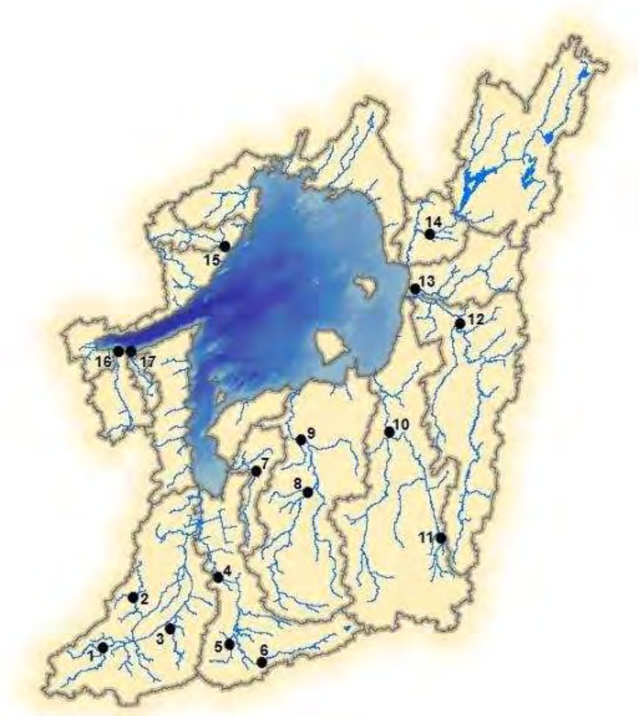


Figure 2-3: Location of flow monitoring stations.

Table 2-3: Water quantity monitoring station names (corresponds to numbering in Figure 2-3)

# on map	Station Name	# on map	Station Name	# on map	Station Name
1	Upper Schomberg	7	Maskinonge	13	Whites
2	North Schomberg	8	Black - Holborn	14	Talbot
3	Kettleby	9	Black - Baldwin	15	Hawkestone
4	Holland Landing	10	Pefferlaw	16	Lovers
5	Tannery	11	Uxbridge	17	Hewitts
6	Vandorf	12	Beaver		

Importance of component:

Stream flow information collected from these gauges has many uses in the Lake Simcoe and surrounding watersheds, including:

- Water resource management and allocation – this data helps to identify how much water is available and how much growth a water supply can support as well as the potential effects of the growth;
- Engineering and urban design – information gained from this monitoring is valuable for the engineering and design of infrastructure projects (such as bridges, culverts, and roads)
- Recreation and navigation – the Trent Severn Waterway Authority relies on accurate stream flow and level information to ensure safe river and lake depths for boat travel
- Flood planning and forecasting – stream flow information is very useful for flood forecasting and high water emergency planning and response, and for identifying floodplain mapping to protect public assets and infrastructure
- Supporting water quality monitoring – using flow information to determine loading volumes of various substances to the lake, and characterizing and evaluating instream conditions.
- Trends in stream flow characteristics

Groundwater

Description (how and when):

Water level and temperature data are collected continuously on an hourly basis from 13 monitoring wells located throughout the Lake Simcoe watershed as part of the Provincial Groundwater Monitoring Network (PGMN) using Solinst Leveloggers (Figure 2-2). The loggers are installed at a set depth; and the data are downloaded quarterly, with manual static water level dip checks being taken to verify the accuracy of the logger data. The manual static water level dip checks are taken with a Solinst Water Level Meter from the same surveyed point of the well casing and are used to correct shifts in the elevations recorded by the logger or eliminate erroneous data. The downloaded data files are sent to the Ministry of the Environment to be incorporated into the Provincial Groundwater Management Information System (PGMIS). A Barologger is used to collect barometric pressure data at the same sampling interval as the Leveloggers and used to compensate the data before the quality check process can commence. Quality checks of the data are undertaken to remove dropped or spiked values that occur while the logger was removed from the well casing due to sampling or logger performance issues.

Importance of component:

The Provincial Groundwater Monitoring Network (PGMN) program provides long-term data for trend analysis, comparison to other sites across the province, and providing information on the changing conditions throughout the watershed from climate change, development, or water taking practices.

TRIBUTARY BIOLOGY

The biological communities within the watercourses of the Lake Simcoe watershed are important indicators of the health of the aquatic ecosystem. Changes in the composition of fish and benthic communities can signify changes in water quality, temperature, flows, and instream habitat.

Fish

Description:

Fish sampling in the Lake Simcoe watershed is conducted between June 1st and September 30th. A total of 451 sites have been monitored over a 10 year period between 2002 and 2011. Of these, 50 are routine monitoring sites that are sampled each year. Assessment of the sites follows the most recent version of the Ontario Stream Assessment Protocol (OSAP). The majority of the sampling is completed using backpack electrofishers, while boats, punts, and shore units are utilized only when necessary. Most fish are identified (to a species level) and enumerated on site and released alive; some specimens may be retained for confirmation of identification. Fish habitat is evaluated by collecting geomorphology data at all new sites or at sites that have not been measured in five or more years. All field data collected is entered into the OSAP database.

Fish population data is analyzed using a modified version of the original Index of Biotic Integrity (IBI) created by James Karr. This IBI was modified by the Toronto Region Conservation Authority to be relevant for Oak Ridges Moraine watercourses (OMNR and TRCA, 2005).

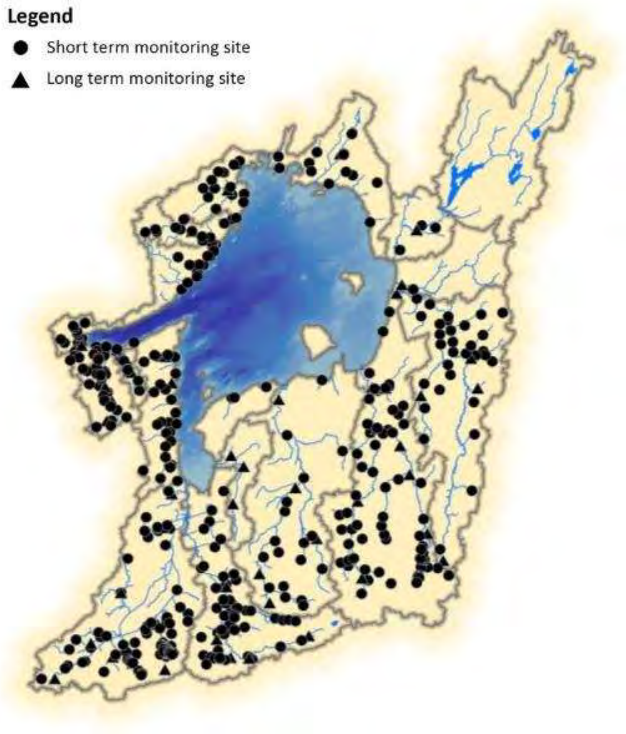


Figure 2-4: Location of fish sampling stations.

Importance of component:

Fish sampling provides data for trend monitoring, individual site assessments and subwatershed assessments. Analysis of fish communities also provides important information on important issues including the introduction and movement of invasive species, and the presence or absence of coldwater indicator species such as brook trout for watershed planning and permitting, and can also be used as a measure of stewardship success.

Benthic Invertebrates

Description:

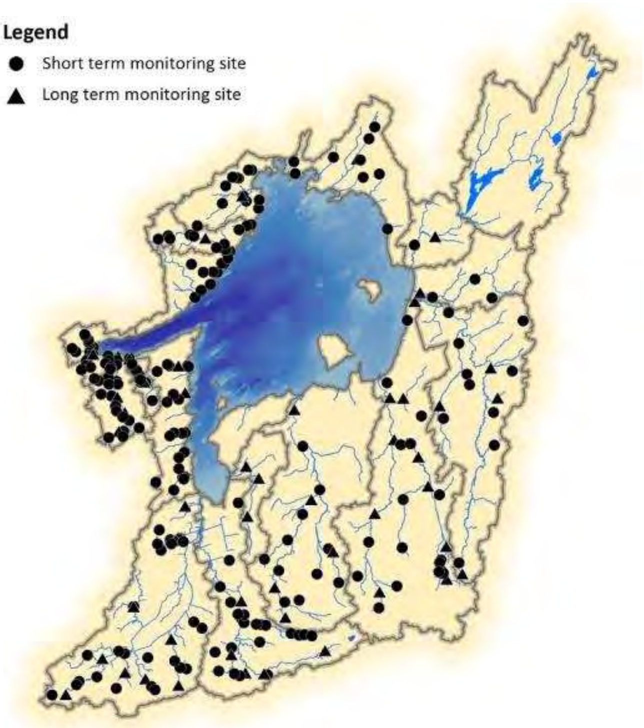


Figure 2-5: Location of benthic invertebrate sampling stations.

Benthic invertebrate sampling in the Lake Simcoe watershed is generally conducted in the fall between September 1st and November 30th, with a small number of sites on watercourses that dry up in the summer being conducted in the spring between May 15th and June 15th. In total, 234 sites were monitored from 2002 to 2011. Of these, 50 are routine monitoring sites that are sampled each year. Assessment of the benthic invertebrate communities follows the most recent version of the Ontario Benthos Biomonitoring Network (OBBN). All samples are collected into 1L jars and preserved in formalin at the site. The routine monitoring sites are identified to a family level and enumerated in house. Exceptions to the OBBN protocol include sampling one riffle instead of two, to save time and money; however, 300 invertebrates are sampled, instead of the recommended 100 to ensure that there is sufficient diversity.

Data analysis consists of three main indices: Hilsenhoff Family Biotic Index (Hilsenhoff, 1998), the BioMap index (Griffiths, 1999), and %EPT [the percentage of the invertebrates that belong to the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)]. The family index is a modified Hilsenhoff index that uses tolerance values derived from Mandaville's work (Mandaville, 2002), and is the index used in this report.

Importance of component:

Benthic biomonitoring is a cost effective way of collecting important water quality information for watershed reports and watershed planning/permitting. It also provides data for trend monitoring, individual site assessments, and subwatershed assessments.

Diatoms

Description:

Diatoms (Bacillariophyceae) are single-celled algae encased in frustules (cell walls) of silicon dioxide that live free-floating in the water column or attached to rocks, plants, sand grains, and other substrates. They are used as indicators of environmental conditions. They are collected in the fall from 50 tributary locations also used for benthic invertebrate monitoring, with sampling being initiated in 2011. Samples are collected at each site by scraping material from all habitats (e.g. rocks, plants, logs, twigs). In the laboratory, diatoms are separated from organic material using hydrogen peroxide, permanently mounted onto microscope slides, then enumerated and identified by oil immersion microscopy. Data are used to assess environmental conditions at each site, and provide a record of change between years.

Importance of component:

The ecological optima and tolerances of diatoms have been well studied, making these organisms excellent, and highly accurate, indicators of many environmental variables (e.g. pH, phosphorus, nitrogen, chloride). A short life cycle enables rapid species response (under 24 hours) to changing environmental conditions. In the Lake Simcoe watershed, diatoms are used to track the flow of phosphorus and chloride from land to lake, determine "hotspots" of environmental concern, and assess the effectiveness of remediation and lake management efforts.

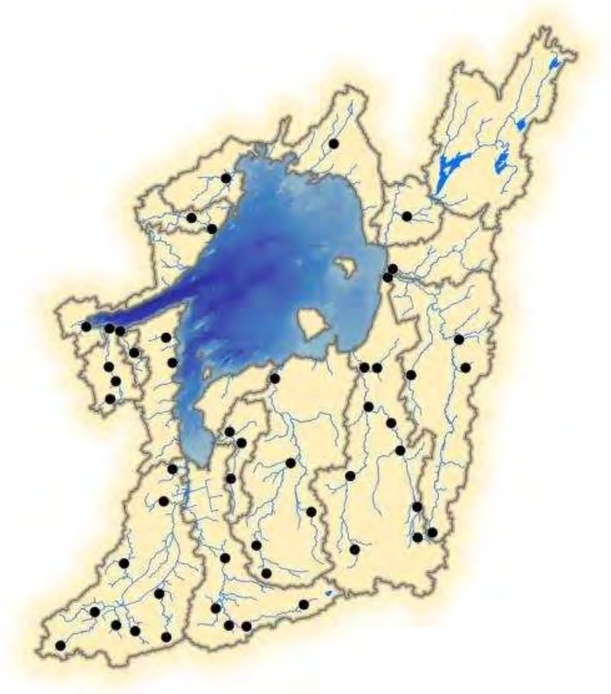


Figure 2-6: Location of diatom sampling locations.

Temperature

Description:

Temperature monitoring has been conducted since 2003 at 338 sites, of which 50 are routine monitoring sites. Hobo temperature loggers are installed in wadeable streams adjacent to fish monitoring stations (at least 10 m downstream of electrofishing sites) and as close to the stream bed as possible without resting on the bottom. The loggers are set for a delayed start (~1 day after deployment) to log temperatures on an hourly basis from May until the end of October. Data collection follows the most recent version of the OSAP (Section 5). Data is downloaded using the Hobo software and transferred to Kisters WISKI hydrologic software and the OSAP database.

Collected data is analyzed using "A Simple Method to Determine the Thermal Stability of Southern Ontario Trout Streams" (Stoneman, C.L. and M.L. Jones, 1996). This analysis defines if a stream at the point where the logger

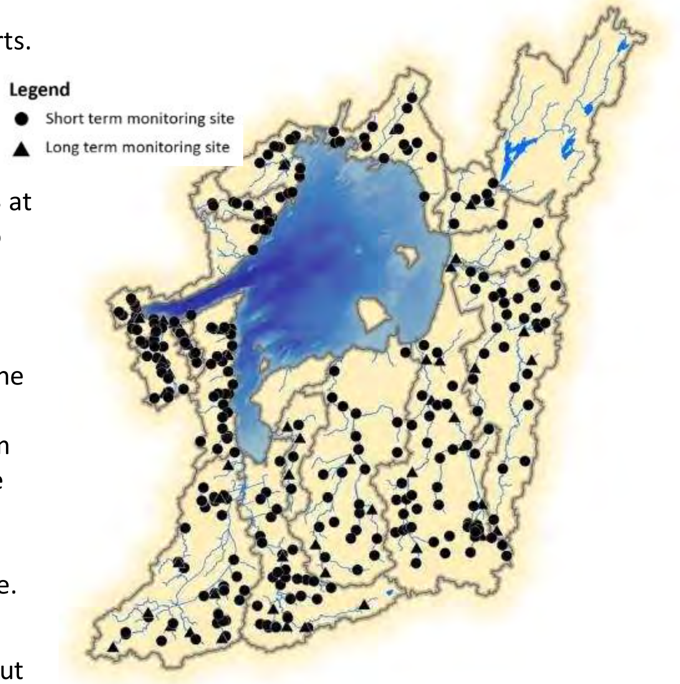


Figure 2-7: Location of tributary temperature monitoring stations.

was located is cold, cool, or warm water habitat. Typically, the average maximum summer water temperatures for a cold water system is 14°C. Cool water is approximately 18°C and warm water systems have an average summer maximum daily water temperature of approximately 23°C (Stoneman and Jones, 1996).

Importance of component:

Water temperature information is collected to see if sections of watercourses are thermally stable and if they can support cold water species. Analysis of water temperature provides important information for watershed reports and watershed planning/permitting.

LAKE SIMCOE NEARSHORE

The LSRCA nearshore monitoring team carries out year-round, scientific studies on the lake, with routine water quality samples at 29 lake stations (8 open-water and 21 nearshore) and six Holland River stations. An additional 142 sites are monitored annually for changes to biological communities and a further 952 sites sampled every five years for long-term community changes.

The LSRCA program to investigate environmental changes in Lake Simcoe was started in May 2008 and is a science-based program on the lake to address changes to Lake Simcoe's health, nearshore biological communities, and specifically target issues of concern to watershed residents. Over the past four years, studies have targeted water quality and changing sediment chemistry; changes to communities of lake organisms such as aquatic plants, benthic invertebrates, and algae; and the impact of invasive species.

Water Quality - Physical Monitoring

Description:

Physical water quality analyses are carried out year round, bi-weekly at the 21 lake and six river monitoring stations. Using a YSI 6600V2 sonde, depth profiles are constructed for key limnological variables including pH, temperature, dissolved oxygen, chlorophyll *a*, and cyanobacterial pigments. Water clarity is recorded using a Secchi disk, bi-weekly at the lake and river stations, and irregular intervals at all other sample stations. These data enable the tracking of changes in lake health between seasons and from year to year.

Importance of component:

These analyses give a direct, *in situ*, measurement of lake health and are used to immediately assess water quality until more detailed results are obtained by lab chemical analysis.

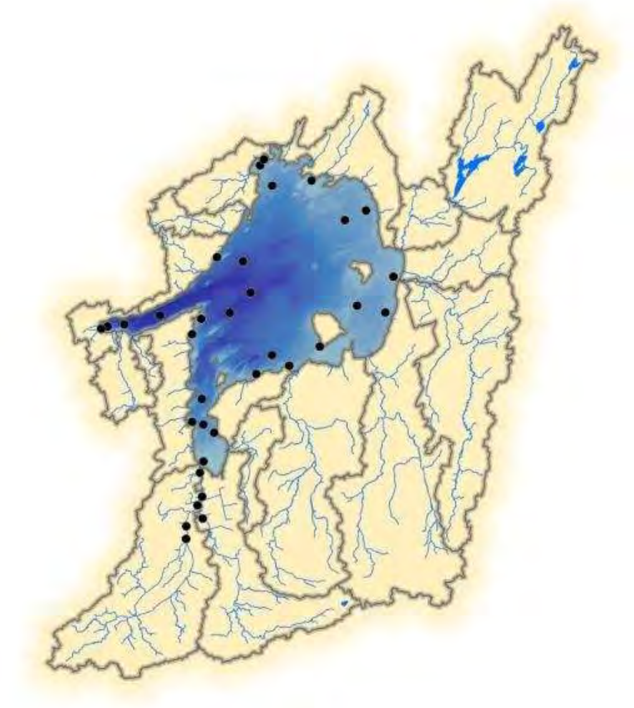


Figure 2-8: Location of physical and chemical monitoring sites for the LSRCA nearshore monitoring program (includes 21 nearshore, eight open-water, and six Holland River sites)

Water Quality - Chemical Monitoring

Description:

Water samples for chemical analyses are collected year round, monthly at ten lake stations, and bi-weekly at the six Holland River stations, using a Van Dorn sampler (Figure 2-8 displays sampling sites). Water chemistry is measured for a number of reasons: to track phosphorus reduction efforts, to detect seasonal changes, and to determine the oxygen availability for aquatic biota. Analyses for over 50 limnological variables are carried out at a contracted laboratory (Inductively-Coupled Plasma Mass Spectrometry (ICP-MS) instrumentation is used to measure many of these). Key limnological variables include phosphorus, nitrogen, dissolved organic carbon, and metals. Concurrent to these water samples, sediments are also sampled at each location using a Petite Ponar Grab to determine the amount of phosphorus available for plant uptake, and to look at the potential changes to nutrient cycling due to the presence of dreissenid mussels. Changes are tracked for eight chemical variables including sediment, nitrogen, and phosphorus.

Importance of component:

Routine monitoring and the direct laboratory analyses of water and sediment samples are the most accurate way to assess water quality. These data are used to track changes in lake environmental conditions, as well as to develop and calibrate biological indicators of limnological change.

Biological Monitoring

Description:

A central activity of the LSRCA nearshore monitoring program has been undertaking the development of biological indicators to infer and track changes in the environmental health of Lake Simcoe. In addition to directly inferring limnological variables (e.g. pH, nutrients, dissolved oxygen, temperature), these studies serve to track changes in biological communities and the presence of invasive species.

Aquatic Plants: A survey of 215 sample sites (Figure 2-9) is carried out every five years (surveyed in 2008 with the next survey in 2013) to monitor for changes in species diversity and community, presence and expansion of invasive species, and changes in aquatic plant habitat such as maximum depth of colonization. On years without a full survey, routine monitoring is carried out three times a year (to record seasonal changes in diversity) at 20 stations in five locations. Samples are collected by Lake Rake® (qualitative analyses) and Petite Ponar Grab (quantitative analyses), identified and enumerated in the laboratory, and biomass (amount of plants per unit area) calculated.

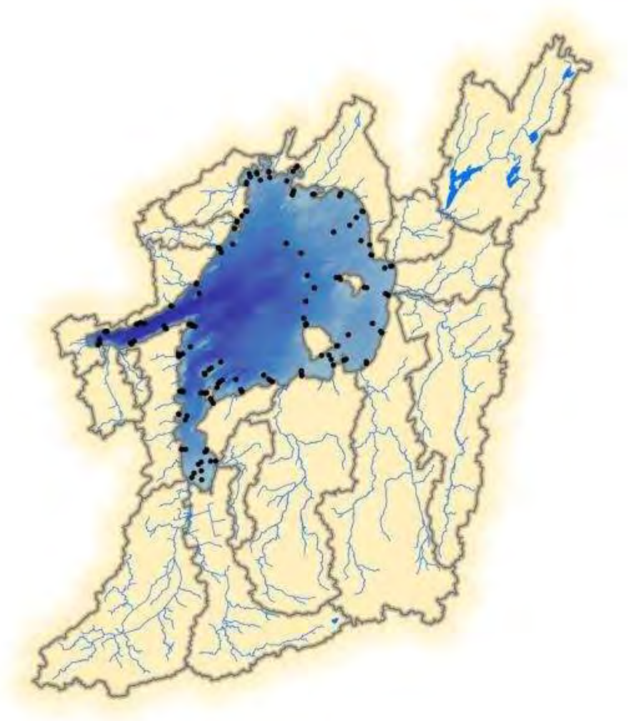


Figure 2-9: Location of survey sites for aquatic plants undertaken through the LSRCA nearshore monitoring program

Benthic Invertebrates: 52 sites are sampled annually in October and are divided by depth to assess the three main lake habitats: 18 shoreline samples (0-1 m depth), 24 littoral samples (~7 m depth), and 10 profundal samples (>20 m depth) (Figure 2-10). At each station, triplicate samples are taken using a Petite Ponar Grab, preserved in 10% buffered formalin, then sorted and identified in the laboratory. These data are used to assess changes in the biodiversity of lake communities (i.e. benthic and fish communities), track presence and impact of invasive species, and infer limnological variables (e.g. annual minimum hypolimnetic dissolved oxygen, water temperature, water turbidity, and presence of organic contaminants). In 2009-10, additional surveys were carried out to assess the impacts of invasive dreissenid (zebra and quagga) mussels in Lake Simcoe. A total of 747 sites were sampled (Figure 2-11) with 43,952 mussels enumerated, shell-length measured, and used to determine species biomass. These data were used to determine distribution of the two species, areas of dense colonization, and population trends.
An investigation currently underway is to replicate sample sites from 1928 to study long-term benthic community changes over an 85-year time period.

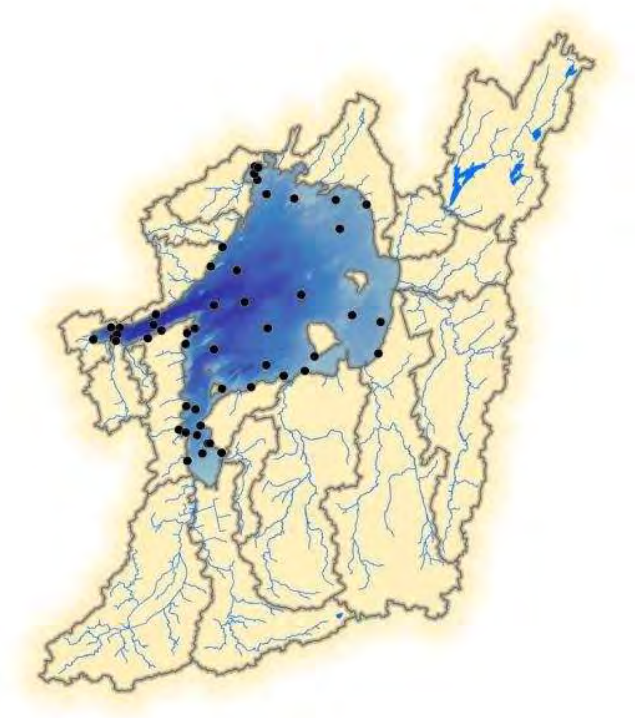


Figure 2-10: Location of benthic invertebrate sampling undertaken through the LSRCA nearshore monitoring program

Importance of component:

These data directly measure the diversity, health, and changes in the biological communities of Lake Simcoe. Using established limnological techniques, the data are directly comparable to other studies and are used to track changes through time. The calibration of species with environmental conditions enables the use of biological community diversity in assessing ecological changes.

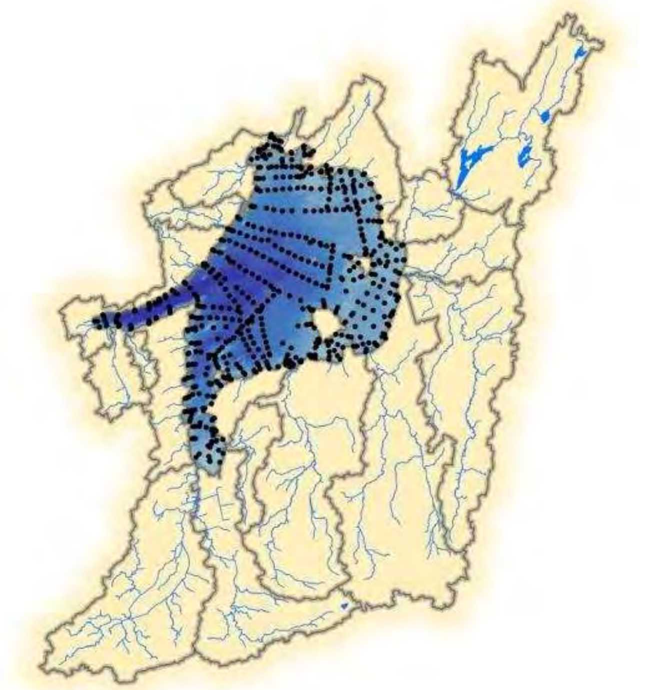


Figure 2-11: Location of dreissenid mussel sampling undertaken through the LSRCA nearshore monitoring program

Many factors affect the conditions in the Lake Simcoe watershed. Some of these, such as spring floods, are natural and annual variations are generally accommodated well by natural systems. Others, such as land use change, the inputs of point source and non-point source contaminants, climate change, and the introduction of invasive species are anthropogenic and often have dramatic results. This section describes these effects as seen in the Lake Simcoe watershed.

CLIMATE

A watershed's climate can have a significant impact on its conditions. The air temperature affects the water temperature in streams and in the lake, thus affecting the aquatic communities living there. It also influences the timing and duration of life cycle events for a number of species living in the watershed. The amount and frequency of precipitation can have a number of effects, depending on where, when, how, and in what form it falls. The influence of climate on natural systems can be exacerbated by land use changes, as natural areas do have some built in capacity to adapt to gradual changes or short term events.

Temperature

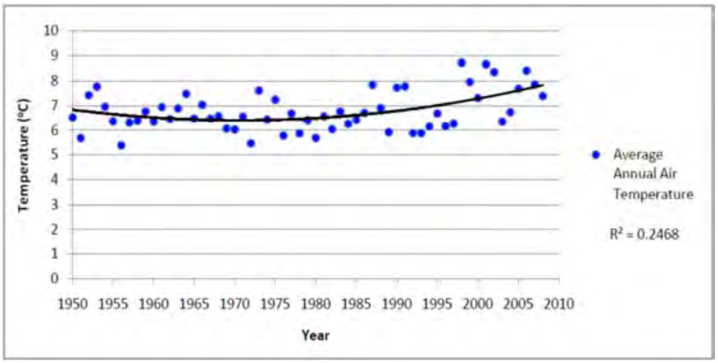


Figure 3-1: Average annual temperature at the Barrie Water Pollution Control Centre meteorological monitoring station

The long term mean annual temperature in the Lake Simcoe watershed, for the years 1971-2000, is 6.7° C. The mean temperatures for the coldest and warmest months, January and July, are -8.1°C and 20.5°C, respectively. The average annual temperature showed a slight decreasing trend from the beginning of the period of record in 1950, until the late 1970s when it began to increase, for an overall increase of 0.67°C over the past 58 years (SGBLS SPC, 2011; Figure 3-1).

Precipitation

The amount of precipitation that a watershed receives can have a significant influence on the conditions in the watershed. Wetter than normal years can lead to impacts on water quality, as more contaminants are washed from ground surfaces into watercourses; and can cause flooding issues. Lower than normal precipitation levels can cause stress to areas such as wetlands and other communities that are dependent on moist soils, and can lead to decreases in levels of both surface and groundwater, which can have impacts on fish and benthic invertebrate communities.

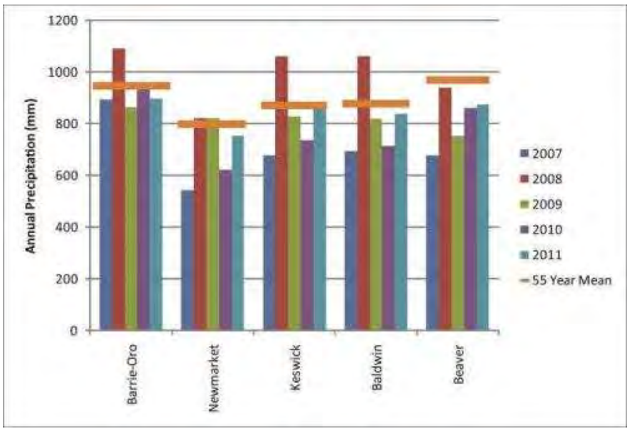


Figure 3-2: Precipitation normals for five Lake Simcoe climate stations

Precipitation amounts vary greatly across the Lake Simcoe watershed, largely due to lake effect snowfall in the north and west section of the watershed. The mean for precipitation across the watershed is 911 mm/year; with the minimum and maximum being 798 mm/yr and 1046 mm/yr, respectively. There have recently been some notable years with respect to precipitation. Dry years were seen in 2007 and 2010, and 2008 was wetter than normal (Figure 3-2). The impact of the changes in precipitation can be seen in the results of our monitoring. For example; the phosphorus loads were significantly higher in 2008, which was the wettest year since 1969 (LSRCA data).

Climate Change

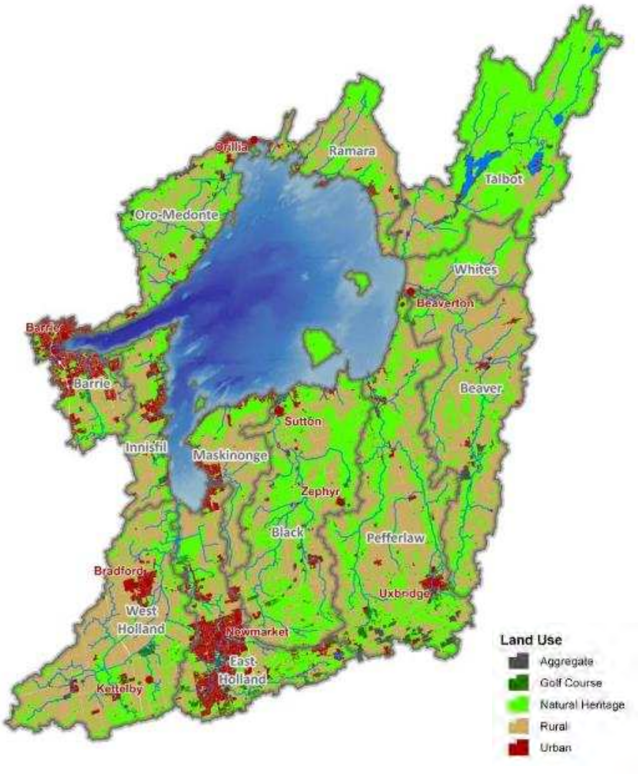
The issue of climate change has been brought to the forefront in the last two decades. For the Oak Ridges Moraine in the south of the watershed, models run to estimate the effects of climate change predict the following conditions by 2100 (in comparison to climate data for the period from 1971 to 2000):

- A 4.4°C increase in maximum temperature in the warmest month
- A 4.3°C increase in maximum temperature in the coldest month
- The growing season will start earlier and end later in the year, with an increase of 36.5 days
- A 9.6 mm increase in annual precipitation, with the summer seeing a 12.7 mm/yr decrease and the winter seeing a 3.8 mm increase (McKenney *et al.*, 2010)

While it is difficult to know the precise impacts at this point, predications include intesnse storms in fall and winter and lower precipitation during summer months; the potential for water shortages during the summer as demand exceeds supply; loss or damage to aquatic and terrestrial habitat; loss or damage to infrastructure; decreasing water quality; decreased opportunities for winter recreational activities; and crop damage, a modified gorwing season, and decrased effectiveness of herbicides and pesticides (. Changes in the way precipitation falls, both timing and intensity, are anticipated to impact the movement of pollutants through the watershed, particularly the amount of phosphorus that reaches Lake Simcoe.

Increasing annual temperatures have been observed in the watershed(Figure 3-2), but seasonal changes are not yet evident. The amount of winter precipitation falling as snow has decreased, a trend that will likely continue with rising temperatures (SGBLS SPC, 2011). This will likely have an impact on surface flow and groundwater recharge characteristics in the watershed. Long term analysis will be required to monitor changes in climate in this area.

LAND USE AND POPULATION



Much of the land within the Lake Simcoe watershed has changed dramatically, particularly since the arrival of European settlers in the early 1800s. The initial changes were mainly for agricultural uses, but the amount of urban land use has increased significantly over the past few decades. As can be seen in the image at right, of the land that has been altered in the watershed (Figure 3-4), the majority has been converted to rural/agriculture and urban land uses. The issues associated with these land uses, as well as their impacts on the watershed's natural systems, are discussed later in this chapter.

Over 400,000 people currently reside in the Lake Simcoe watershed. With the growth projected for the watershed's municipalities in the Province of Ontario's *Growth Plan for the Greater Horseshoe, 2006*, however, this population is anticipated to rise to over 600,000 people by 2031. While this plan strives to minimize the impact of population growth through such activities as intensification in existing urban areas, this population increase is bound to have impacts on the watershed's natural areas and resources. It will be important to implement best management practices in existing areas and ensure that new developments utilize Low Impact Development practices to mitigate these impacts to the extent possible.

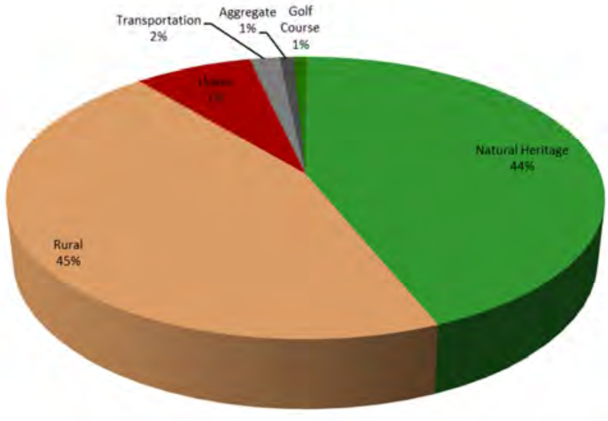


Figure 3-5: A breakdown of land uses in the Lake Simcoe watershed

As can be seen in Figure 3-5, there is a fairly high level of natural cover still remaining in the Lake Simcoe watershed (44% of the land use). This is a higher level than has previously been reported (38%), as the watershed boundary was expanded to include the lands within the Upper Talbot River subwatershed under the Lake Simcoe Protection Plan (LSPP). The Upper Talbot has a high level of natural heritage cover (over 80%), and its inclusion in the watershed boundary demonstrates how large concentrations of natural features in certain areas of the watershed can affect the watershed-wide percentage.

The LSPP sets a goal of 40% *high quality* natural heritage coverage. *High quality* has currently been defined in the LSPP as natural areas greater than 25 ha in size. These areas have been mapped by the Ministry of Natural Resources, and while 44% is a relatively healthy level of natural cover, many of these areas are in patches smaller than 25 ha, and would thus not be considered high quality. This highlights the importance of preserving existing natural features, and undertaking restoration efforts where possible in order to maintain watershed health.

URBAN LAND USE

The development of land for urban, industrial, and institutional uses is among the most drastic changes to a natural system. Levels of impervious cover increase as natural surfaces are covered in impervious concrete, asphalt, and roof tops. Watercourses are often altered to accommodate development and the majority of the vegetation in the riparian area is often removed, leaving narrow corridors. Forests, wetlands, and grasslands are often removed, filled in, or significantly reduced in size. These changes can have dramatic impacts on virtually all aspects of watershed health, and can be observed in the results of the monitoring work that is undertaken in the watershed. The evidence seen throughout the watershed includes:

- changes to the flows in urban watercourses, including shorter time to peak flows, higher peak flows and increased flow velocities, and decreased baseflow as little of the precipitation that falls percolates into the ground, but is instead forced to flow overland to storm drains and watercourses;
- degraded water quality due to contaminants being transported via overland flow including sediment, nutrients, metals, and chloride from winter salt; as well as decreased dissolved oxygen concentrations;
- changes to sediment transport, including bank erosion due to high flows, and sediment deposition as the velocity of the water slows and sediment drops out of suspension;
- changing temperature regimes, as water temperature tends to increase as it flows over impervious surfaces, particularly in the summer months; and
- changes to aquatic communities due to all of the above impacts.

Many of these impacts are demonstrated in the diagram below:

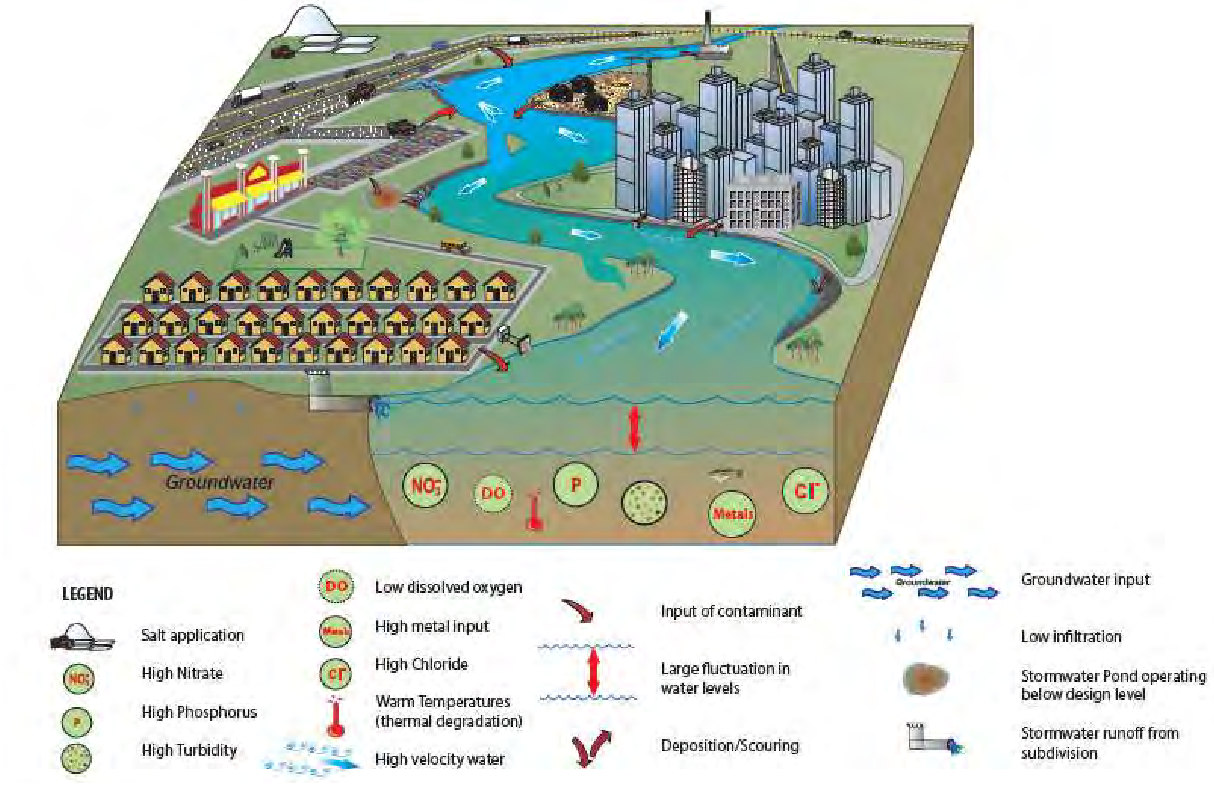


Figure 3-6: Potential impacts of urban land uses in a subwatershed

A number of activities have been and are currently being undertaken to help mitigate some of the issues discussed above. The Lake Simcoe Protection Plan contains several policies to address some of these concerns, including a number around treating stormwater, some around limiting the impacts of construction activities in new developments, requirements for monitoring of water quality in the watershed, and the completion of a Phosphorus Reduction Strategy, which was undertaken in 2009. In addition, the Lake Simcoe Conservation Authority continues to undertake works, both through its stewardship and science and research programs, including projects to mitigate bank erosion, working with municipalities to complete stormwater retrofits, assessing the effectiveness of existing and new technologies, and undertaking water quality monitoring to detect where water quality issues are occurring and see whether actions being undertaken to deal with these issues are successful. Subwatershed plans developed by the LSRCA and its partners also contain recommendations aimed at reducing the impacts of urban areas and making sure that new urban areas are built in a more environmentally sustainable manner; including the use of Low Impact Development practices, protecting and restoring sensitive habitats, minimizing impervious surfaces, the use of effective erosion and sediment controls during construction, and controlling the use of winter salt. The photos below (Figure 3-7) depict a project undertaken through the LSRCA's stewardship program to mitigate significant bank erosion and channel braiding and create a naturalized stream channel and fish habitat in an urban area.

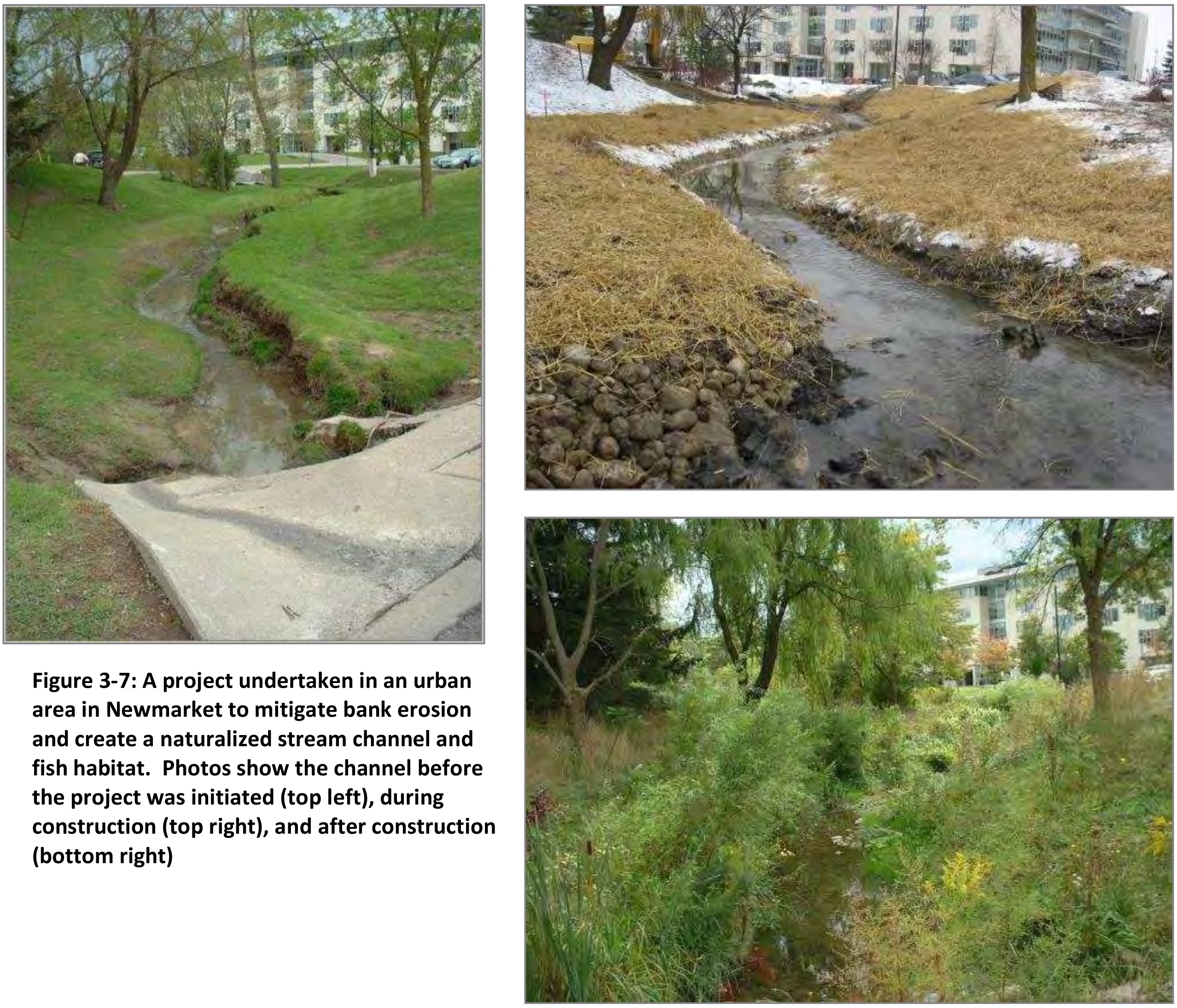


Figure 3-7: A project undertaken in an urban area in Newmarket to mitigate bank erosion and create a naturalized stream channel and fish habitat. Photos show the channel before the project was initiated (top left), during construction (top right), and after construction (bottom right)

SEWAGE TREATMENT PLANTS

Within the Lake Simcoe watershed there are 15 sewage treatment plants. All but one of these are municipal sewage treatment plants (STPs), the other is an industrial sewage treatment plant. The main contaminant of concern from these sources is phosphorus. Seven of these facilities discharge directly to the lake, the rest to its tributaries. These point sources contribute to the phosphorus load in the Lake Simcoe watershed, accounting for an average of 6% of the load to the lake in the 2004-2009 reporting period. The locations of these point sources are shown in the Figure 3-8.

With the growing population in the watershed, it will be necessary to utilize the most up-to-date technologies for removing phosphorus and other contaminants from wastewater in order to maintain and/or improve the water quality in the watershed.

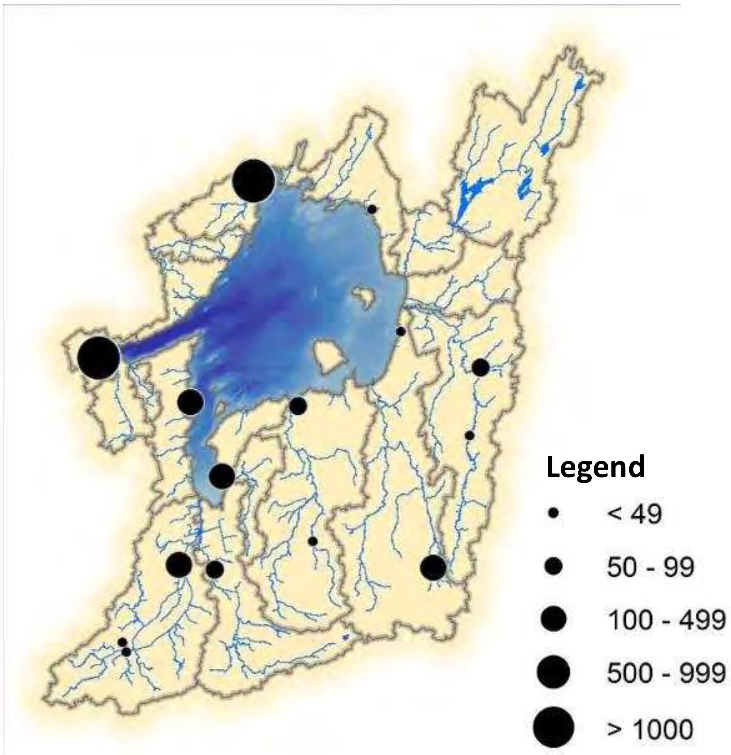


Figure 3-8: Phosphorus inputs from water pollution control plants in the Lake Simcoe watershed

In order to reduce the contribution to the phosphorus load from STPs an interim regulation, Ontario Regulation 60/08, was introduced under the Ontario Water Resources Act, to limit phosphorus loads from STPs to 7.3 tonnes/year, with a limit being set for each facility. The limits set in this regulation expired in 2010, and new phosphorus effluent limits and loading caps were introduced in the Province's Phosphorus Reduction Strategy, which was released in June of 2010. The Phosphorus Reduction Strategy established a baseline load for all STPs in the watershed of 7.2 tonnes/year (consistent with 7% of the annual phosphorus load, which was the estimated contribution from this source at the time the Strategy was published), which would be applied to each STP at its next expansion or by 2015, whichever occurs first. This is to give STP owners a reasonable timeframe to plan required upgrades or expansions. The Phosphorus Reduction Strategy states that 'to ensure that the STP contribution of phosphorus meets the whole-lake phosphorus-laoding goal for Lake Simcoe of 44 T/yr, their total load must be reduced to 7% of 44 T/yr, which works out to 3.2 T/yr.' Details around these further reductions will be determined after 2015.

AGRICULTURAL LAND USE

Close to half of the land within the Lake Simcoe watershed is used for agricultural purposes (Figure 3-9), including hay and pasture, cropland, and turf and sod operations. The removal of natural features to accommodate these uses, as well as the associated activities, causes a number of changes in a natural system. The impacts observed in the Lake Simcoe watershed include:

- Degraded water quality, due to the contribution of contaminants such as nutrients, sediment, pesticides, and, potentially, bacteria to watercourses. The sources of these contaminants include the erosion of exposed soils, particularly shortly after a fertilizer application; grazing of cattle; and bank erosion. This can lead to eutrophication of the waterbody and the deterioration of aquatic habitat;
- Channelized watercourses and the removal of their riparian vegetation to provide additional space for planting. This leaves little habitat value for aquatic communities, and removes the opportunity for the filtering of contaminants as runoff passes through the riparian area. In addition, watercourses are dammed in many areas to create water retention ponds, causing extensive changes to aquatic habitat;
- The presence of tile drains, which can impact the local hydrology – while they drain excess water from fields, they can also lower the water table, making less water available for wetlands. The size of ephemeral ponds, and the amount of time that they contain water can be significantly affected; these pond are critical for the survival of certain species of frogs, salamanders, and waterfowl.

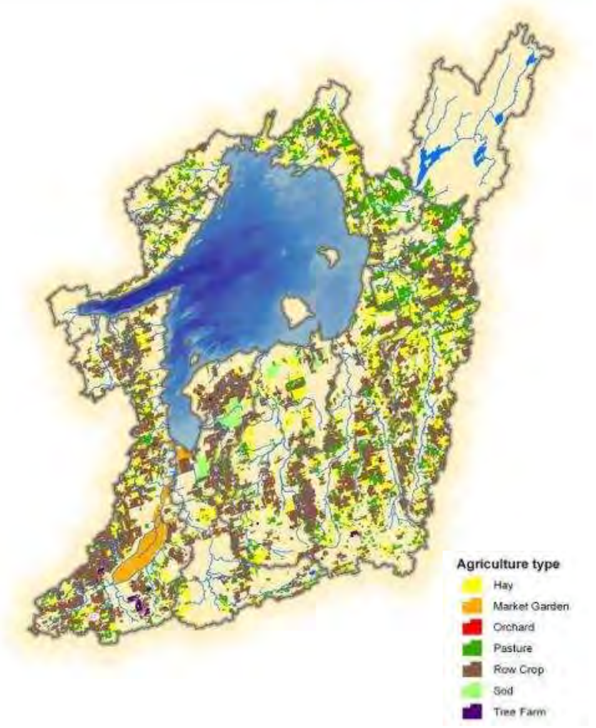


Figure 3-9: Distribution of agricultural land uses in the Lake Simcoe watershed

A number of these impacts are demonstrated in the diagram below:

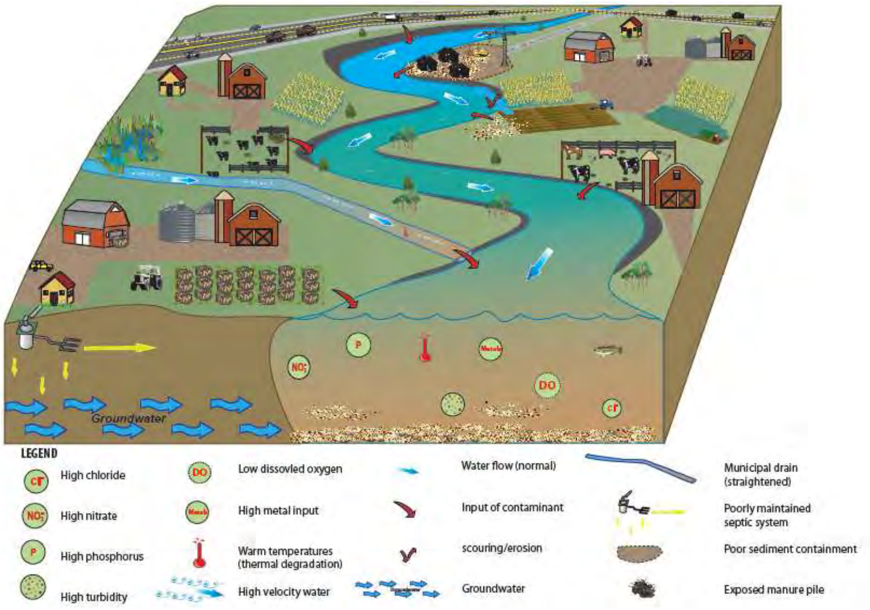


Figure 3-10: Potential impacts of agricultural practices on a watershed

Many activities have been undertaken around the watershed to reduce the impacts of agricultural activities; however, much remains to be done. The Lake Simcoe Protection Plan includes policies around agricultural impacts, such as that requiring the development of the Phosphorus Reduction Strategy, which deals in part with phosphorus inputs from agricultural sources; those around water conservation and efficiency; the development of a stewardship network; and the promotion of best management practices and pilot projects to promote new and innovative practices. A good deal of the work that has been undertaken by the LSRCA through the Landowner Environmental Assistance Program (LEAP) has been to undertake agricultural best management practices; these types of projects continue to be a prominent part of the LEAP. There are a number of other programs operating throughout the watershed that undertake similar works as well. The subwatershed plans that have been developed so far also contain a number of recommendations around agricultural practices; including those around prioritizing and implementing best management practices, leaving vegetated stream buffers intact and planting buffers where they have been removed, and naturalizing agricultural drains. Examples of stream buffer restoration in agricultural areas are shown in the Figure 3-11 below:

Figure 3-11: Riparian plantings undertaken in agricultural areas to mitigate bank erosion and prevent nutrients and sediment from reaching the watercourse

RECREATION

The Lake Simcoe watershed is home to a number of recreational activities, including boating, angling, swimming, hiking, cycling, golfing, birdwatching and snowmobiling (examples are shown in Figure 3-12). Many of these activities, if not managed correctly and undertaken in a responsible manner, can have negative effects on the natural system. These effects include the build-up of garbage and debris; impacts on water quality from the dumping of black or grey water and chemicals from boats; soil erosion, from boat wakes as well as from the improper construction and/or use of trails; loss of habitat; introduction and spread of invasive species; and inputs of nutrients and pesticides into watercourses. As natural areas diminish further and the population of the watershed grows, there will be ever more stress on the remaining natural areas as watershed residents seek recreational opportunities.

In contrast, the issues being seen in the watershed can also have an effect on the quality of recreation activities. Excessive growth of plants and algae, as well as zebra mussels, in the lake affects swimming and boating activities; invasive species can affect hiking trails and fishing experiences; water quality and quantity issues have an impact on fish communities; and so on.

Figure 3-12: Common recreational activities in the Lake Simcoe watershed

INVASIVE SPECIES

Native systems have a natural balance of trophic levels and many species interacting, each fulfilling a specific role within the system. The introduction of non-native species disrupts this natural balance, often with profound impacts. This is due in part to the physiological characteristics of many non-native species that become invasive, as well as the inability of the natural system to cope with the changes. The characteristics that make these species invasive include: prolific, often frequent reproduction; fast growth; the ability to disperse easily; and a tendency to be habitat generalists, easily able to adapt and thrive in a wide variety of environmental conditions. They take advantage of stresses in the native ecosystem, including disturbances such as urbanization, agriculture, contaminant inputs, recreational trails, and roads. As they are less robust, these native systems and the species that live within them are not as able to sustain themselves in the face of increased competition for resources by the invading species, and are eventually replaced by the invading species. Where they successfully colonize, invasive species tend to decrease biodiversity, and can impact the entire system, as they generally have few if any predators; and the species that depend on the native species that is replaced will also suffer. This pattern can reverberate throughout the system, causing major shifts in community composition, and can be exacerbated with the introduction of multiple invasive species in a short period.

The extent of terrestrial invasive species in the Lake Simcoe watershed is not well known; however, aquatic invasive species are quite well tracked through the aquatic monitoring program. Species commonly found are shown in Figure 3-13.

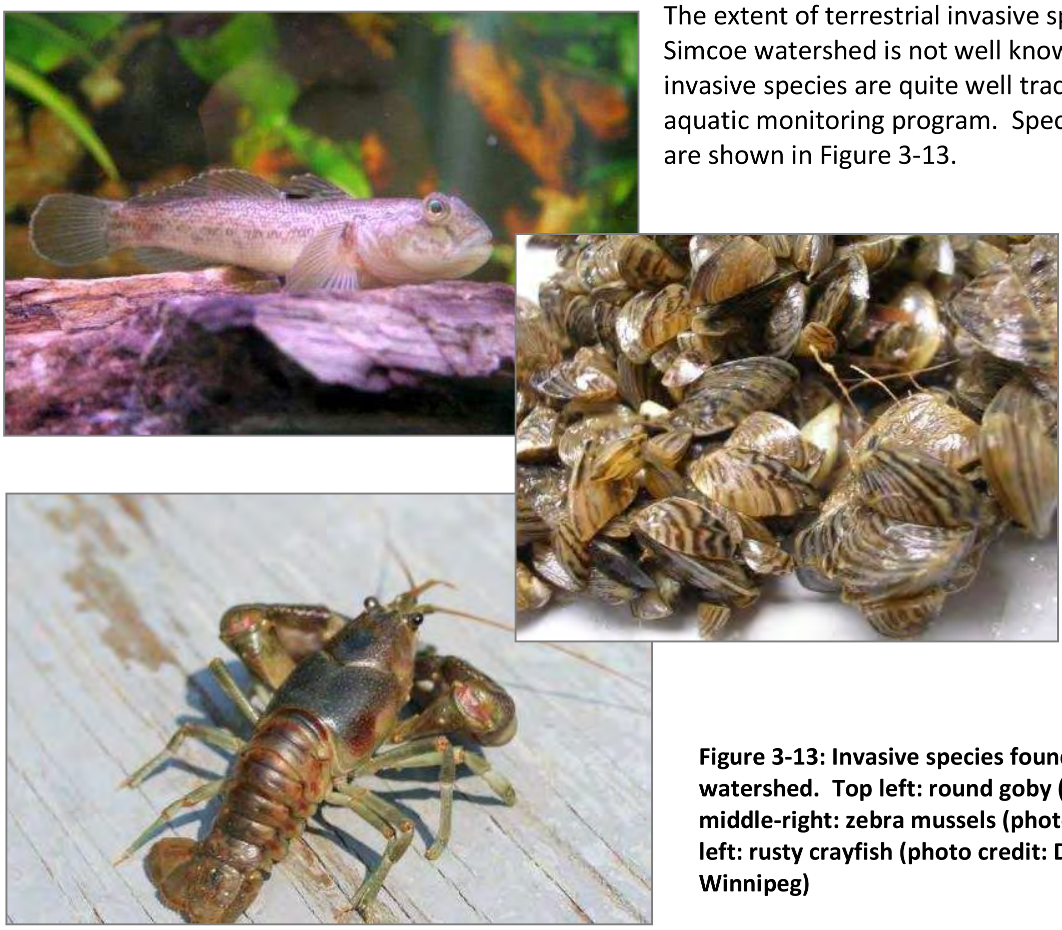


Figure 3-13: Invasive species found in the Lake Simcoe watershed. Top left: round goby (photo credit: Matt Vardy); middle-right: zebra mussels (photo credit: LSRCA); bottom left: rusty crayfish (photo credit: Doug Watkinson, DFO, Winnipeg)

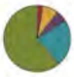
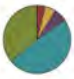
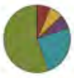
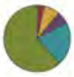
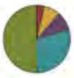
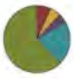
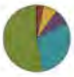
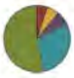
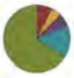
PHOSPHORUS LOADS

Information presented in this chapter is based on the report *'Annual Water Balances and Total Phosphorus Loads to Lake Simcoe (2007-2009)'* released by LSRCA and the Ministry of theEnvironment in 2013.

What is phosphorus loading?

The total amount of phosphorus that gets carried into Lake Simcoe is called the phosphorus load. This is expressed in metric tonnes or in kilograms (1 tonne = 1,000 kg), and is measured over a hydrological year. A hydrological year goes from June 1st to May 31st, for example, the 2009 hydrological year is from June 1, 2009 to May 31, 2010. It is important to measure how much phosphorus is going into the lake in order to understand and address the problems associated with it. Phosphorus is measured from five main sources in order to calculate the annual load, these include tributaries, polders, sewage treatment plants (STPs), septic systems and atmospheric deposition (Figure 4-1, Table 4-1).

Table 4-1: Total phosphorus loads for the years 1998-2009, and the relative contribution from the measured sources

Year	Load by source	Total TP load (tonnes)	Year	Load by source	Total TP load (tonnes)
1998		66	2004		77
1999		77	2005		74
2000		72	2006		71
2001		54	2007		97
2002		68	2008		116
2003		73	2009		72

Phosphorus source

🟥 Polders	🟦 Atmospheric
🟨 STPs	🟩 Tributaries
🟪 Septics	

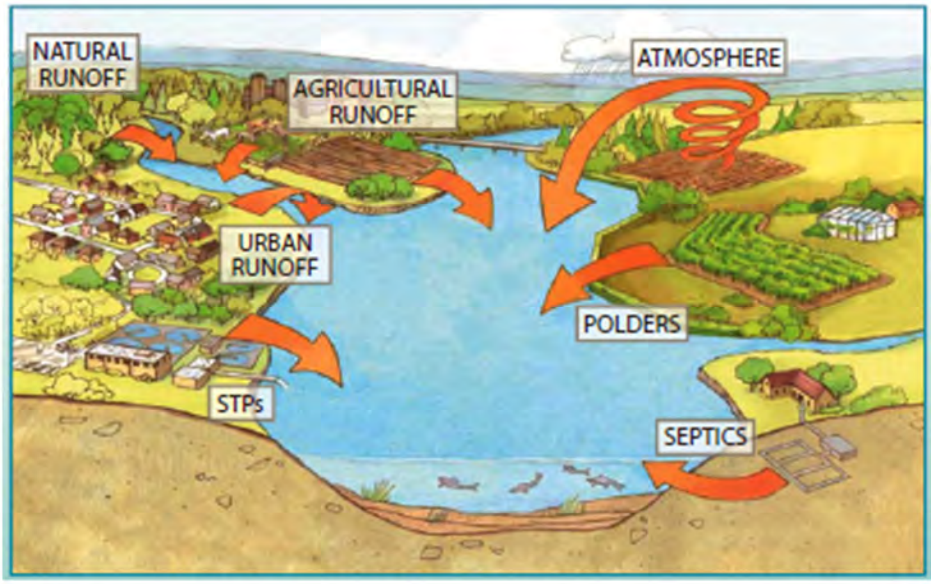


Figure 4-1: Sources of phosphorus loading in the Lake Simcoe watershed

Phosphorus loading to Lake Simcoe

The estimated annual total phosphorus loads to Lake Simcoe for the most recent reporting period (2007 to 2009) range from 71.9 to 115.5 tonnes per year. The largest source was from tributaries, ranging from 47.4 to 80.6 tonnes per year.

The amount of phosphorus loading to the lake changes from year to year (Figure 4-2). Changes in land use and the climate, for example, will influence the amount of phosphorus loading.

Loads from tributaries are most affected by yearly fluctuations in climate. This was very apparent in the 2007 and 2008 hydrological years, when water flows were greater than normal (Figure 4-2). In 2007, the winter and spring flows in particular were very high, and 2008 was almost twice as wet compared to the 1990-2006 average annual tributary flow. Based on records going all the way back to 1969, the 2008 hydrologic year was the wettest year by far (see Water Quantity section for more detail).

These very high flows in 2007 and 2008 were the main reason that loads were higher in these years. In 2009, when loads returned to similar levels seen in 2006 and earlier, tributary flow was also more typical.

Total phosphorus loading

Hydrological Year	Tonnes/Year
2007	97.4
2008	115.5
2009	71.9

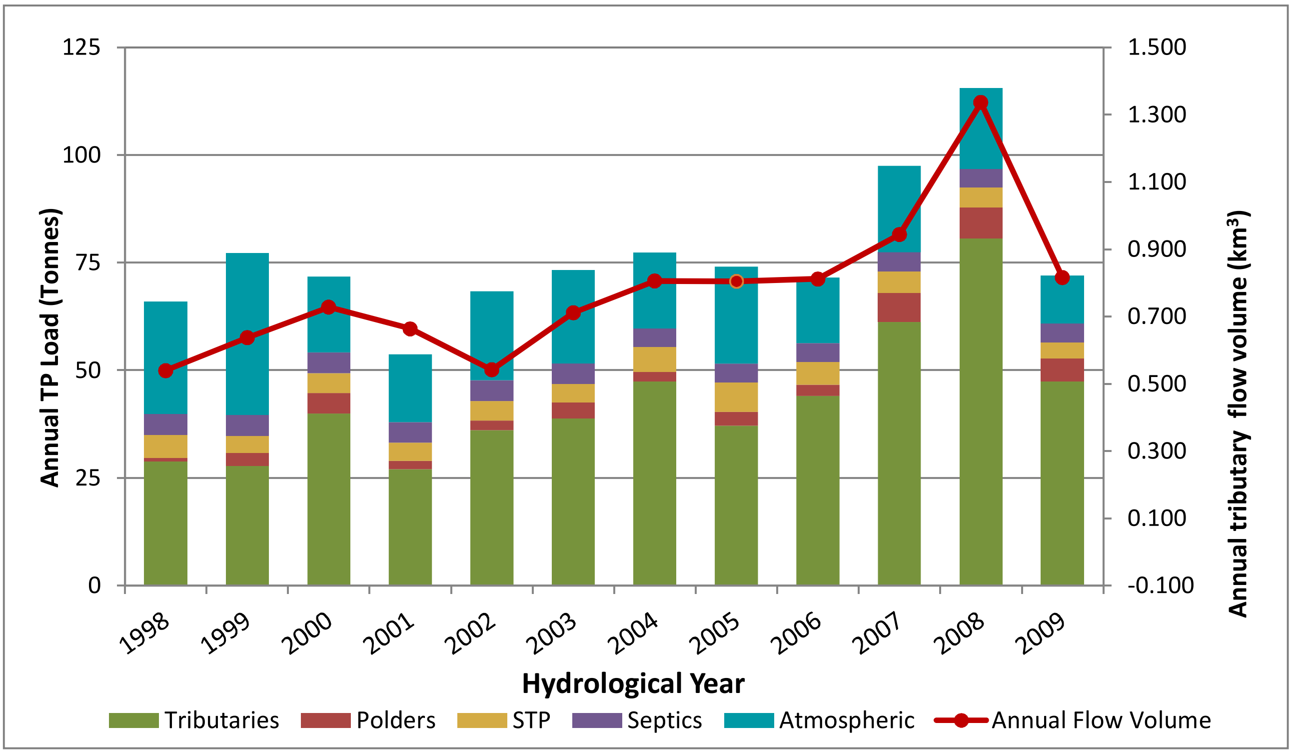


Figure 4-2: Annual phosphorus loads and annual flow volume, 1998-2009, highlighting the most recent period of record (2007-2009)

The phosphorus loads are presented in Figure 4-3 below in two ways: average annual total load by subwatershed and average annual phosphorus export rate by subwatershed for the 2007 to 2009 hydrologic years. The phosphorus export rate is calculated as the phosphorus load divided by the land area. These two ways of representing the data help us to understand how land use and subwatershed size affect phosphorus loading.

The highest phosphorus loads occur in the West and East Holland River subwatersheds; on average the loadings are 14.5 and 12.9 tonnes per year, respectively. The reason these have the highest loads are that they are large subwatersheds that are heavily urbanized or highly agricultural and also have high flow volumes. Barrie Creeks had the highest export rate at 109 kilograms per square kilometres per year. It is also a heavily urbanized subwatershed.

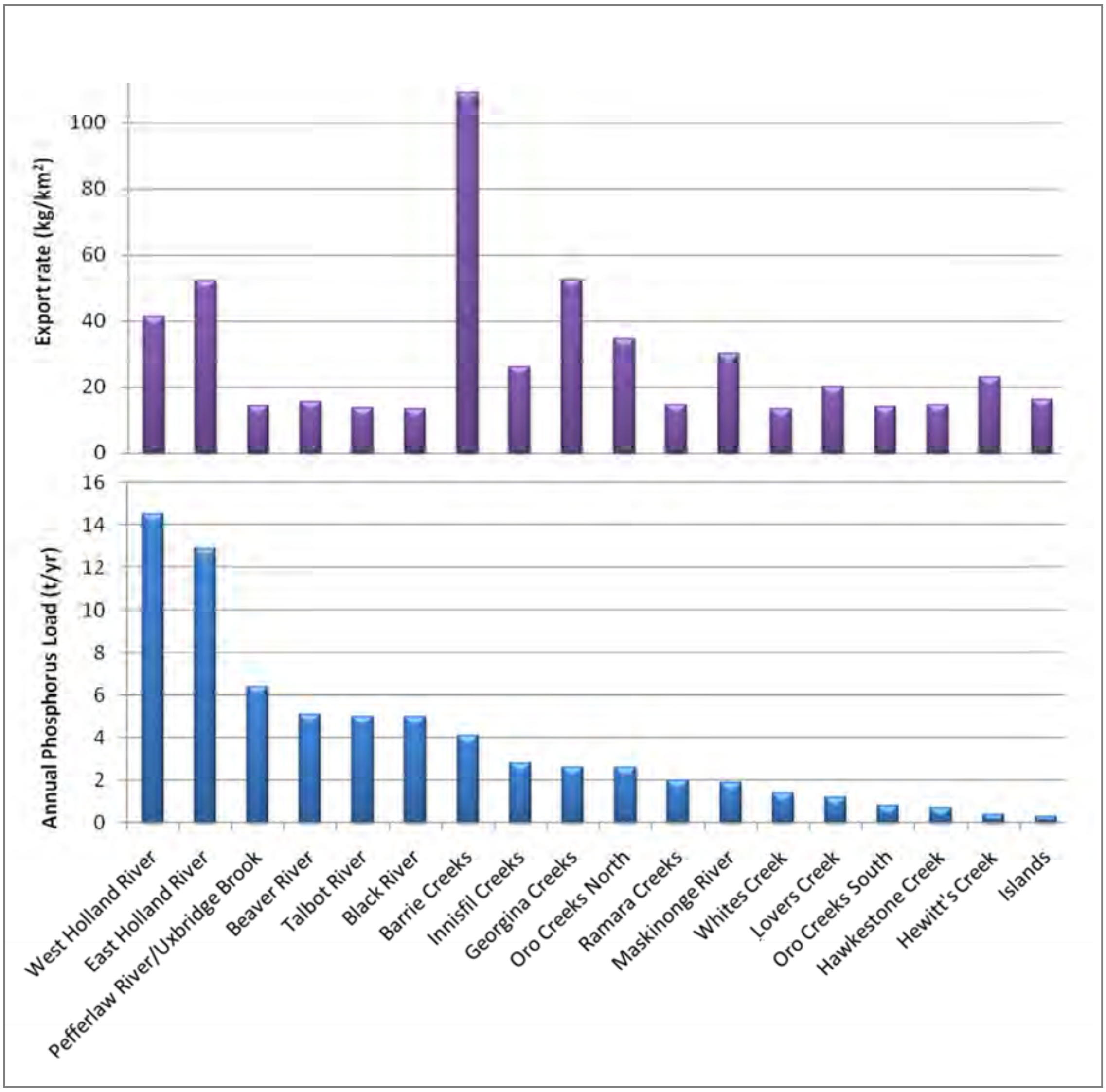


Figure 4-3: Phosphorus loads and export rates for each subwatershed

Sources of Phosphorus

Tributary load

Total tributary loading	
Hydrological Year	Tonnes/Year
2007	61.2
2008	80.6
2009	47.4

When water from rain or melted snow flows over land, it can pick up dirt, dust, oil, salt, fertilizers, manure, animal waste, and detergents. These particles, which can contain phosphorus, are washed into creeks and rivers, and eventually into the lake. Creeks and rivers — referred to as tributaries — collect phosphorus from urban, agricultural and natural areas. Phosphorus can also be deposited directly on tributaries from the atmosphere.

For the purposes of understanding phosphorus loads, each tributary subwatershed is divided into urban and non-urban areas. In urban areas, the main source of phosphorus is stormwater runoff. Sewage treatment plants, which are located in urban areas, are accounted for separately. In non-urban areas, phosphorus comes from agricultural and natural/other areas.

A. What is measured?

In order to estimate how much phosphorus is entering Lake Simcoe through the tributaries, flow and phosphorus concentration are monitored. Phosphorus is measured in many of the tributaries throughout the watershed (referred to as monitored subwatersheds). Tributaries where phosphorus is not monitored are referred to as unmonitored subwatersheds and islands (Figure 4-4).

Monitored subwatersheds

In monitored subwatersheds, phosphorus samples are collected year round; winter months are sampled less frequently, and extra sampling is carried out during periods of heavy rain and in the spring when the snow melts (see Tributary Water Quality in the Methods section for more details). These data are used to determine loadings for all areas upstream of the monitoring stations, including urban and non-urban areas.

For areas downstream from the monitoring stations, since no further samples are taken, phosphorus must be estimated based on other sources of information. For urban areas, stormwater loading rates are estimated based on the Ministry of the Environment Storm Water Analysis and Monitoring Program. For non-urban areas, estimates are based on upstream measurements.

Unmonitored subwatersheds and islands

Loads from unmonitored subwatersheds and islands need to be included in the total load to the lake. Phosphorus loads for unmonitored areas are therefore estimated based on loads in monitored areas most similar in land use.

Please refer to Figure 4-4 below to view the monitored and unmonitored subwatersheds for the 2007–2009 reporting period.

B. Why is tributary load an important factor?

Urban areas

The lake, which for some time has been showing signs of damage from human activities, is under increasing stress due to urban growth. Currently, seven percent of the watershed is urban. Urban development changes the land from natural, porous surfaces like soil and grasses to hard surfaces like pavement and asphalt. Rainwater and snow melt cannot seep into the ground naturally, so the stormwater runs over the hard surfaces and washes into creeks, rivers, and eventually the lake. Stormwater runoff can also increase erosion in streams causing dirt and debris to be carried downstream.

Agricultural areas

Currently, 45 per cent of the Lake Simcoe watershed is made up of agricultural areas, including a variety of crops, livestock, and vegetable farming. Rainfall and melting snow cause water to run over the ground in agricultural areas, picking up fertilizers and contaminants from feedlots, manure storage, and bare fields. Factors that can increase the phosphorus loads from agricultural sources include poorly located or managed animal feeding operations; overgrazing; plowing too often or at the wrong time; and improper, excessive, or poorly timed application of irrigation water and fertilizers.

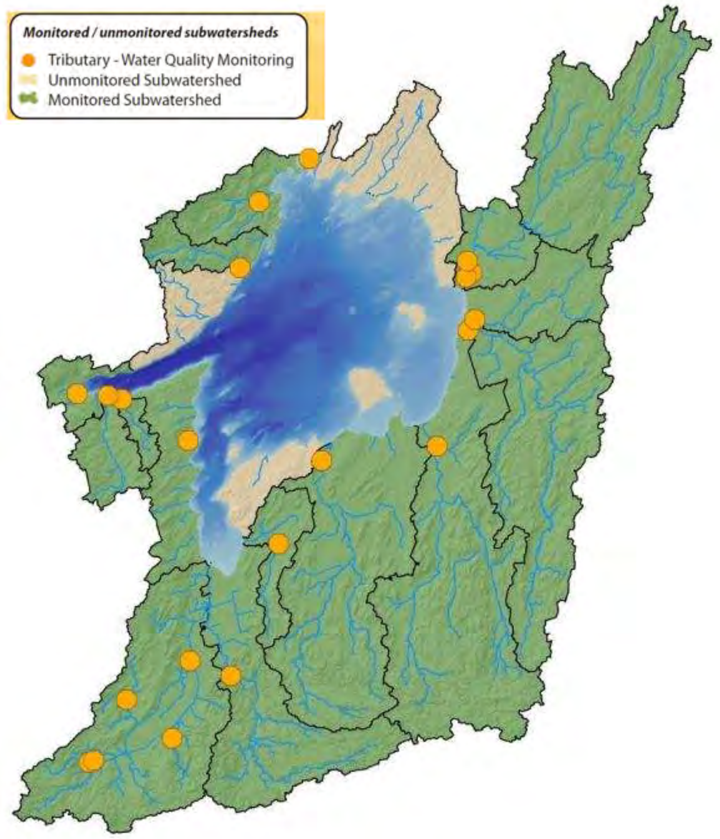


Figure 4-4: Monitored and unmonitored subwatersheds (coloured green and beige, respectively) and water quality monitoring stations

C. What is being done?

In the past, it was common practice to channel stormwater directly into streams, rivers, or the lake without treating it. Recent efforts have been made to intercept and treat stormwater, although in some older urban areas stormwater still reaches waterways untreated. The LSRCA and MOE, in partnership with municipalities and the development community, have identified opportunities where municipal stormwater facilities could be introduced or upgraded to improve overall treatment and phosphorus removal. As well, we are promoting the use of Low Impact Development (LID). LID is a term used to describe stormwater management techniques that mimic the natural flow of water as it infiltrates into the soil. This minimizes the impact of urban development by reducing the volume of stormwater runoff as well as potential pollutants the runoff may carry.

Farmers and other land owners have been working with the LSRCA and the provincial government to reduce phosphorus loading to Lake Simcoe by implementing agricultural best management practices. Examples of this are appropriate manure and fertilizer storage and application, and planting of cover crops and windbreaks. Information about current programs to help offset the costs of implementing measures to further reduce phosphorus inputs to the lake is available online at www.lsrca.on.ca and www.ontario.ca\lakesimcoe.

Polders

Total polder loading	
Hydrological Year	Tonnes/Year
2007	6.8
2008	7.2
2009	5.3

Polders are drained wetlands used for agriculture. Pump-off water from polders is also a source of phosphorus to rivers downstream. The watershed's five polders (the Keswick, Colbar, Bradford, Deerhurst, and Holland marshes) are former wetlands that were drained so that the rich soils could be used for agriculture.

A. What is measured?

Samples are collected at the outlet of the Holland Marsh as part of our regular sampling routine. These data are used to estimate loadings from the Holland Marsh, which are then used in calculations to estimate phosphorus loadings from the other polders. The estimated loads from the polders are shown in the table at the right.

B. Why are polders an important factor?

Water levels in the polders are controlled by a series of pumps and canals. Because polders are low-lying, excess water accumulates and must be pumped off. Pump-off water is generally very high in phosphorus from fertilizers, and the load from this source is greater in years with high rain and snowfall because more water has to be pumped off the fields.

C. What is being done?

Options are currently being investigated to find cost-effective ways to promote and implement agricultural best management practices. These include reducing the application of fertilizer and investigating the feasibility of treating pump-off water from the Holland Marsh.

Sewage treatment plants (STPs)

Municipalities operate sewage treatment plants (STPs) that process our sewage before disposing of it into the lake or to rivers flowing into the lake. Although the sewage is treated to a high standard, it still contains phosphorus.

Total STP loading

Hydrological Year	Tonnes/Year
2007	5.0
2008	4.6
2009	3.7

A. What is measured?

There are 14 municipal and one industrial sewage treatment plants (STPs) in the Lake Simcoe watershed, all of which are operating at a level that meets or is better than regulatory standards. Seven of the plants discharge directly into Lake Simcoe while the other eight discharge into watercourses that eventually drain into the lake. Sewage effluent is monitored from these facilities to ensure it meets criteria defined by the province. The estimated loads from the STPs are shown in the table at the right.

B. Why are STPs an important factor?

One consequence of a growing population is the need to provide sanitary services and potable water to the people living within the community. When water from toilets, sinks, washing machines, etc. runs down the drain, it goes to an STP where it is treated and then discharged into the lake or a river. With a watershed population in excess of 400,000, municipal STPs are handling a very large amount of water. Although the discharge is treated to a high standard, it still contains phosphorus.

C. What is being done?

The STPs in the Lake Simcoe watershed are among the most effective in Ontario at removing phosphorus. In March 2008, interim limits were placed on STPs around Lake Simcoe to help protect water quality. In 2010, under the Phosphorus Reduction Strategy, baseline phosphorus effluent concentrations (limits) and loading caps were established for each STP. In June 2012, the Environmental Compliance Approvals for all of the STPs were amended to include the new phosphorus limits and loads. These replaced the historical phosphorus caps and the limits from the interim regulation. The new requirements are to be met by 2015 or by the next expansion, whichever comes first.

Septic Systems

Septic systems, in particular those that are located in close proximity to the lake and watercourses and are faulty, improperly sized, or poorly maintained, are a potential source of phosphorus to rivers and lakes downstream.

Total septics loading

Hydrological Year	Tonnes/Year
2007	4.4
2008	4.4
2009	4.4

A. What is measured?

A significant amount of phosphorus from toilets, sinks and washing machines flows through private septic systems. This section includes those adjacent to the lake. Others are captured in the tributary loads, described above. The estimated loads from septic systems adjacent to the lake are shown in the table at right.

B. Why are septic systems an important factor?

Discharge from a residential septic tank is rich in phosphorus. It is normally dispersed by the drainage tiles and absorbed into the ground where contaminants decompose. However, if soil conditions are poor, phosphorus can be picked up by surface water and carried into the lake. Also, many cottages are now being used year-round and the original septic systems in place may not be designed to properly handle this greater use.

C. What is being done?

Effective January 2, 2011, the Ontario Building Code Act was amended to require a mandatory maintenance inspection, within five years, for all sewage systems within 100 metres of the Lake Simcoe shoreline. On January 1, 2016, this mandatory inspection will also apply to sewage systems within 100 metres of any river or stream in the Lake Simcoe watershed. This phased approach targets priority areas within the watershed.

The LSRCA provides financial assistance through its Landowner Environmental Assistance Program (LEAP) to help property owners upgrade their septic systems.

Atmosphere

Phosphorus is carried in the atmosphere and is deposited directly onto the lake in rain, snow, or dust. The phosphorus comes from sources many miles away and from closer to the lake. Sources include dust from land disturbed by agriculture, unpaved roads, and aggregate operations, as well as soil that has been left bare by construction.

Total atmosphere loading

Hydrological Year	Tonnes/Year
2007	20.1
2008	18.7
2009	11.1

A. What is measured?

In order to measure how much phosphorus is entering Lake Simcoe from the atmosphere, samples are collected at precipitation collectors throughout the watershed. The collectors capture "wet and dry" deposition, including phosphorus in the rain and snow (wet) and the phosphorus attached to soil and dust particles deposited on the collectors (dry). Samples are analyzed for phosphorus and then loads are calculated by multiplying the phosphorus concentration in the sample by the amount of precipitation. The estimated loads from the atmosphere are shown in the table at right.

B. Why are atmospheric sources an important factor?

Atmospheric phosphorus comes from natural sources like pollen, human sources like the burning of fossil fuels, and through wind transport of disturbed soils. When land is stripped of vegetative cover for uses such as construction, aggregate operations, unpaved roads, or bare fields between crops, wind blows the soil away. Pollutants (including phosphorus in various forms) become airborne and eventually fall to the surface.

C. What is being done?

Windborne dust is an important source of the phosphorus load from the atmosphere. Because these particles are carried in the air, they can come from many kilometres outside the Lake Simcoe watershed. Studies on windborne sources of phosphorus are underway. Preliminary results indicate that the primary source of dust is soil erosion as a result of agricultural practices. Dust also comes from unpaved roads, aggregate operations and construction sites. Best practices to control soil erosion and excess dust include adopting and enforcing soil conservation by-laws, preserving existing vegetation, and controlling the speed of traffic over unpaved roads. In the agricultural sector, best practices include leaving soil intact instead of turning it over (no-till techniques), planting windbreaks, leaving un-harvested plant material on the field, and using cover crops to hold the soil in place.

PROGRAM OVERVIEW

As was described in Chapter 2, the LSRCA has been monitoring the nearshore areas of Lake Simcoe since 2008. The nearshore zone is the area between zero and 20 metres in depth, and encompasses 67% of the lake area. This work has included monitoring of the physical characteristics, such as clarity, temperature, and the dissolved oxygen content of the water; the chemical characteristics of the water and sediment; and the biological community, including the composition and distribution of aquatic plants and benthic invertebrates, as well as tracking the spread of invasive species such as zebra and quagga mussels.

The nearshore monitoring program has addressed a previous monitoring gap in the Lake Simcoe watershed. Prior to the initiation of the program, the watercourses draining into Lake Simcoe and the pelagic zone of the lake itself were well monitored by the LSRCA and MOE. However, we have since learned that the nearshore zone responds earlier and much differently to environmental changes than other areas of the watershed, and is impacted by changes in both the aquatic and terrestrial environments , including zebra mussel colonization, changes to nutrient inputs and surface water runoff, the removal of terrestrial natural vegetative cover and other land use changes, the loss of habitat due to shoreline hardening, and the loss of species diversity.The nearshore program aims to complement existing monitoring that is undertaken in other areas of the watershed to formulate a complete picture of watershed health.

Figure 5-1: ***R/V Ouentironk*****, LSRCA's lake research vessel**

PHYSICAL MONITORING

WATER CLARITY

The depth to which sunlight penetrates into Lake Simcoe greatly affects a variety of lake processes: the depth of the upper, warmer, epilimnion (the upper layer of a waterbody when it becomes stratified in the summer months); mixing of the water column; primary production by plants and algae; cycling of nutrients; the maximum depth and area of plant colonization; and length of the ice-free, or open-water, season. The primary measure of water clarity, or transparency, is the depth to which an observer can see a Secchi disk suspended in the water column.

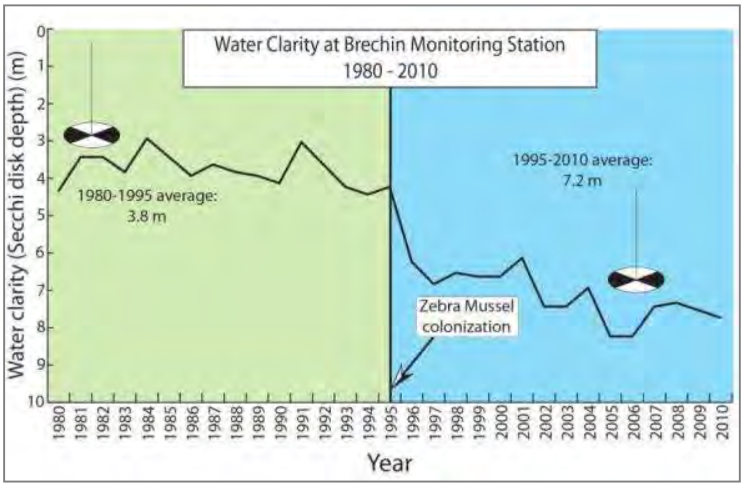


Figure 5-2: Water clarity at Brechin (data from MOE and LSRCA)

In most nutrient-rich lakes, the water column is turbid and green in colour due to suspended particles and algae abundantly growing in the presence of excess phosphorus. Due to scattering by these algae and particles, sunlight cannot penetrate very far into the water column, and a shallow Secchi depth is recorded; aquatic plants are restricted to relatively shallow depths in these lakes. In Lake Simcoe, Secchi depth records from 1980 to 1995 are relatively shallow (for example at Brechin the mean depth was 3.8 m) and lake users report the water having a green colour. Since 1995, Secchi disk depth has averaged 7.2 m with maxima of 9-10 m (Figure 5-2). A contributor to this increase in water clarity was invasion by zebra mussels (*Dreissena polymorpha*) which, due to their high rate of filtering water and removing particles, increased the transparency of the water column. As a demonstration (Figure 5-3), two 4L jars were filled with water from the Holland River (which does not have a population of zebra mussels and therefore still has turbid water): the jar on the right shows the turbid green of river water, the jar on the left shows an identical water sample 20 minutes after a small handful of zebra mussels was added to the jar. While phosphorus loads to Lake Simcoe have shown modest declines in response to lake management plans, the lake remains nutrient rich. As algae and particles are quickly removed from the water column, aquatic plants have made use of available phosphorus and increased light transparency to increase their abundance and area of habitats.

Figure 5-3: A demonstration of the filtering capacity of zebra mussels: two jars were filled with water from the Holland River (which does not have zebra mussels, and therefore still has water which is turbid and green in colour). A handful of zebra mussels was deposited into the jar on the left 20 minutes prior to this photo being taken.

TEMPERATURE

Lake Simcoe exhibits typical seasonal temperature patterns for a temperate region lake. Kempenfelt Bay is dimictic and strongly stratified; whereas Cook's Bay and the main basin are weakly stratified and polymictic due to wind action. As with the Great Lakes and other aquatic systems, Lake Simcoe is being affected by climate change. Since the start of monitoring by MOE in 1980, Lake Simcoe has experienced an earlier onset of water column stratification in spring and a later onset of fall overturn which has resulted in a longer ice-free period (an increase of a month when comparing 2008 to 1980). Similarly, the period of ice cover on Lake Simcoe has been steadily decreasing from a five-year running average of 118 days (1853-1900) to 76 days (2000-2013). The five years of longest ice cover were all prior to 1900: 1857 and 1870 (140 days), 1881 (139 days), 1861 (132 days), and 1867 (131 days, tied with 1931). The five years with shortest ice cover have all been since 2000: 2000 and 2010 (71 days), 2009 (70 days), 2002 (34 days), and 2012 (0 days) the first time since record keeping began (1853) that Lake Simcoe did not entirely freeze over (http://www.naturewatch.ca/english/icewatch/). These changes are being reflected in biological communities such as pelagic (open-water) diatom species which, since the 1990s, have been dominated by species which thrive under longer periods of lake stratification.

DISSOLVED OXYGEN

Since historic lows in dissolved oxygen starting in the 1950s, indicated by the collapse of recruitment in coldwater fish species (lake trout, lake whitefish, lake herring), and recorded anoxia in the 1980s, the concentration of deepwater dissolved oxygen in Lake Simcoe has improved dramatically in response to lake management strategies. Improvements in the health and sustainability of the coldwater fish community and the natural recruitment of lake trout are evidence of this positive trend in dissolved oxygen. While isolated events of low deepwater dissolved oxygen continue to occur, predominantly in fall, these events are less frequent and of shorter duration.

The nearshore zone of Lake Simcoe experiences a greater variation in dissolved oxygen. Our monitoring data in Cook's Bay records a daily cycle during summer with the water column being supersaturated by oxygen during daylight (from plant and algae photosynthesis) and a rapid decline to hypoxic or anoxic conditions after sunset (due to plant respiration).

WATER CHEMISTRY

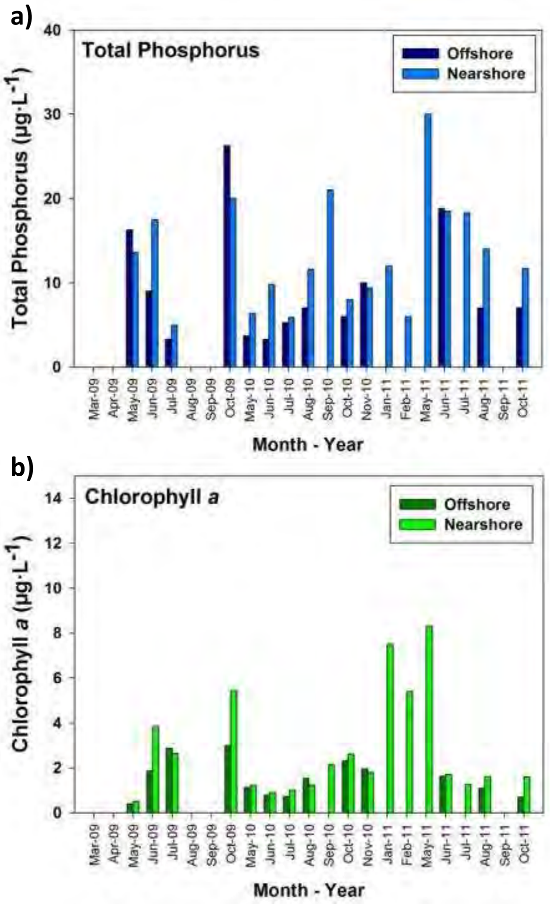


Figure 5-4: Concentrations of total phosphorus (a) and chlorophyll *a* (b) in the open water and nearshore zones of Lake Simcoe (LSRCA data)

<u>Water column total phosphorus:</u> Total phosphorus data show fluctuations based on annual lake processes (e.g. seasonal changes in algae and plant biomass which use and release nutrients) and supply to the lake (e.g. precipitation and inflow from tributaries). Overall, the nearshore zone of Lake Simcoe has a higher total phosphorus concentration than open-water areas (Fig. 5-4a) due to terrestrial-source inputs and retention by aquatic plants and zebra mussel cycling. Total phosphorus in the nearshore zone also shows more variation than in the open-water, as the nearshore is more influenced by individual precipitation events, whereas the open-water zone shows slower cycles more influenced by seasonal climate patterns. Lake-wide, total phosphorus concentrations have remained relatively stable since the spike seen in the wetter year of 2009, but have shown declines since the 1980s, particularly in Cook's Bay, where the MOE reported mean total phosphorus in 1980 was ~ 35 µg/L, compared to our records of 15-20 µg/L in 2008.

<u>Water column chlorophyll *a*:</u> Chlorophyll *a* is a pigment produced by algae (and other plants) and is a key component of photosynthesis, which converts sunlight and carbon dioxide to oxygen. The concentration of chlorophyll *a* in the water is an indicator of how much algae is present. In Lake Simcoe, chlorophyll *a* concentrations are low, compared to other lakes with similar phosphorus concentrations, as algae are consumed by zebra mussels. As expected with relatively higher total phosphorus concentrations, the nearshore zone has a relatively higher algal biomass than open-water areas (Fig. 5-4b). Due to reduced on-ice snow cover in winter 2010-11, the increased nearshore chlorophyll *a* records an under ice algal bloom.

SEDIMENT CHEMISTRY (TOTAL PHOSPHORUS)

Sediment phosphorus varies considerably across Lake Simcoe with high values being recorded near nutrient inputs at Barrie, as well as the Black, Beaver, and Talbot River subwatersheds. A high value of 1400 $\mu g \cdot g^{-1}$(or parts per million) was recorded along the eastern shoreline in the vicinity of the outlets of the Beaver and Talbot Rivers. Of particular interest are the very low sediment total phosphorus values recorded in southern Cook's Bay (340 $\mu g \cdot g^{-1}$) near the highest nutrient inputs from the Holland River. While one would expect this area to have the highest sediment TP concentrations, this area also has Lake Simcoe's highest biomass of aquatic plants (Figure 5-5), which obtain up to 97% of their nutrients from lake sediments.

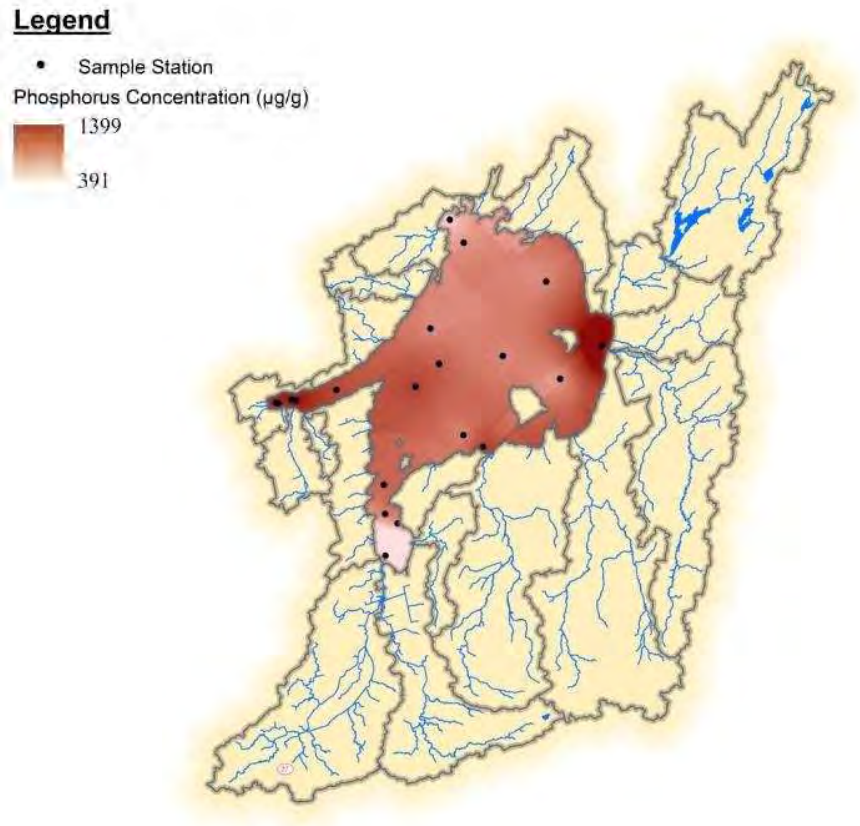


Figure 5-5: Distribution of sediment phosphorus concentrations in the nearshore are of Lake Simcoe (LSRCA data)

BIOLOGICAL MONITORING - AQUATIC MACROPHYTES

Studies to determine the biomass of Lake Simcoe's aquatic macrophytes were first undertaken in 1971, with additional studies occurring in 1984, 1987, and 2006. However, the most detailed of these studies (1984, 1987, 2006) focused only on Cook's Bay. The LSRCA began its surveys in 2008, a study which covered the entire lake, encompassing over 200 sites along the nearshore. The study results documented 20 species of submerged and floating macrophytes found in the lake, and also recorded several areas of high plant biomass in the lake, as depicted in dark green on the map at right (Fig. 5-6).

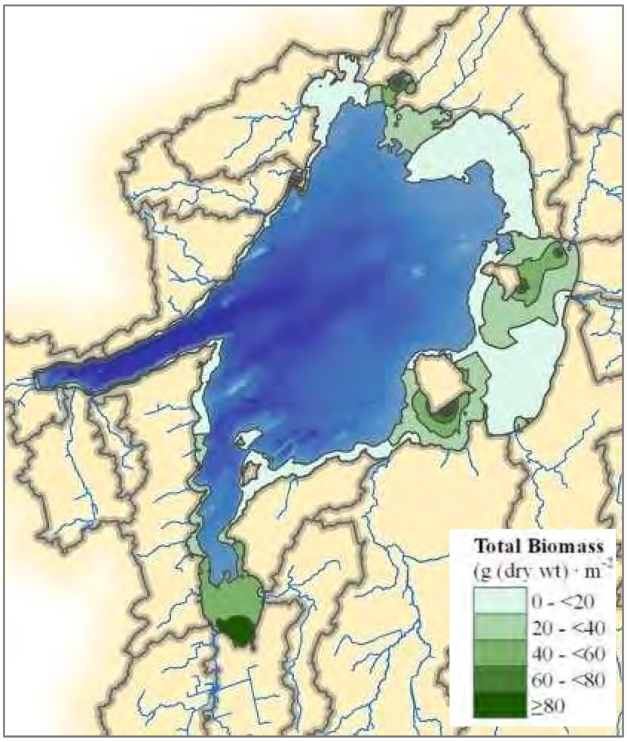


Figure 5-6: Plant biomass in Lake Simcoe's nearshore (LSRCA data)

The five most abundant species (by weight, accounting for over 90% of the plant biomass) found in the lake were:

- *Ceratophyllum demersum* (coontail), at 34.5% of the total plant biomass
- *Myriophyllum spicatum* (Eurasian watermilfoil, an invasive species), 21%
- *Chara* spp. (muskgrass), 19.5%
- *Zosterella dubia* (water stargrass), 10.5%
- *Elodea* spp. (waterweed), 5%

The various species of plants tended to occupy specific areas of the available habitat. Shallow areas (less than 3.5 m deep) were dominated by *M. spicatum* on silt substrates or a combination of *M. spicatum* and *Chara* spp. on sandy substrates. *M. spicatum*'s dominance at these depths is likely due to its high light requirement, high photosynthetic and growth rates, rapid dispersal through fragmentation, rapid uptake of sediment nutrients, and ability to outcompete other shallow water species by shading the substrate with thick canopies. *M. spicatum* is replaced at sites deeper than 3.5 m by *C. demersum*, which is more tolerant of low light levels, and therefore tends to be dominant at these depths. Plants were not found at depths greater than 10.5 m.

Likely reasons that high levels of plant biomass were observed at certain sites include: (1) shelter from wind and waves – the bays and leeward side of the islands allow larger growth without the fragmentation of the plants; (2) substrate – these sheltered areas allow the accumulation of finer sediments which are rich in phosphorus; (3) the input of large amounts of phosphorus draining from the tributary subwatersheds in the vicinity – the larger subwatersheds drain larger areas, and thus have high phosphorus loads from the sheer volume of water, despite the fact that the actual concentration in the water may be low.

Figure 5-7: Three of the most common plant species found in Lake Simcoe *(from left): Ceratophyllum demersum* (photo: Friends of Chorlton Meadows, UK), ***Myriophyllum spicatum*** (photo: Wisconsin DNR), ***Chara* spp.** (photo: Alabama DCNR)

Changes over time

Since the initial studies of the lake's aquatic macrophytes, there have been significant changes to their distribution, species composition, and density. Figure 5-8 depicts some of these changes.

Since 1984, the maximum depth of plant colonization has increased from 6.5 m to 10.5 m, which has resulted in a large increase in potential habitat. This is demonstrated by a doubling in the areal coverage of macrophytes (Depew *et al.*, 2011), increasing from 9.5 km^2 in 1984 to 18.1 km^2 in 2008. The mean wet weight biomass has also increased from 1.2 kg/m^2 (in 1984) to 3.1 kg/m^2 (in 2008).

The most significant change in the distribution of plant species is the increase in the distribution of the invasive species *M. spicatum*, which was only recorded at five sites near the Maskinonge River in 1984. In 1984 the mean biomass of *M. spicatum* was only 44.5 g/m^2; while in 2008 it had increased to 272.5 g/m^2. This increase has come at the expense of other shallow water species, particularly *Chara* spp., which was dominant in 1984 at 123.3 g/m^2 wet weight, but declined to 7.9 g/m^2 in 2008. Changing environmental conditions in the lake since 1984 have also resulted in an increase in the biomass of other species that are common in nutrient-enriched lakes, such as *C. demersum, Vallisneria americana*, and *Elodea* spp., likely as a result of increasing water clarity due to the removal of algae and suspended particles by the filtering of dreissenid (zebra) mussels. For example, *C. demersum* occupied the deeper habitats in both 1984 and 2008, but its area of colonization has expanded significantly, most likely due to the increased light penetration, enabling it to grow in deeper areas. In addition, warmer water temperatures, a longer period of water column stratification, and reduced cover has allowed a longer growing season for aquatic plants.

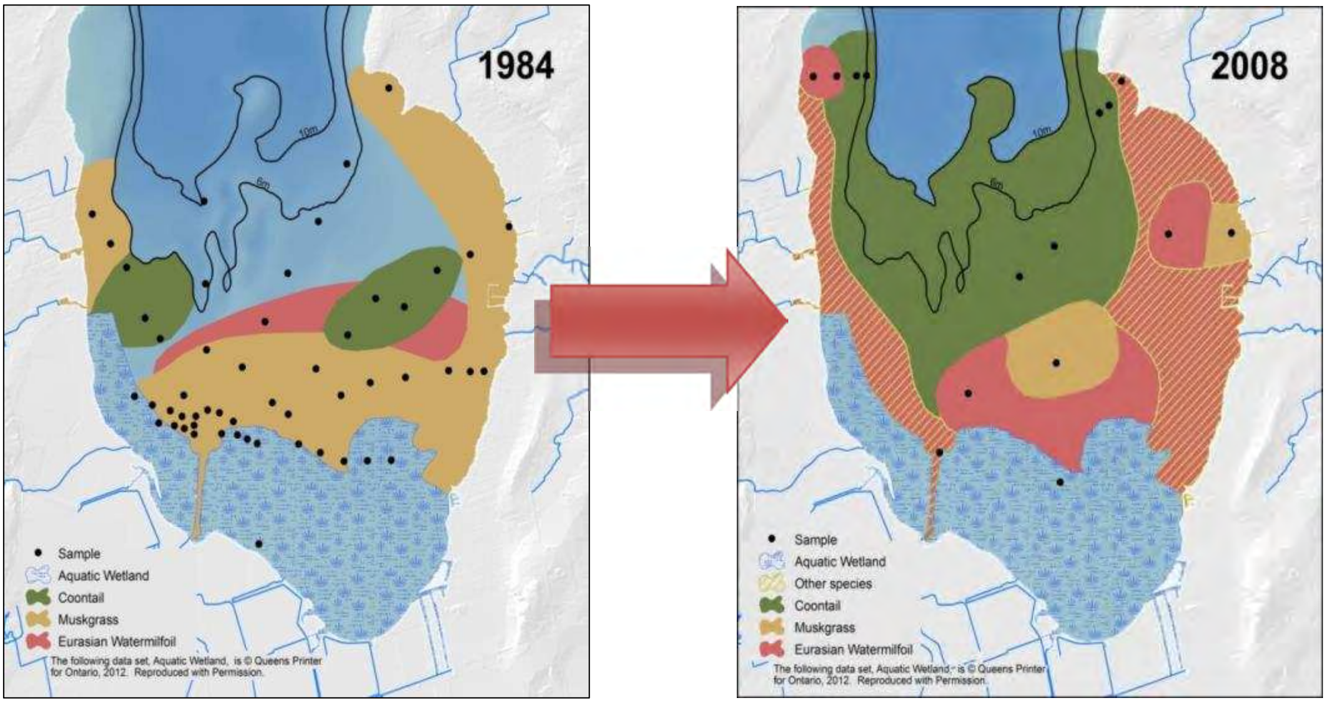


Figure 5-8: Changes in the composition and distribution of the aquatic macrophyte community in Cook's Bay from 1984 to 2008. These changes can be attributed to increasing water clarity, and the associated increase in depth of sunlight penetration, due to the filtering activity of zebra mussels as well as a longer growing period.

BIOLOGICAL MONITORING – BENTHIC INVERTEBRATES

Monitoring of benthic invertebrates in Lake Simcoe is one of the key activities of the LSRCA Nearshore Monitoring Program. These animals, predominantly larval stages of common insects, respond quickly to environmental changes in the lake and, as a food source for fish, can be used to track changes in Lake Simcoe's fish community. One of the first benthic invertebrate studies in North America was carried out on Lake Simcoe in 1926 and developed many of the methods still in use today. At that time, there was 185 species of benthic invertebrates in the lake with 16 species of bivalves (native mussels and clams). In our monitoring since 2008, LSRCA has recorded 105 species living in Lake Simcoe, with only four species of bivalves, two of which are invasive species (*Dreissena polymorpha*, zebra mussel; *D. rostriformis bugensis*, quagga mussel). This loss of species diversity in the bivalve community clearly shows the impact of invasive species in Lake Simcoe.

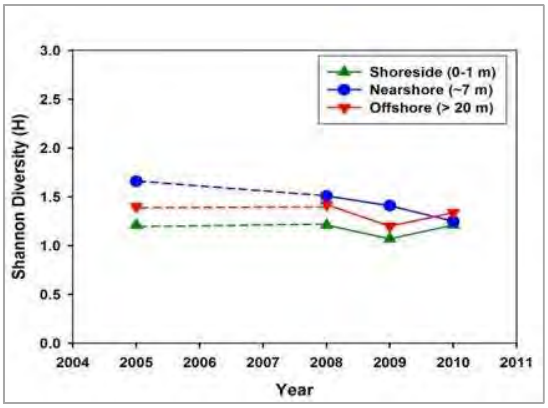


Figure 5-9: Diversity of the benthic community among monitored habitat types

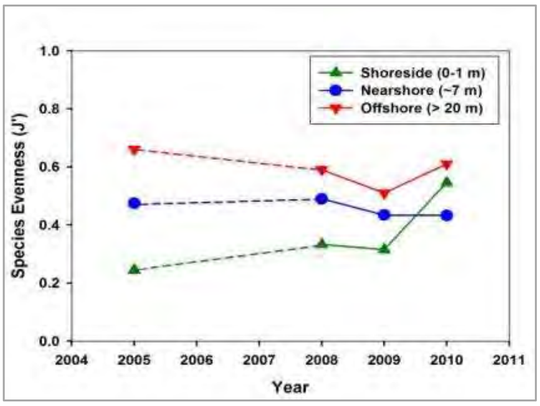


Figure 5-10: Species evenness among monitored habitat types

LSRCA's studies since 2008, which use methods based on a preliminary study in 2005, have shown no significant change in the diversity of the benthic community among the three habitat types monitored: shoreline, nearshore, and offshore (Figure 5-9). In terms of species evenness, or how equally the community is distributed among the taxa recorded, the community has been relatively stable with the exception of shoreline habitats which recorded a large increase in the evenness score between 2009 and 2010 (Figure 5-10). The cause of this increase was a significant decline in the formerly dominant amphipod taxa (Figure 5-11a), likely due to predation by invasive gobies. With fewer amphipod taxa, the evenness score increased because the community was more evenly balanced. In the littoral zone, dreissenids (mostly zebra mussels) have been the dominant taxa until 2009-2010 when abundances started declining (Figure 5-11b). The cause of this decline may be due to the expansion of another invasive species in Lake Simcoe, the round goby (*Neogobius melanostormus*), which feeds on zebra mussels. In Lake Erie, the expansion of round goby resulted in a substantial decline of zebra mussel populations in that lake. Changes in the profundal zone (Figure 5-11c) include a steady increase in the abundance of dreissenids (in this habitat, quagga mussels) which are expanding in the cooler, deeper habitat.

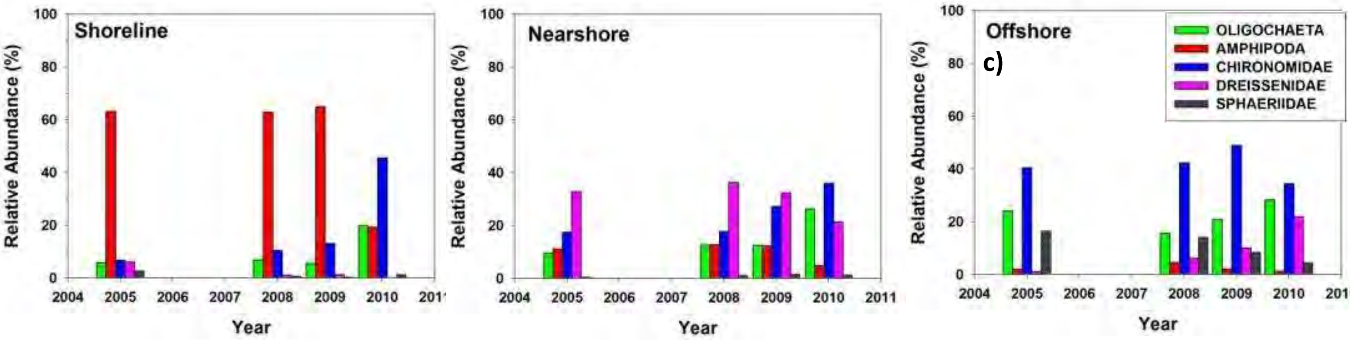


Figure 5-11: Relative abundance of benthic invertebrate taxa in the shoreline, nearshore, and offshore zones (note the common legend for the three graphs is displayed on the profundal zone graph to the right)

ZEBRA MUSSELS

Since becoming established in Lake Simcoe around 1995 (zebra mussels) and 2004 (quagga mussels), *Dreissena* spp. mussels have been a dominant group in the Lake Simcoe benthic community. In 2009-10, LSRCA undertook a specialized study to map the extent of these invasive mussels and determine population trends. Samples were collected at 747 sites in Lake Simcoe with almost 44,000 mussels being collected, measured, and weighed. The results of this study show high populations on hard substrates, boulder, cobble, sand, and shell in Lake Simcoe (Figure 5-12) They were found to be limited to a depth of less than 20 m due to temperature (zebra mussels are intolerant of cooler water) and habitat (substrates are mostly mud below this depth). One exception is in Kempenfelt Bay where dreissenids are recorded to depths of 31 m. Further studies are being carried out to determine how these animals exist in deeper water in Kempenfelt Bay. Overall, Lake Simcoe has an average of 4015 invasive mussels per m^2, with a composition of 75% zebra mussels, and 25% quagga mussels, although the percentage of quaggas is showing a steady increase.

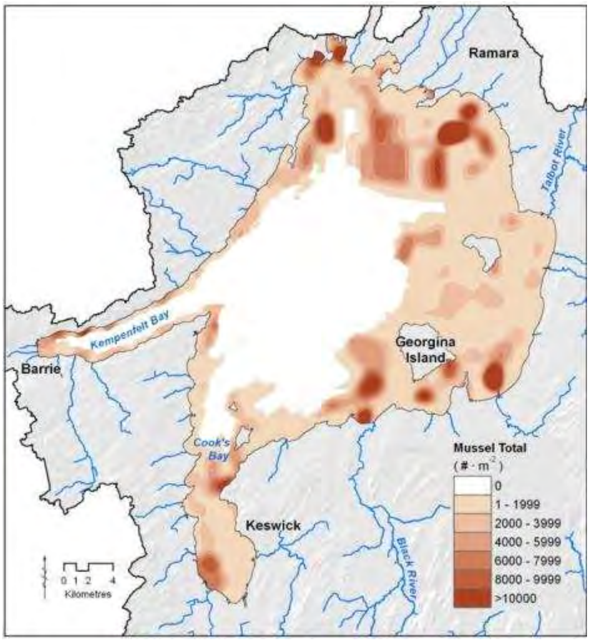


Figure 5-12: Distribution of zebra mussels along Lake Simcoe's nearshore

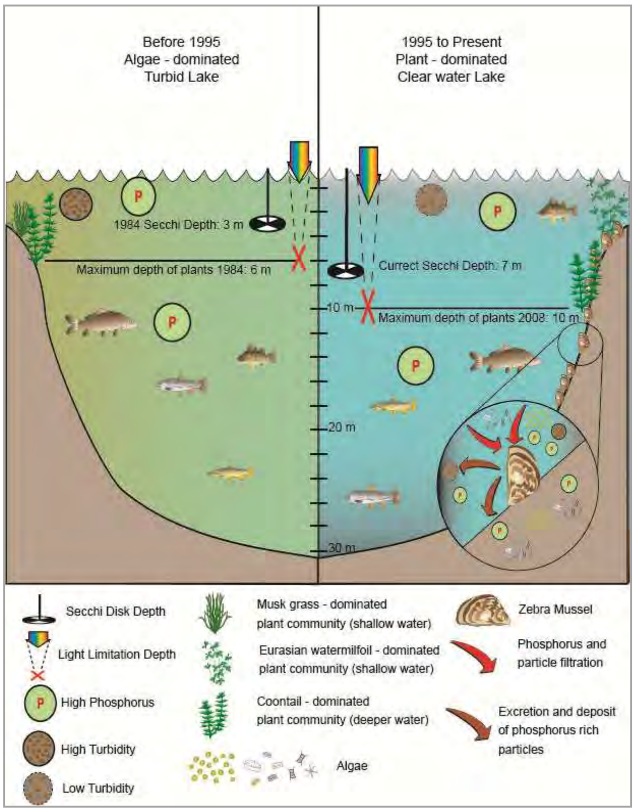


Figure 5-13: Changes to the lake ecosystem following the establishment of zebra mussels

As mentioned above, zebra mussels have had a profound impact on the ecology of Lake Simcoe, especially in terms of a sudden increase in water clarity following their lake-wide colonization by ~1995. Typically, lakes have two stable ecological states: (1) a clear water state, which has low concentrations of phosphorus, high water clarity, and is dominated by aquatic plants; (2) a turbid state which has a high concentration of phosphorus, low water clarity, and is dominated by algae living in the water column. In Lake Simcoe, the increase in phosphorus loading following European settlement and land clearance resulted in the lake being transformed from a clear water state to the turbid state. Since zebra mussels have a high filter rate and efficiency (they filter an equivalent volume to Lake Simcoe every five days) there was a significant increase in water clarity (see Fig. 5-2). The result is a new stable state “engineered” by these invasive species which has high water clarity and high phosphorus (Figure 5-13) – a perfect environment for aquatic plants which has resulted in a large increase in plant biomass and habitat available for colonization (Figure 5-8).

TOTAL PHOSPHORUS IN THE HOLLAND RIVER

The Holland River (comprised of the East Holland and West Holland tributaries) is the largest tributary of Lake Simcoe and contributes the largest phosphorus inputs at an annual mean (2007-2009) of 27 tonnes; 14.5 t from the agricultural West Holland River and 12.9 t from the East Holland River which drains the urban areas of Aurora and Newmarket. Total phosphorus (TP) concentrations (Figure 5-14) are significantly higher than the maximum recorded in Lake Simcoe (black dashed line on graph) and show a strong correlation with precipitation and surface run-off. Chlorophyll *a* data, while also much higher than in Lake Simcoe, records typical annual trends with low concentrations under ice during winter, and peaks during the summer.

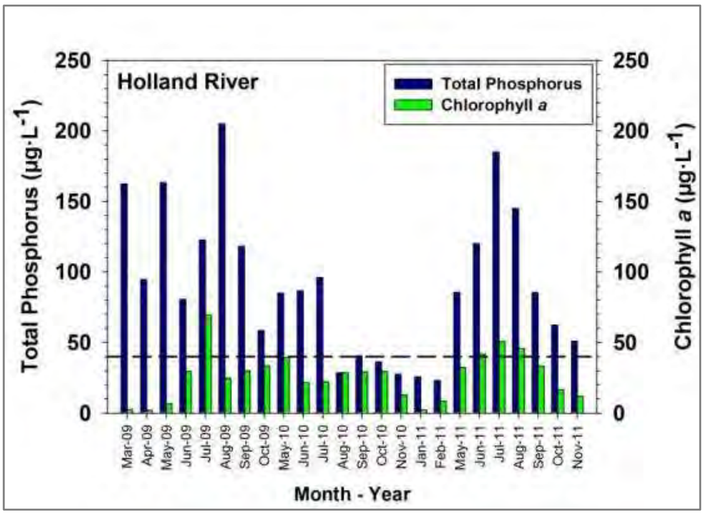


Figure 5-14: Total phosphorus (TP) and chlorophyll-*a* in the Holland River. Note the black dashed line is the maximum TP recorded in Lake Simcoe.

The Holland River also has very high sediment phosphorus concentrations. This phosphorus is bound to either mineral particles in the sediment, or more loosely to compounds that include iron. During periods of warm water and a stratified water column, dissolved oxygen is depleted near the sediment surface. Under these low oxygen conditions, this loosely-bound phosphorus is released from the sediment back into the water column. Our monitoring data (Figure 5-15) records that while the concentration of mineral-bound P is stable in Holland River sediments, the more loosely-bound phosphorus is released from sediment during periods of strong water column stratification and algal growth when dissolved oxygen reaches low concentrations near the sediment surface (e.g. September 19 in Figure 5-15).

Figure 5-16: Duckweed growth in the lower Holland River

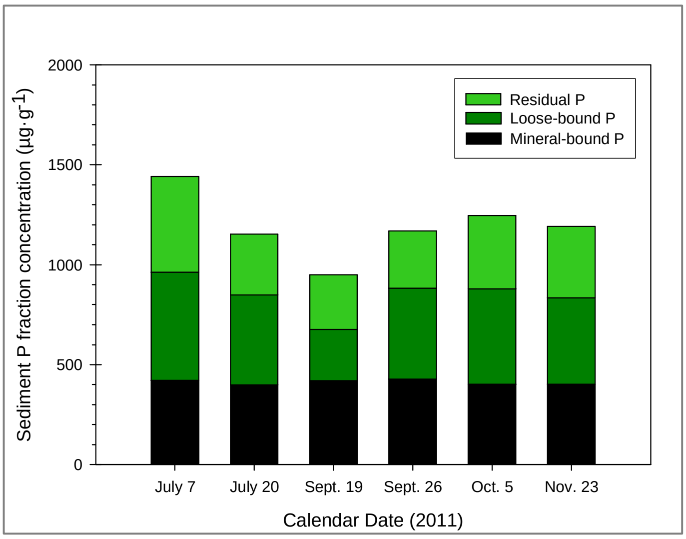


Figure 5-15: West Holland River sediment phosphorus concentrations, broken down by form of phosphorus (July to November 2011)

PHOSPHORUS

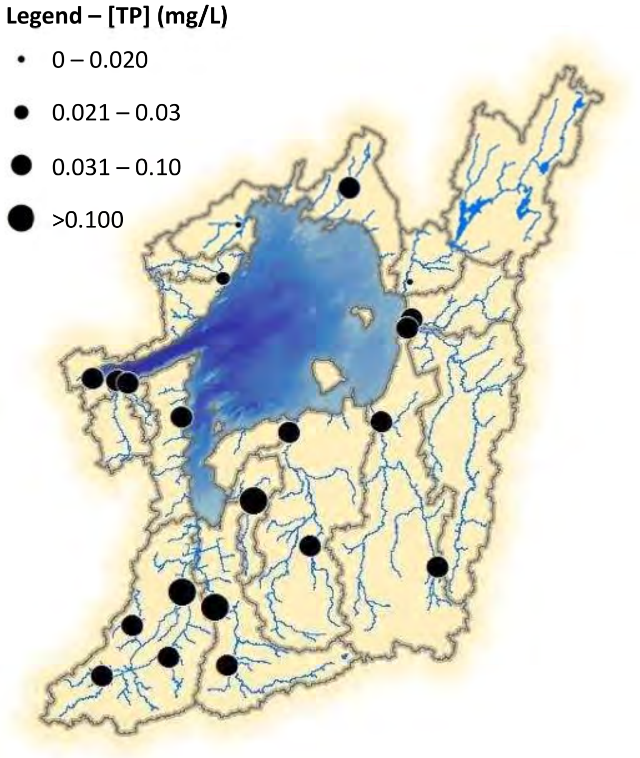


Figure 6-1: Average total phosphorus concentrations (2007-2011) at Lake Simcoe water quality stations (Provincial Water Quality Objective = 0.030 mg/L)

Phosphorus is a naturally occurring nutrient that, when present in high concentrations, has a negative impact on the health of aquatic ecosystems. It has been found to be the most prevalent pollutant in the Lake Simcoe watershed, and as such is scrutinized closely through our monitoring activities. The concentrations found through monitoring the tributaries are measured against the Provincial Water Quality Objective (PWQO), which is 0.03 mg/L for phosphorus.

The impacts of land use on phosphorus concentration become obvious when looking at the distribution across the watershed. The stations with the highest concentrations are generally found in the subwatersheds with the highest levels of urban and agricultural land uses in the basin. These include the East Holland station, found downstream of Newmarket and Aurora, with an average concentration of 0.15 mg/L; the West Holland station, downstream of the Holland Marsh, at 0.14 mg/L; and the Maskinonge station, found in the subwatershed with the highest level of agriculture, at 0.12 mg/L. Conversely; Bluff's and Hawkestone Creeks, which have among the highest level of natural cover in the basin, have the lowest average concentration for the study period, at 0.02 mg/L. The Beaver River, Pefferlaw River, and Black River stations, which are all found in subwatersheds with relatively high levels of natural cover, all display lower total phosphorus concentrations, at 0.03 mg/L, 0.04 mg/L, and 0.04 mg/L, respectively (Figure 6-1).

Just over half of the monitoring stations fail to meet the PWQO the majority of the time. The most degraded station was found to be the East Holland, where 97% of the samples fail to meet the PWQO; and this number is over 90% at the West Holland River, Tannery Creek, and Maskinonge River stations. At the Hawkestone Creek station, only 16% of the samples fail to meet the PWQO, indicating a significantly healthier subwatershed (Table 6-1).

Table 6-1: Summary of total phosphorus conditions at the Lake Simcoe water quality stations. Results expressed as long and short-term trend and the proportion (%) of samples collected at specific concentration ranges

Monitoring station	% of samples	Short-term trend	Long-term trend	Monitoring station	% of samples	Short-term trend	Long-term trend
West Holland River		⇔	↓	Kettleby Creek		⇔	↓
Tannery Creek		↑	↓	North Schomberg		⇔	↓
Mt. Albert Creek		↑	⇔	Talbot River		⇔	↓
Beaver River		⇔	↓	Whites Creek		⇔	⇔
Pefferlaw River		↑	↓	Uxbridge Brook		⇔	N/A
Lovers Creek		↑	↑	Hewitt's Creek		N/A	N/A
Upper Schomberg River		⇔	↓	Leonard's Creek		N/A	N/A
Maskinonge River		⇔	↑	Bluff's Creek		N/A	N/A
East Holland River		⇔	↓	Hotchkiss Creek		N/A	N/A
Black River		⇔	⇔	Ramara Drain		N/A	N/A
Hawkestone Creek		⇔	⇔				

Total phosphorus(mg/L)

🟩 0-0.020 🟥 0.031-0.100

🟩 0.021-0.030 🟥 >0.100

↑ Increasing Trend ⇔ No trend

↓ Decreasing Trend N/A Insufficient data available for determining trend

Short term trend - 2002-2011 (or from the initiation of the station to 2011, if monitoring began later than 2002)
Long term trend - 1980-2011

Green in the pie charts indicates samples below the PWQO (0.03 mg/L); red indicates samples above the PWQO

Trends

Seasonal Kendall trend analysis has been completed on the phosphorus data for all stations with a suitable dataset for this analysis. Trends were calculated for both the long-term (1980 - 2011 – see Appendix A) and short-term (about 2002-2011); these are shown in Table 6-1.

Long-term trends

The majority of stations show decreasing concentrations in the long-term analysis; examples of this are shown in Figure 6-2. Four stations show no trend, equating to stable concentrations, and only two stations show an increasing trend in concentrations. The Maskinonge River and Lovers Creek stations, both of which show a statistically significant increasing trend over the long-term, are likely displaying the impacts of urban growth and intensive agricultural activity.

Short-term trends

Examination of the short-term trends shows that the decreasing trend that was so apparent in the long-term data does not hold in the more recent data. Four stations show statistically significant increasing trends in the short-term period, although it is important to note that, generally, the increases seen in recent years are on a much smaller scale than the decreases that have been achieved over the long-term (Figure 6-2). For example, the increase in concentrations in Tannery Creek between 2002 and 2009 is very slight. The remaining twelve stations show no trend.

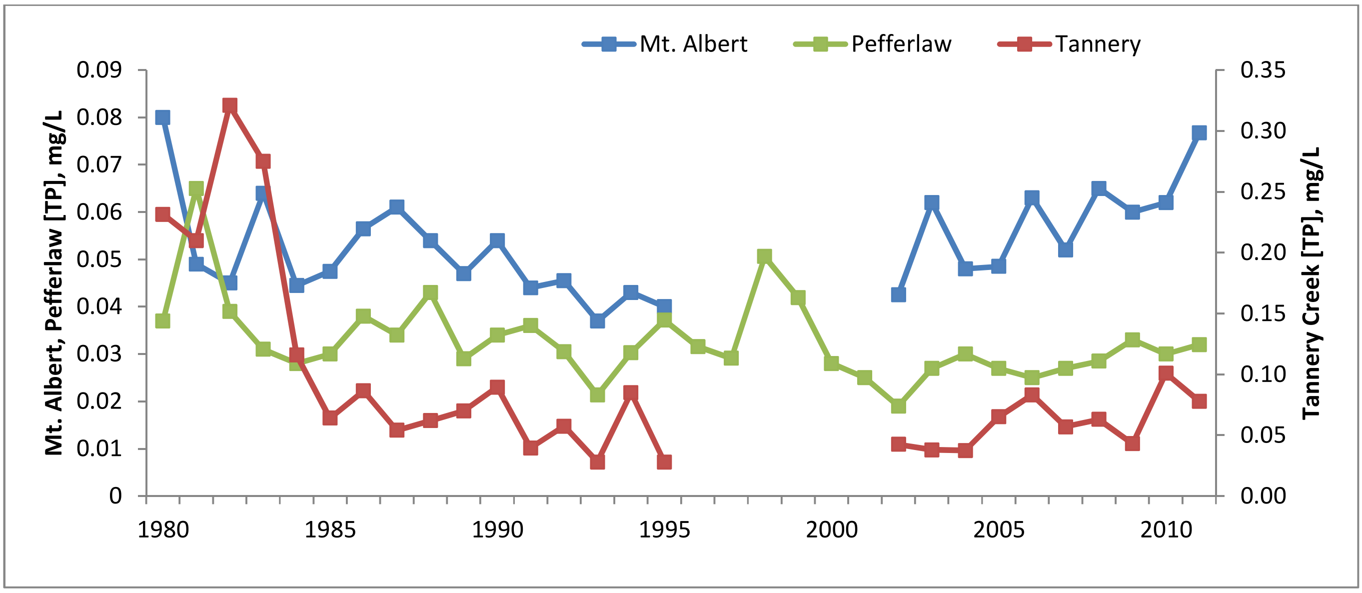


Figure 6-2: Median annual total phosphorus concentrations at the Mt. Albert Creek, Pefferlaw River, and Tannery Creek stations, displaying the decreasing trend in the long-term and increasing trend in the short-term that is being seen at some stations in the watershed. Note the scale for Tannery Creek is two orders of magnitude greater than that of Mount Albert and Peferlaw.

The data show that great strides have been made in phosphorus reduction activities since the initiation of the monitoring program. However, in looking at the data it also becomes apparent that the larger, more easily achieved reductions, such as taking waste water treatment plants offline and the use of phosphorus-free detergents were completed early on in the program, and reductions are now becoming more difficult to achieve. This can be seen through the trend analysis, where stations that had been showing reductions over the long-term are now seeing no trend, or in a few cases are actually seeing an increasing trend.

CHLORIDE

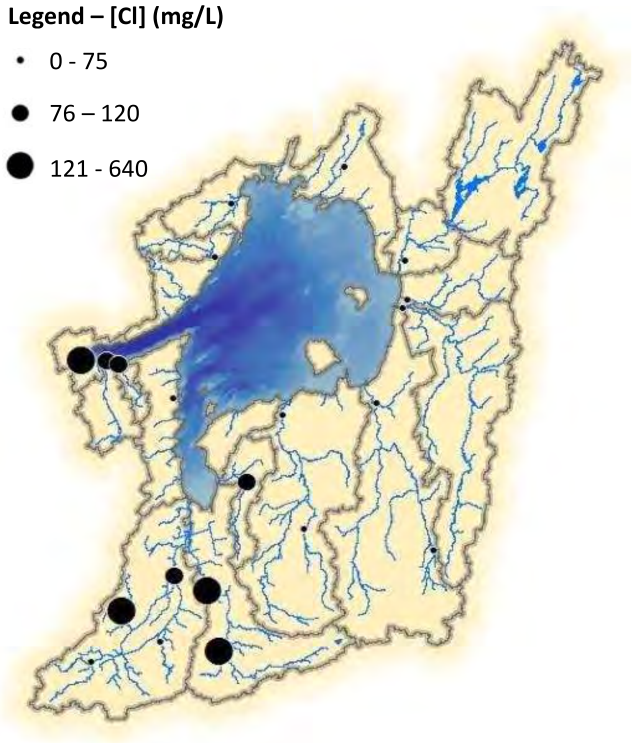


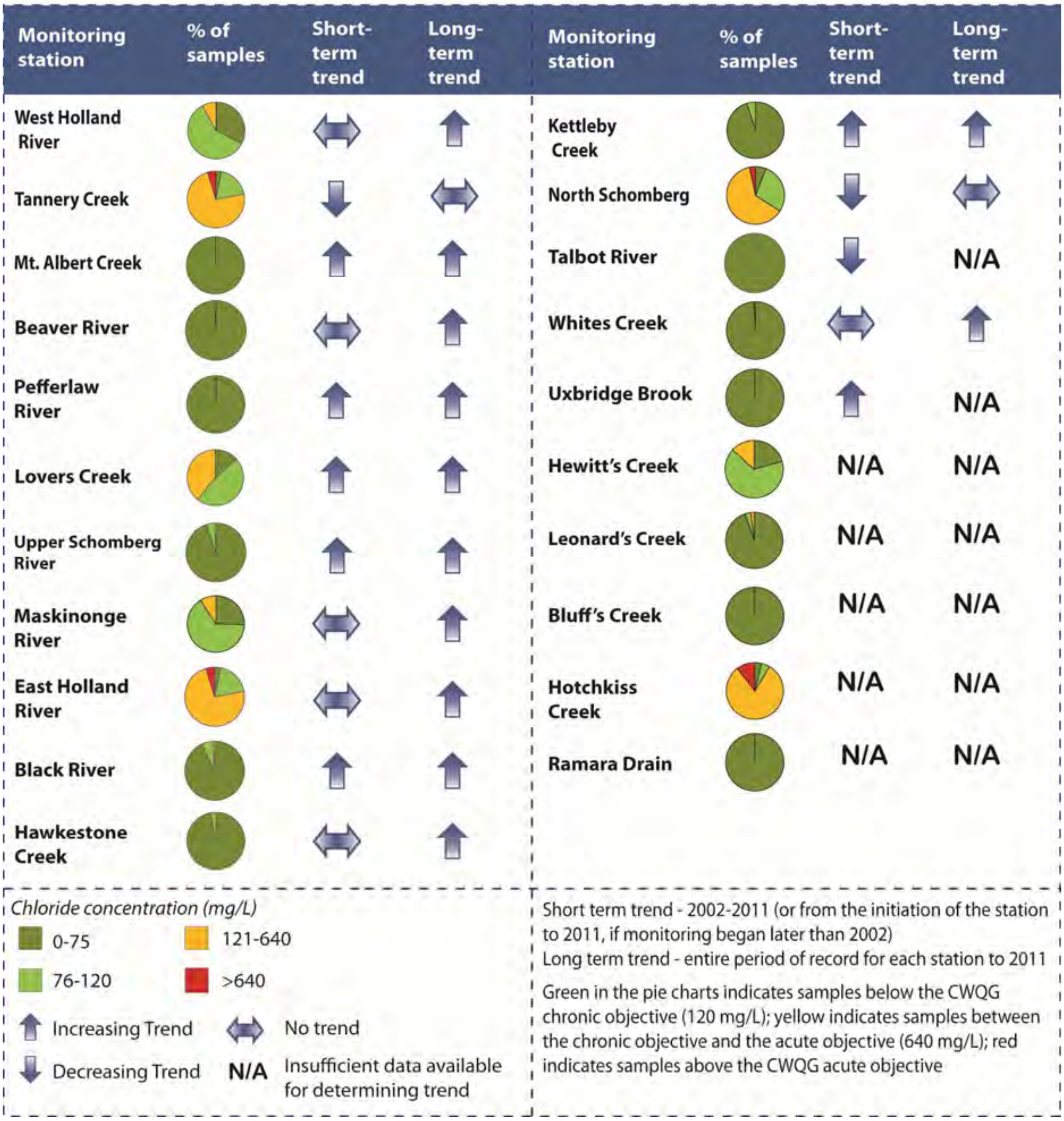
Figure 6-3: Average chloride concentrations (2007-2011) at Lake Simcoe water quality stations

Chloride is a naturally occurring element widely distributed in the environment. Chloride is an essential element for the health of all organisms, humans included; however, at elevated levels it can have detrimental impacts. Background chloride concentrations in natural surface waters are typically below 10 mg/L. Increased levels of chloride in surface waters are typically the result of salt application in winter months. In 2001 The *Canadian Environmental Protection Act* defined road salts containing chloride as toxic. This was based on research that found that the large amount of road salts being used can negatively impact ground and surface water, vegetation, and wildlife. While elevated chloride levels are primarily found around urban centres and major roads and highways, chloride levels have been found to be steadily increasing across the Lake Simcoe watershed, and throughout Ontario (MOE, 2011) as well as in Lake Simcoe itself (Eimers and Winter, 2005).

Recently the guidelines for chloride in surface waters were revised and the current Canadian Water Quality Guideline (CWQG) for the protection of aquatic life is 120 mg/L for chronic (long-term) exposure and a benchmark concentration of 640 mg/L was set for acute (short-term) exposure. The acute guideline estimates the point at which severe effects to the aquatic ecosystem are likely to occur over a 24 to 96 hour exposure period.

With respect to the chronic guideline, the majority of samples are below the guideline at all but five stations, those stations being Tannery Creek, Lovers Creek, East Holland River, North Schomberg, and Hotchkiss Creek. With winter salt being the main source of chloride in surface waters it is not surprising that all five of these stations are within an urban catchment or near a major highway (Figure 6-3). Of all stations only three reported exceedances of the acute guideline, these being East Holland River (5% of samples), North Schomberg River (3%), and Hotchkiss Creek (10%). The maximum concentration recorded (2007 to 2011), occurred in Hotchkiss Creek at 3510 mg/L in November, 2008 (Table 6-2).

Table 6-2: Summary of chloride conditions at the Lake Simcoe water quality stations. Results expressed as long and short-term trend and the proportion (%) of samples collected at specific concentration ranges



Monitoring station	% of samples	Short-term trend	Long-term trend	Monitoring station	% of samples	Short-term trend	Long-term trend
West Holland River		↔	↑	Kettleby Creek		↑	↑
Tannery Creek		↓	↔	North Schomberg		↓	↔
Mt. Albert Creek		↑	↑	Talbot River		↓	N/A
Beaver River		↔	↑	Whites Creek		↔	↑
Pefferlaw River		↑	↑	Uxbridge Brook		↑	N/A
Lovers Creek		↑	↑	Hewitt's Creek		N/A	N/A
Upper Schomberg River		↑	↑	Leonard's Creek		N/A	N/A
Maskinonge River		↔	↑	Bluff's Creek		N/A	N/A
East Holland River		↔	↑	Hotchkiss Creek		N/A	N/A
Black River		↑	↑	Ramara Drain		N/A	N/A
Hawkestone Creek		↔	↑				

Chloride concentration (mg/L)

🟩	0-75	🟨	121-640
🟩	76-120	🟥	>640

↑ Increasing Trend
↔ No trend
↓ Decreasing Trend
N/A Insufficient data available for determining trend

Short term trend - 2002-2011 (or from the initiation of the station to 2011, if monitoring began later than 2002)
Long term trend - entire period of record for each station to 2011

Green in the pie charts indicates samples below the CWQG chronic objective (120 mg/L); yellow indicates samples between the chronic objective and the acute objective (640 mg/L); red indicates samples above the CWQG acute objective

Trends

Seasonal Kendall trend analysis has been completed on the chloride data for all stations with a suitable dataset for this analysis. Trends were calculated for both the long-term (entire period of record for each station – see Appendix A) and short-term (about 2002-2011); these are shown in Table 6-2.

Long-term trends

When examining the period of record for 14 long-term stations, all but two are showing an increasing trend in chloride concentrations. This trend is not unique to the Lake Simcoe watershed, with similar trends being observed across Canada. These trends have been driven by increasing urbanization, increasing density of road networks, and changes to road clearing practices with the requirement for more “bare pavement” policies on roadways. As a result, Canada has seen an increase in annual road salt tonnage and application rates since the 1970s. Lovers Creek and the East Holland River are shown in Figure 6-4 below as examples of stations with an obvious increasing trend.

In the Lake Simcoe watershed increasing trends in long-term data are found in subwatersheds with a wide range of conditions, from mostly urban, to mostly agricultural, to predominantly natural. The two stations that do not show a trend in long-term dat do however, show regular exceedances of the chronic guideline, these being Tannery Creek and the North Schomberg River. Although high chloride levels are routinely observed here, it is important to note that the short-term trends show a decreasing trend.

Short-term trends

It is encouraging that an examination of chloride trends over the last decade (approximately 2002-2011) shows that some progress is being made. Of these 16 stations, three are showing decreasing trends, including Tannery Creek and North Schomberg River, and a further six are showing no trend, indicating concentrations may be stabilizing. One of the stations showing no trend is East Holland River, which was also one of the stations that recorded exceedances of the acute guideline. This is incouraging as it suggests that some progress is being made in salt management practices in the East Holland Subwatershed. Seven stations are recording increasing concentrations in the short-term data (Table 6-2). A sufficient period of record has not yet been collected at Hotchkiss Creek to allow for trend calculation.

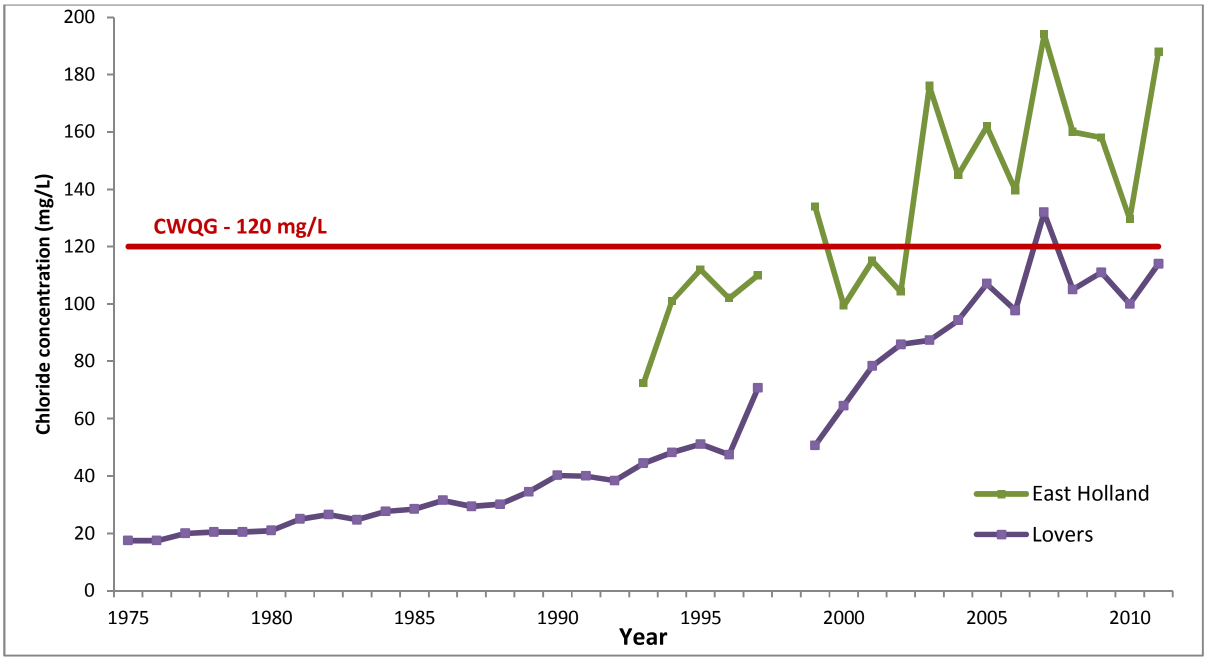


Figure 6-4: Increasing trend in the median annual chloride concentration (mg/L) at the East Holland River and Lovers Creek water quality stations

Since 2001, greater attention and emphasis has been placed on the storage and application of road salt, most notably with the *Canadian Environmental Protection Act* designation of road salt as a toxic substance. This also led to Environment Canada publishing of a Code of Practice for the Environmental Management of Road Salts in 2004 that was widely adopted by Canadian municipalities. While the added attention and adoption of a Code of Practice has likely played a role in the stabalizing or declining trends observed in the short-term data, the amount of road salt applied in a given year is greatly influenced by the severity of the winter. Therefore, year-to-year climate fluctuations are also likely exerting an influence on trends in chloride concentrations. Of key importance will be focusing attention on those systems that are recording exceedances of the acute guideline, as these systems are being highly impacted by chloride concentrations. However, it is important to note that if we fail to manage road salt use, it has the potential to affect the health of Lake Simcoe over the long term; therefore chloride concentrations in all systems will need to be addressed.

TOTAL SUSPENDED SOLIDS

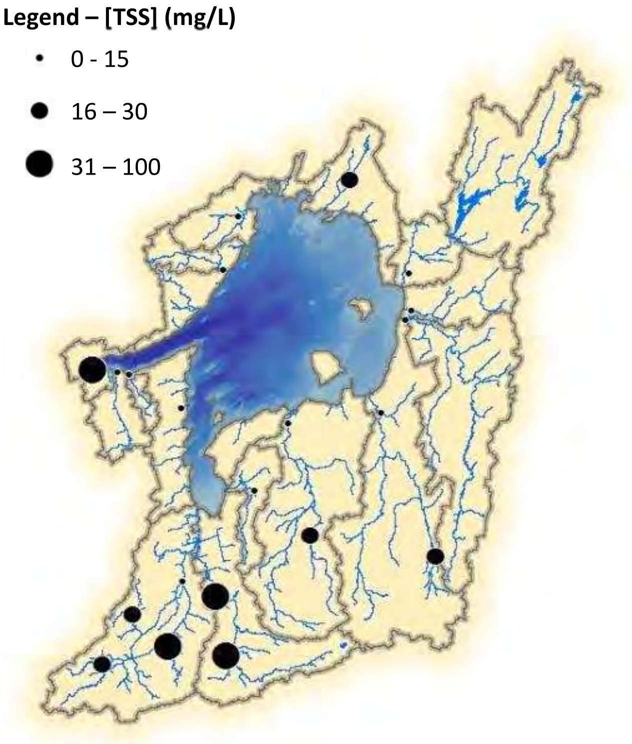


Figure 6-5: Average total suspended solids concentrations (2007-2011) at Lake Simcoe water quality stations (Canadian Water Quality Guideline – 30 mg/L)

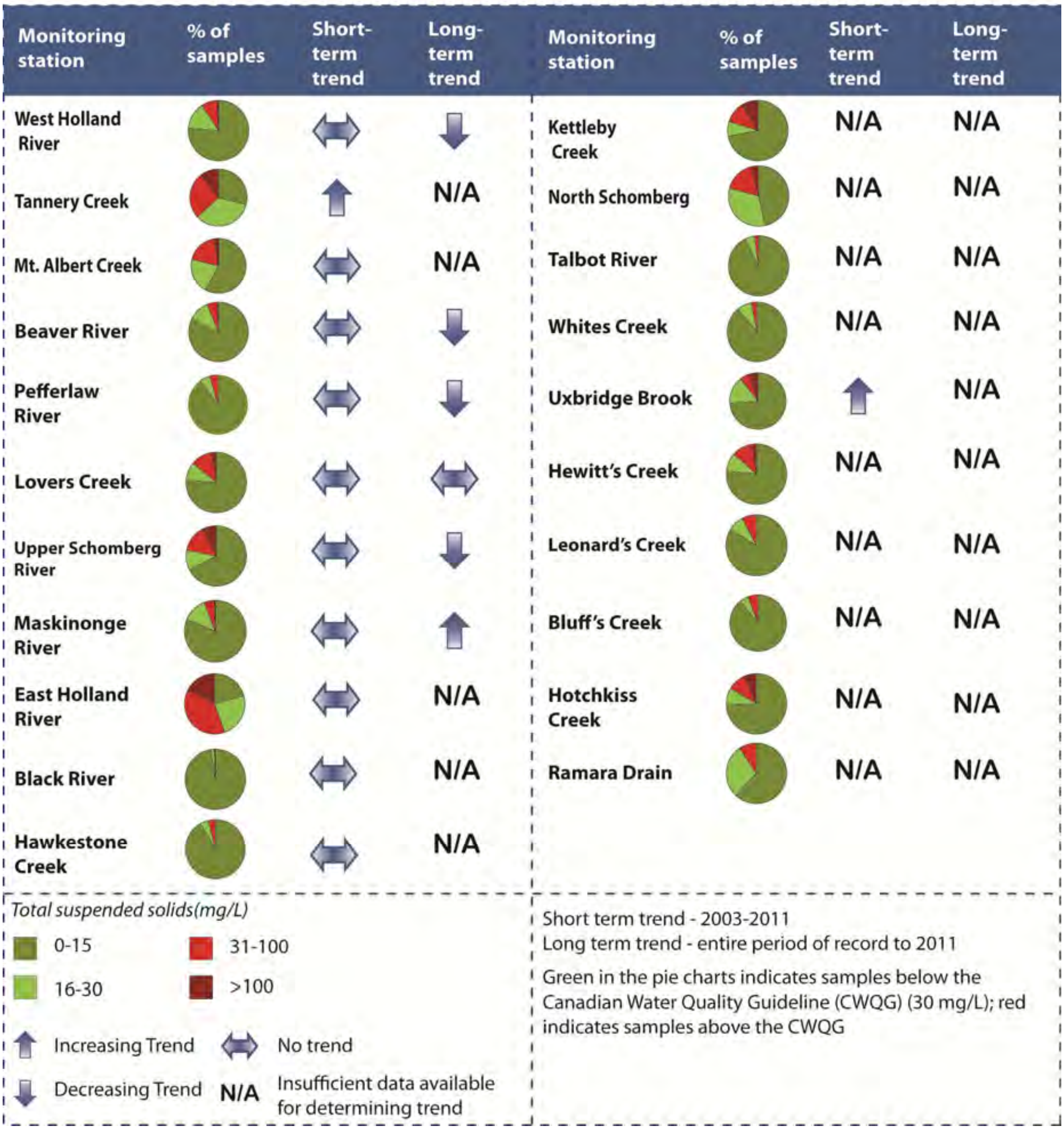
The water quality parameter Total Suspended Solids (TSS) is a measure of any material in suspension in the water column. This can include a wide variety of material, such as silt, microorganisms, decaying plant and animal matter, and industrial wastes. This is an important measure because TSS can act as a transport mechanism for a variety of other parameters, some in a benign form, such as clay-bound aluminum, while others can cause water quality issues. For example, sediment-bound phosphorus can cause excessive nutrient loading downstream. Excessive amounts of TSS may also have negative impacts on fish and benthic organisms. For example, reduced water clarity can inhibit the ability of aquatic organisms to find food. High TSS concentrations would be expected during and following rain events as soil from pervious areas and accumulated grit and dirt from impervious surfaces are washed into streams.

The Canadian Council of Ministers of the Environment (CCME) outlines that TSS concentration should not exceed background concentrations by 25 mg/L for short-term exposures (24 hour period; Canadian Water Quality Guideline, 1999). Background levels are site-specific, but can be generalized for the watershed at 5 mg/L in clear flow conditions, making the short-term guideline about 30 mg/L. On a regular basis, the concentrations should be even lower to avoid chronic exposure. Higher concentrations are acceptable during high flow events. The majority of samples for most stations in the Lake Simcoe watershed are below 30 mg/L except during storm events.

The East Holland River had a high number of samples (collected at the Holland Landing station) over the short-term exposure guideline (55%), many of which occurred in low flow conditions. TSS concentrations were sometimes extremely high during storm events (maximum = 485 mg/L). Tannery Creek, which is a tributary of the East Holland River system, has a similar pattern of elevated TSS, though not as extreme. These sites, which have constantly elevated concentrations of TSS, are particularly at risk for problems associated with TSS (Figure 6-5, Table 6-3).

Other systems with numerous samples containing elevated TSS concentrations include Mount Albert Creek, Upper Schomberg River, and North Schomberg River. The elevated concentrations typically occur during high flows and are not extremely high (Figure 6-5, Table 6-3). A similar pattern with low concentrations during low flows and higher concentrations during high flows is also seen in Kettleby and Hotchkiss Creeks, however the pattern is exaggerated in these systems. The low flow concentrations are very low (approximately 5 mg/L) and the high flow concentrations are extremely high (maximum = 770 mg/L in Kettleby Creek and 890 mg/L in Hotchkiss Creek). Farming practices and pressures from urban development might explain these exaggerated patterns. Further monitoring would provide more insight.

Table 6-3: Summary of total suspended sediment conditions at the Lake Simcoe water quality stations. Results expressed as long and short-term trend and the proportion (%) of samples collected at specific concentration ranges



Monitoring station	% of samples	Short-term trend	Long-term trend	Monitoring station	% of samples	Short-term trend	Long-term trend
West Holland River		⇔	↓	Kettleby Creek		N/A	N/A
Tannery Creek		↑	N/A	North Schomberg		N/A	N/A
Mt. Albert Creek		⇔	N/A	Talbot River		N/A	N/A
Beaver River		⇔	↓	Whites Creek		N/A	N/A
Pefferlaw River		⇔	↓	Uxbridge Brook		↑	N/A
Lovers Creek		⇔	⇔	Hewitt's Creek		N/A	N/A
Upper Schomberg River		⇔	↓	Leonard's Creek		N/A	N/A
Maskinonge River		⇔	↑	Bluff's Creek		N/A	N/A
East Holland River		⇔	N/A	Hotchkiss Creek		N/A	N/A
Black River		⇔	N/A	Ramara Drain		N/A	N/A
Hawkestone Creek		⇔	N/A				

Total suspended solids(mg/L)

🟩 0-15 🟥 31-100

🟩 16-30 🟥 >100

↑ Increasing Trend ⇔ No trend

↓ Decreasing Trend N/A Insufficient data available for determining trend

Short term trend - 2003-2011
Long term trend - entire period of record to 2011

Green in the pie charts indicates samples below the Canadian Water Quality Guideline (CWQG) (30 mg/L); red indicates samples above the CWQG

Trends

Seasonal Kendall trend analysis has been completed on the TSS data for all stations with a suitable dataset for this analysis. Trends were calculated for both the long-term (entire period of record for each station – see Appendix A) and short-term (about 2002-2011); these are shown in Table 6-3.

Though it is important to explore the water chemistry datasets available, there are limitations to the datasets that should be taken into consideration when interpreting the results of Seasonal Kendall trend analysis. These limitations for TSS include varying sampling frequency through the time period, low sampling frequency for some stations, and/or periods where no samples were collected.

There was typically less data available for trend analysis of TSS in comparison with other water chemistry parameters (chloride and total phosphorus). There was also a gap in long-term stations from about 1996 to 2002. If more than 33% of the time period had no samples (i.e. the gap), they were not used in analysis. While there is the potential that these variations in sampling frequency could bias the results, techniques have been used to minimize error. However the trend analysis of TSS should be interpreted with caution. Continued, consistent monitoring in the future with help to mitigate some of these challenges and help build a more robust TSS dataset.

Long-term trends

Long-term TSS datasets suitable for examining trends are only available for six stations. Four stations, the West Holland River, Beaver River, Pefferlaw Brook, and Upper Schomberg River, show a decreasing trend of TSS. The Maskinonge River station shows and increasing trend and Lovers Creek station does not show a trend (Table 6-3). The decreasing trend in the long-term for the West Holland River and Beaver Rivers are displayed graphically in Figure 6-6.

Short-term trends

Examination of the short-term trends shows a different pattern than the long-term datasets. There were 12 stations in this analysis, with none of the stations showing a decreasing trend. Ten stations do not show a trend with only Tannery Creek and Uxbridge Brook showing an increasing trend (Table 6-3).

These trends are similar to phosphorus where concentrations are decreasing in comparison to the earlier parts of the record, but have been stabilizing or increasing in the last decade or so. Fortunately, the majority of stations have TSS concentrations that are below the guideline during clear flows. As long as reduction activities (typically aimed at phosphorus) continue to be undertaken, TSS concentrations should remain stable during this period of urban development and continued agricultural activity in various parts of the watershed. That said, certain tributaries, such as the East Holland River, are impacted by high levels of TSS and further efforts are required to improve the water quality.

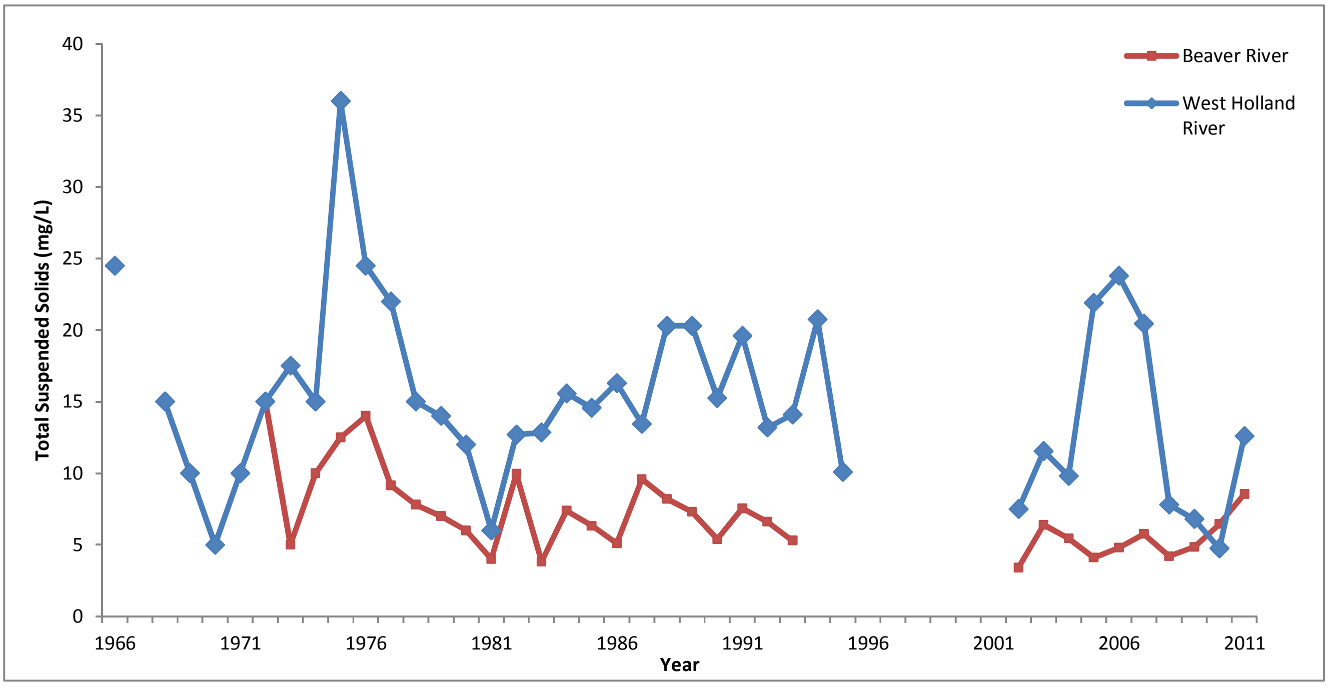


Figure 6-6: Trends in median annual concentration of total suspended solids at the Beaver River and West Holland River stations. Both stations display a decreasing trend in the long-term. In the short-term, the Beaver Rivers displays an increasing trend, while the West Holland River continues to show a decreasing trend, although there is a great deal of inter-annual variability.

METALS

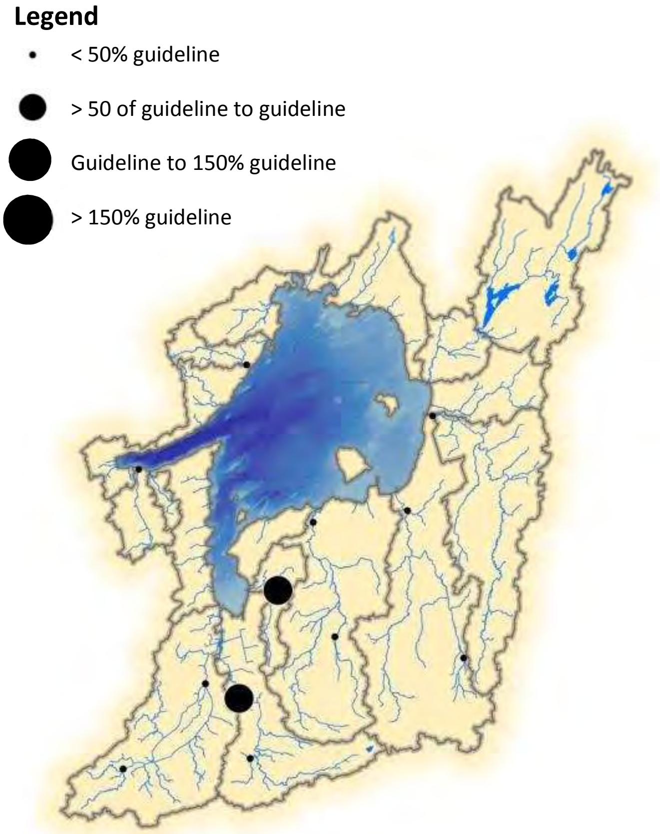
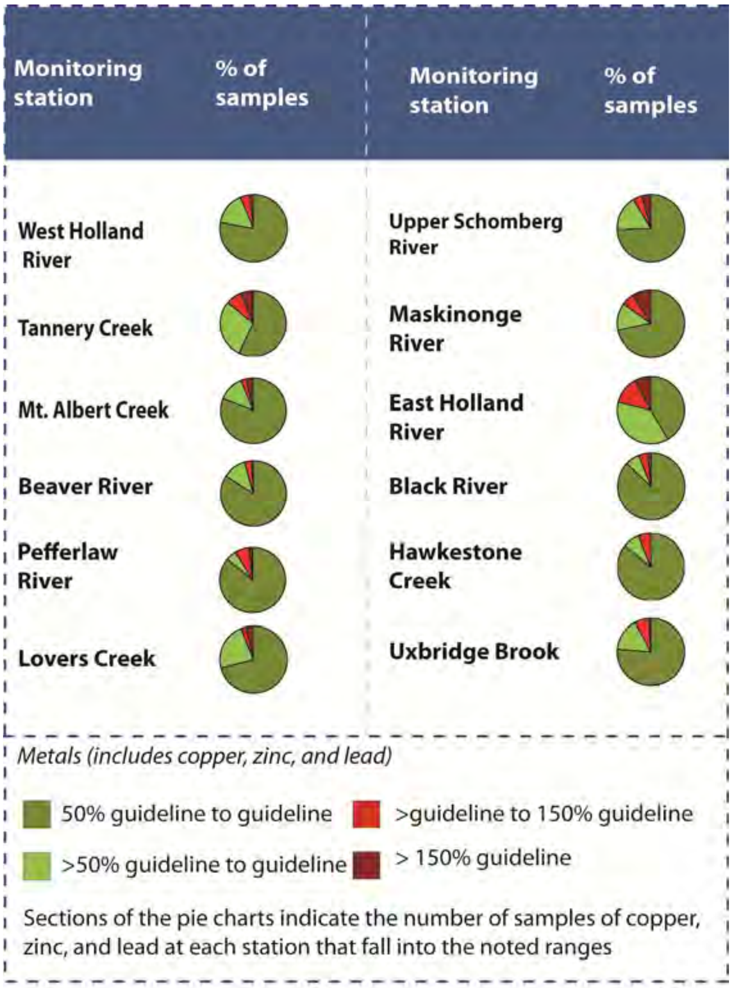


Figure 8-7: Metals (combination of zinc, copper, and lead) (2007-2011) at Lake Simcoe water quality stations. Note: the size of the marker corresponds to the division into which average concentrations of at least two of the three metals fall. The majority of metals samples are below the guidelines.

Metals are monitored in surface waters at 12 stations throughout the Lake Simcoe watershed (Figure 8-7). A total of 20 different metals are analyzed. For the purposes of this report, three metals (copper, lead, and zinc) were selected to examine the potential impact of metals on the health of the aquatic ecosystem in Lake Simcoe tributaries. These metals are good indicators of anthropogenic influences such as urbanization and agricultural activities. As there are no real point sources of metals contamination in Lake Simcoe tributaries, the metals concentrations detected are typically a combination of natural background concentrations and non-point sources such as soil disturbance, pesticide and fungicide application, automotive tire and breakpad wear, burning of fossil fuels, and many more. Elevated concentrations in the Lake Simcoe watershed are typically a result of human activities.

Both copper and zinc are essential elements that play a role in normal biological processes. However, at elevated concentrations all three metals will have toxic effects on aquatic organisms. The water quality guidelines for these metals are therefore set to avoid toxic impacts to sensitive aquatic organisms and are 5µg/L for copper and lead, and 20 µg/L for zinc (Figure 6-7). In the 2007 to 2011 data set the majority of samples recorded values below the metals guideline. For Beaver River 96% of samples met the metals guidelines and 94% of samples met guidelines at the Black River, Hawkestone, Lovers Creek, Mount Albert Creek, and West Holland River stations. The lowest compliance was 79% at the East Holland River station. Overall, while there are some samples exceeding guidelines for metals in the watershed, they are generally not considered to be a serious concern (Table 6-4).

Table 6-4: Summary of conditions of selected metals at the Lake Simcoe water quality stations. Results expressed as long- and short-term trend and the proportion (%) of samples collected at specific guideline ranges



Monitoring station	% of samples	Monitoring station	% of samples
West Holland River		Upper Schomberg River	
Tannery Creek		Maskinonge River	
Mt. Albert Creek		East Holland River	
Beaver River		Black River	
Pefferlaw River		Hawkestone Creek	
Lovers Creek		Uxbridge Brook	

Metals (includes copper, zinc, and lead)

🟩 50% guideline to guideline

🟥 >guideline to 150% guideline

🟩 >50% guideline to guideline

🟥 > 150% guideline

Sections of the pie charts indicate the number of samples of copper, zinc, and lead at each station that fall into the noted ranges

Trends

Due to the fact that a large proportion of the metals data set falls below the laboratory analytical detection limit, Seasonal Kendall trend analysis could not be performed on any metals data set. Examination of the data set over time instead consisted of observing the percentage of samples that were above the detection limit to determine if there has been any discernible shift in concentration over time, possibly indicating increasing or decreasing concentrations. This analysis was limited to data from after 2003, as there were changes to analytical methods before this time that changed the method detection limit.

For copper, there appeared to be a general shift to having more sample concentrations greater than the detection limit as time went on (Figure 6-8). Most copper concentrations at Holland Landing were greater than the detection limit for the entire period. Zinc showed no discernible pattern, although the two most recent years had the most concentrations above the detection limit. Most of the concentrations at East Holland River, Tannery Creek, West Holland River, and Uxbridge Brook were greater than the detection limit for zinc for the entire period. For lead, almost all samples at all stations were below the detection limit for the entire period.

There are some indications that metals concentrations are increasing in the watershed; continuing or increasing anthropogenic activities have the potential to see metals continuing to increase in concentration, if not curtailed. However, the majority of metals concentrations are below the relevant guideline indicating that, at this time, metals concentrations in the Lake Simcoe tributaries are not impacting the aquatic system.

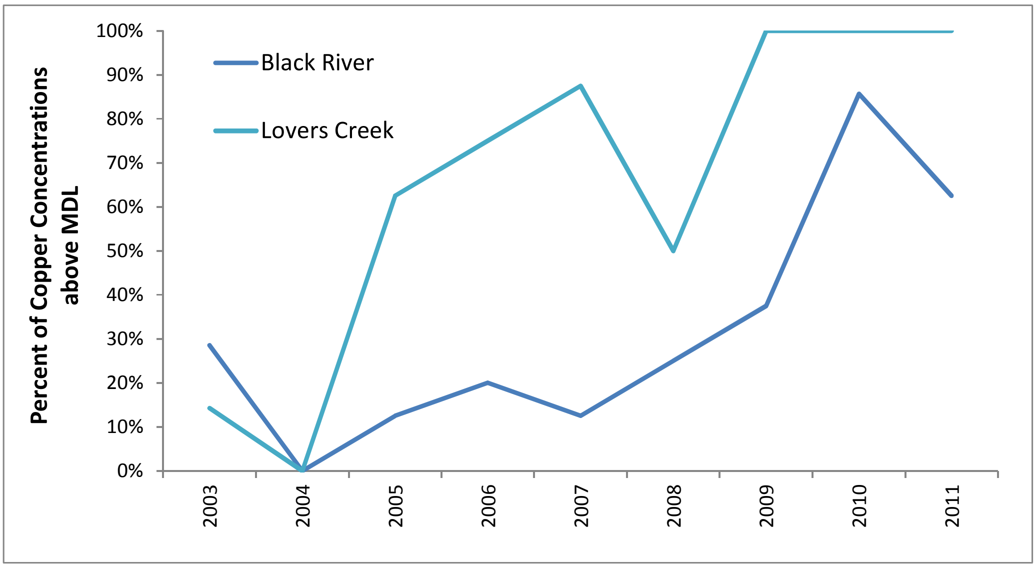


Figure 6-8: Median annual concentration of zinc (µg/L) at the Mount Albert Creek and Lovers Creek water quality stations, showing decreasing trends over the long-term, but increasing trends in the short-term data

CHLORIDE

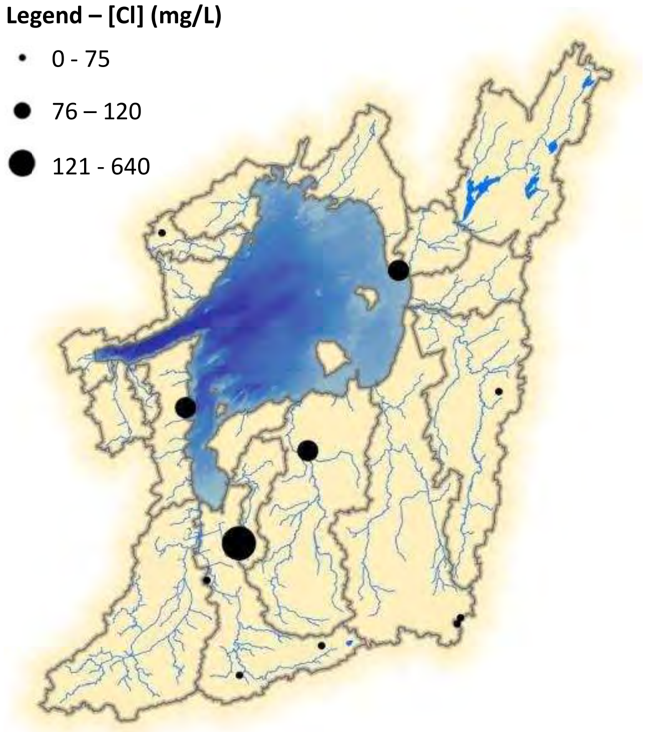
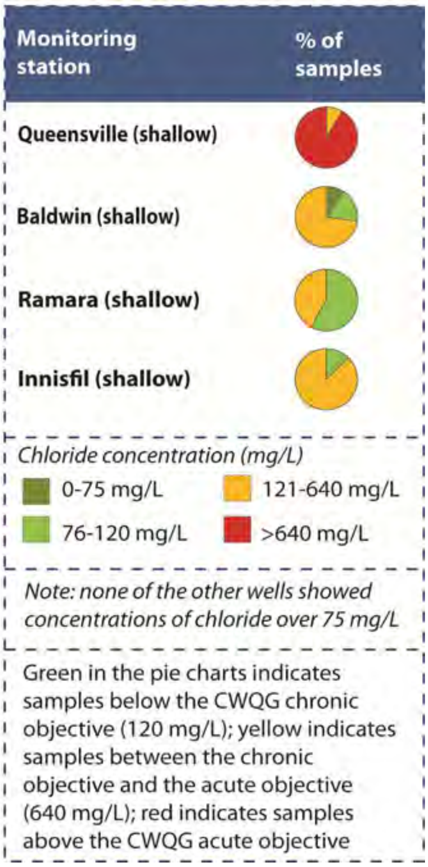


Figure 6-9: Average chloride concentrations (2007-2011) at Lake Simcoe groundwater quality monitoring stations

Table 6-5: Summary of chloride concentration results at selected Provincial Groundwater Monitoring Network stations (2007-2011)



Monitoring station	% of samples
Queensville (shallow)	
Baldwin (shallow)	
Ramara (shallow)	
Innisfil (shallow)	

Chloride concentration (mg/L)

🟩 0-75 mg/L
🟨 121-640 mg/L
🟩 76-120 mg/L
🟥 >640 mg/L

Note: none of the other wells showed concentrations of chloride over 75 mg/L

Green in the pie charts indicates samples below the CWQG chronic objective (120 mg/L); yellow indicates samples between the chronic objective and the acute objective (640 mg/L); red indicates samples above the CWQG acute objective

Chloride is a naturally occurring element that can be found at high concentrations (i.e. greater than the water quality standards) under natural conditions. The concentration of chloride in groundwater can be related to the type of rock the groundwater is coming from; however, high concentrations of chloride can also be related to anthropogenic impacts (e.g. winter salt and landfills). When determining the source of chloride in groundwater it is necessary to have an understanding of the type of aquifer and the recharge location for that particular well.

In general, chloride is not harmful to humans but can indicate higher concentrations of sodium which are a concern to people on sodium restricted diets. Because of the close connection of groundwater to surface water, the concentrations found within the groundwater monitoring wells are measured against the Canadian Water Quality Guideline (CWQG) for the purposes of this report, which is 120 mg/L for chronic (long-term) exposure, and 640 mg/L for acute (short-term) exposure.

The impacts of land use on chloride concentration become obvious when looking at the distribution within the various aquifer complexes across the watershed. The highest concentrations of chloride are found in shallow wells that obtain their recharge locally to that well; all of these in the vicinity of roadways (Figure 6-9). These include wells in Queensville, with an average concentration of 906 mg/L; Innisfil, at 263 mg/L (this well was decommissioned in 2010); Baldwin, at 140 mg/L; and Ramara, at 130 mg/L. The remaining ten wells are located within intermediate or deep aquifers, or a shallow aquifer further from urban areas; with average concentrations ranging from 1 to 27 mg/L, well below the CWQG. All of the samples exceed the guideline at the Queensville well; 88% of the samples at the Innisfil well; 72% at Baldwin; and 42% at Ramara. Samples at the rest of the wells meet the CWQG for chloride all of the time. Results are summarized in Table 6-5.

The samples from wells with the highest concentrations of chloride are within shallow aquifers and near urban areas, which suggests these wells are influenced by anthropogenic activities, such as winter salt use.

Trends

Groundwater sampling has been occurring in the LSRCA watershed since 2004, although consistent sampling only began in 2007; therefore it is not possible to determine long-term trends at the present time. However, an examination of the short-term trends over the last five years indicates that many of the wells show seasonal trends (e.g. Baldwin well, Figure 6-10). Seasonal trends can be an indication that they are influenced by seasonal recharge events and the quality of water being recharged. In addition, the more prominent seasonal trends are seen in wells located within shallow aquifers which tend to be more influenced by local recharge events.

Only two stations have shown an increasing trend, Innisfil and Holland Landing. This may be due to increasing winter salt use or the storage of snow in the vicinity of the wells. Conversely, samples from six wells, Cannington (shallow), Aurora (intermediate), Baldwin (shallow), Oro-Medonte (deep), Baldwin (deep), and Ramara (shallow), show a decline in chloride concentration starting between 2007 (Ramara) and 2010 (Baldwin) (Figure 6-10). The remaining wells show no trends. Since the wells that show trends are either within a shallow aquifer or a deep aquifer near urban activities it suggests these wells are influenced by anthropogenic activities, such as winter salt use.

The decline in chloride concentrations the past few years could be due to the decrease in snow, resulting in a reduction in the amount of winter salt being applied. The implementation of salt management plans by municipalities may also be playing a role. Further sampling is needed to understand the long-term trends and confirm the sources of chloride found within the wells.

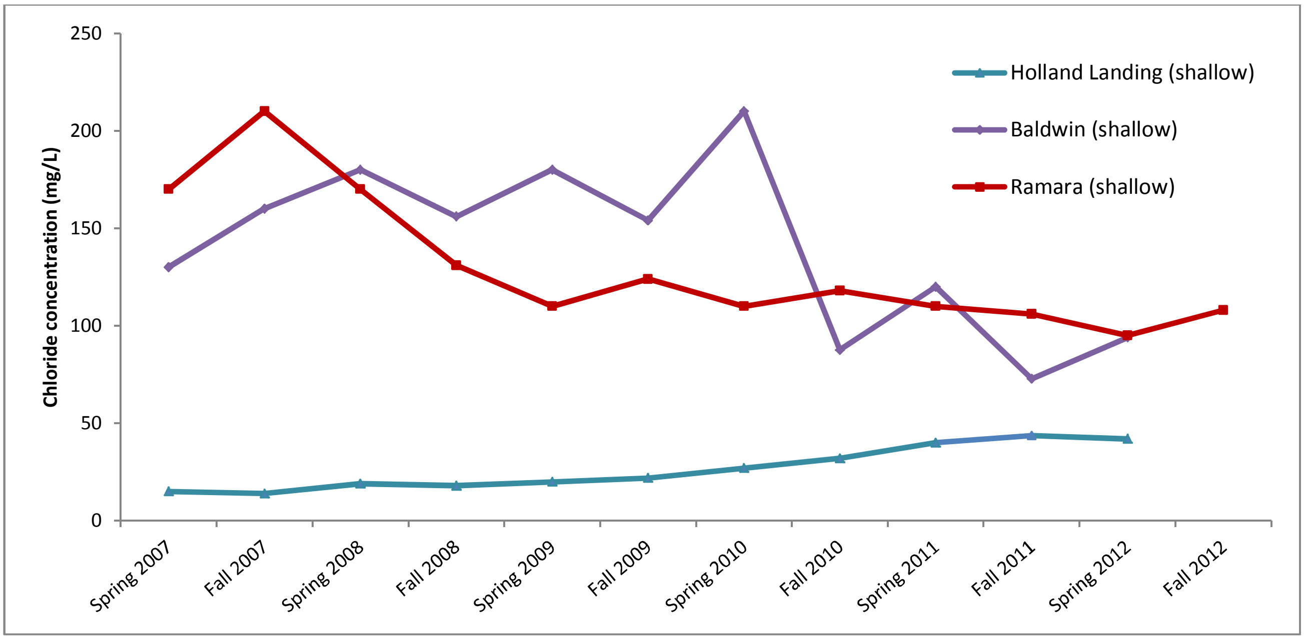


Figure 6-10: Average seasonal chloride concentrations for the Holland Landing, Baldwin, and Ramara PGMN wells (all shallow wells). A decreasing trend is seen in both Baldwin and Ramara, while concentrations are seen to be increasing at Holland Landing.

NITRITE + NITRATE

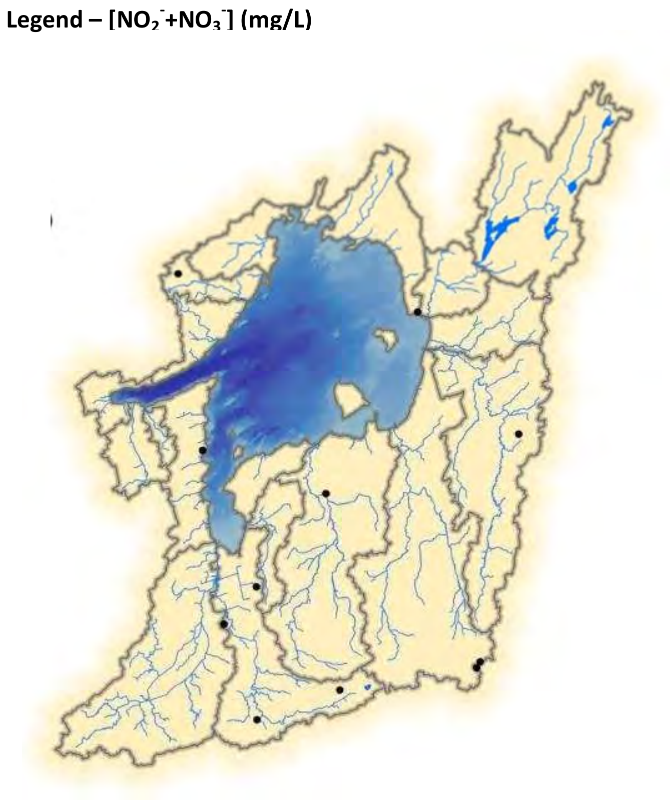


Figure 6-11: Average nitrite+nitrate concentrations (2007-2011) at Lake Simcoe groundwater quality monitoring stations (CWQG is 2.9 mg/L)

Nitrogen occurs naturally in rocks and groundwater. The forms of nitrogen found in water include nitrite (NO_2) and nitrate (NO_3^-). The concentration of nitrogen in groundwater can be significantly increased by anthropogenic activities such as applications of excessive amounts of fertilizer and manure, and poorly functioning septic systems.

The interim Canadian Environmental Quality Guideline for the protection of aquatic life is 2.9 mg/L. All wells within the watershed exhibit low concentrations of nitrate + nitrate, with almost all samples falling well below of the guideline. The average concentrations range from 0.01 to 0.9 mg/L (Figure 6-11). Samples with concentrations being consistently low are normally an indication of background groundwater levels found within the target aquifers. Of all wells, the Aurora (intermediate) well has exhibited the highest concentrations, with values ranging from 0 to 3.56 mg/L.

Trends

Groundwater sampling has been occurring in the LSRCA watershed since 2004 with consistent sampling only since 2007, therefore long-term trends are unknown at the present time. However, an examination of the past five years of data shows no obvious trends.

A few wells show higher concentrations for nitrate + nitrite within the fall samples. This may be an indication that the spring groundwater samples are being diluted during the spring recharge event(s), creating artificially low concentrations (Figure 6-12).

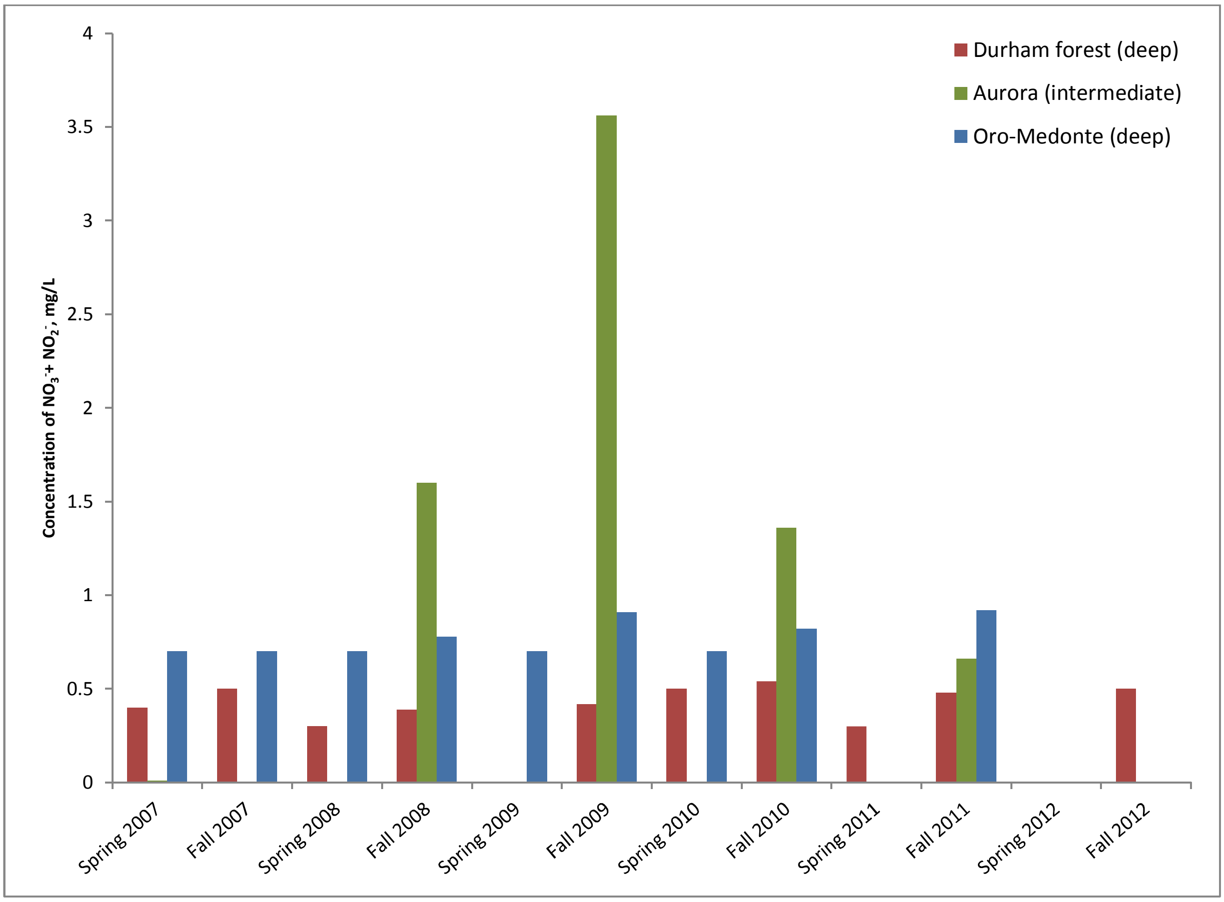


Figure 6-12: Nitrite + nitrite concentrations at selected Provincial Groundwater Monitoring Network stations. These wells generally show higher concentrations in some of the fall samples, which may indicate that samples are being diluted during spring recharge events, creating artificially low concentrations.

STREAM FLOW

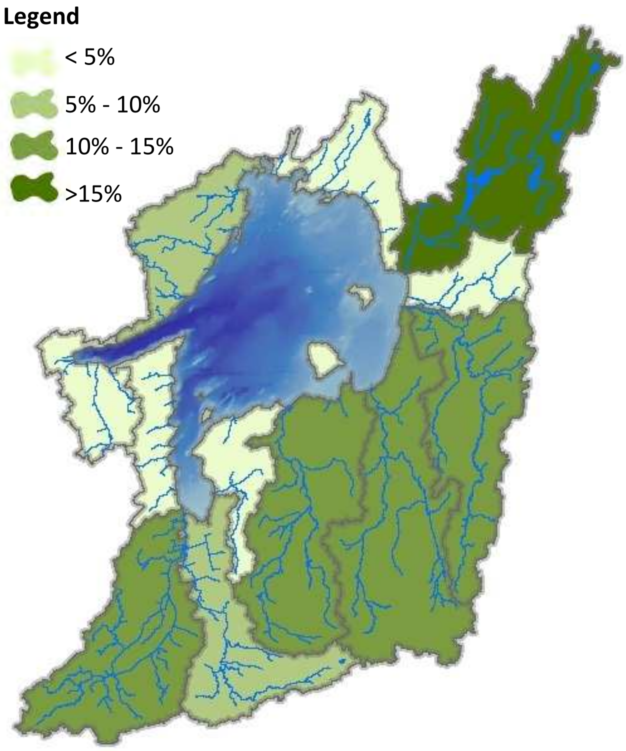


Figure 7-1: Percentage of total tributary flow from each subwatershed into Lake Simcoe for the period 2007-2010

The near continuous data set generated by a typical stream flow station, coupled with the longer period of record, makes stream flow one of the more powerful datasets for characterizing and assessing changes a watershed over time. As stream flow is greatly influenced by the landscape it drains, changes to this landscape will be reflected in changing streamflow thresholds. Established streamflow thresholds also allow for yearly climatic variation to be examined and put into perspective.

2007 – 2010 – Four Years of Highly Variable Flow

The years 2007-2010 were highly unusual from a stream flow perspective in that they captured both the driest and the wettest conditions recorded at a number of gauges. All of the long-term Lake Simcoe flow gauges exhibited much lower than average annual discharge in 2007, greater than average annual discharge in 2008 and 2009, followed by a return to average annual discharge in 2010. Discharge to lake from each tributary during this period is shown in Figure 7-1

2007 – Low Water Conditions

The summer (Jun –Aug) of 2007 was one of the driest recorded in the Lake Simcoe watershed. The East Holland and Pefferlaw Rivers (45- and 41-year records, respectively) observed their lowest summer discharge with average discharges of 0.249 and 1.060 m^3/s, respectively. The Black, Beaver, and Schomberg Rivers all observed their second lowest recorded summer average discharges in 2007 with average discharges of 0.348, 0.188 and 0.029 m^3/s, respectively. See Table 7-1.

2008 – Extreme Winter Flow Events

2008 was much wetter than 2007, with the Beaver River exhibiting the greatest annual discharge in a 41-year period of record (0.147 km^3); 0.038 km^3 or 26% of the record high stream flow occurred in April. The spring freshet alone (Mar-May) accounted for 42% of the 2008 annual flow. The next greatest monthly discharge in 2008 was in December with a volume of 0.020 km^3, almost three times greater than the Beaver River long-term average December discharge volume (Table 7-1). The large December discharge resulted from rain-on-snow events that occurred in late December of 2008. The Pefferlaw, Black, East Holland, and Schomberg Rivers all exhibited annual discharges that were greater than the long-term average and also had very high December discharge volumes resulting from these rain on snow events.

2009 – An Unusually Wet Year

2009 was also an extremely wet year, with the East Holland, Pefferlaw, and Black Rivers all observing their greatest recorded annual discharges with annual volumes of 0.152, 0.106 and 0.065 km^3. The Beaver River observed a very high discharge volume in 2009, second only to 2008, making 2008 and 2009 the two wettest years in the period of record of the Beaver River gauge. The Schomberg River also observed greater than average annual discharge in 2009 but not to the same extent as other Lake Simcoe gauges (Table 7-1). Seasonally, each of the long-term Lake Simcoe gauges had very high winter (Dec-Feb), spring (Mar-May), and summer (Jun-Aug) discharges in 2009. Again the high winter discharges resulted from rain on snow events; these occurred in February of 2009. Despite the depleted snow pack that resulted from the winter melt in 2009, the spring freshet was also very high. Numerous large precipitation events that occurred during March and April augmented the spring freshet flow; moreover approximately 135 mm of precipitation fell in April 2009, twice the long-term average precipitation for April (based on catch from eight precipitation gauges located throughout the Lake Simcoe watershed). The wet winter and extremely large spring freshet saturated the Lake Simcoe watershed maintaining high stream flow levels throughout the summer of 2009 despite only moderate precipitation rates. Fall (Sep – Nov) 2009 had more typical stream flow levels despite low precipitation rates; approximately half of the historic normal precipitation was received in the months of September and November of 2009.

2010 – Normal Flow Conditions Return

2010 brought a return to a more typical flow regime for the Lake Simcoe river systems. Annually, the long-term Lake Simcoe gauges returned to average volumes (Table 7-1) with Pefferlaw, Beaver, Black, East Holland, and Schomberg discharging 0.095, 0.076, 0.061, 0.039 and 0.008 km^3, respectively. The greatest seasonal volume was observed in the spring, with March having the greatest monthly discharge, which is typical for the Lake Simcoe tributaries. The second greatest seasonal flow contribution was seen in the fall, with fairly typical monthly volumes. The third greatest discharge volume in 2010 occurred in the winter, with slightly greater than average discharges resulting from mild temperatures in January and February. Unlike 2008 and 2009, 2010 lacked the large rain-on-snow events that caused the extremely high winter discharge volumes. Summer was the driest season in 2010 with August having the lowest flows of the year.

Table 7-1: Ranked total annual and total winter discharge (1 = wettest on record)

	Period of Record (years)	Greatest annual discharge (rank)				Wettest year in period of record		Greatest winter discharge (rank)				Wettest winter in period of record
River		**2007**	**2008**	**2009**	**2010**		**River**	**2007**	**2008**	**2009**	**2010**	
East Holland [1966-2010]	45	44	6	1	30	2009	East Holland [1966-2010]	17	14	2	29	1997
Schomberg [1967-88, 1991-97, 2003-2010]	37	34	8	3	30	1996	Schomberg [1967-88, 1991-97, 2003-2010]	12	11	4	29	1996
Beaver [1967-02, 2005, 2007-2010]	41	37	1	2	30	2008	Beaver [1967-02, 2005, 2007-2010]	15	8	1	29	2009
Pefferlaw [1969-75, 1980-2010]	38	36	2	1	23	2009	Pefferlaw [1969-75, 1980-2010]	17	8	1	22	2009

BASEFLOW AND QUICKFLOW

The water that flows through streams and rivers could be simplified as being supplied by either precipitation in the form of rain and snow, or by groundwater that discharges to streams from aquifers and surface water bodies such as groundwater-fed wetlands and ponds. Typically, stream flow generated by precipitation events (quickflow) is characterized by high energy, short duration flow with higher water levels and greater water velocities that cause more erosion and greater sediment transport. Stream flow generated by groundwater (baseflow) is lower energy and longer duration, with slower water velocities and less erosional forces and therefore less sediment transport.

Both quickflow and baseflow are important components of a river's natural flow regime and provide the different environmental conditions necessary to support the many ecological, hydrological, and physiological functions of rivers. Hydrograph separation techniques (which are mathematical equations) allow for the partitioning of stream flow into quickflow and baseflow to analyze the flow regime of a river and identify natural or anthropogenic factors that might influence or alter river functions, such as:

Natural influences

- Watershed size, slope, and aspect
- Groundwater discharge
- Precipitation
- Evapotranspiration

Anthropogenic influences

- Water taking
- Water control structures (e.g. dams, diversion canals)
- Land use (e.g. urbanization, agriculture)

Hydrograph separations were performed and annual baseflow index values were calculated for the 2007-2010 monitoring period for five of the Lake Simcoe gauges with a relatively long continuous period of record (i.e. > eight years). The hydrograph separation for the East Holland River is shown in Figure 7-2; this figure displays the relatively small contribution of baseflow to streamflow due to the high levels of impervious surfaces and the associated lack of storage in this urban subwatershed, and also displays the influence of this land use on quickflow. While the baseflow contribution does vary throughout the year, its highs and lows are muted in comparison with the peak flows which tend to increase and peak quickly after a precipitation event or snow melt, and then quickly return to normal. This occurs because of the quick flow of precipitation over paved surfaces, as well as the efficient conveyance of these waters to local watercourses and stormwater ponds. The baseflow index is the percentage of the total annual flow that is generated by baseflow, and is a useful metric for examining the low flow characteristics of a system, including the influence of catchment land use and topography, the stability and significance of groundwater contributions, and the system's response to drought. Baseflow indices for the subwatersheds analyzed are shown in Figure 7-3.

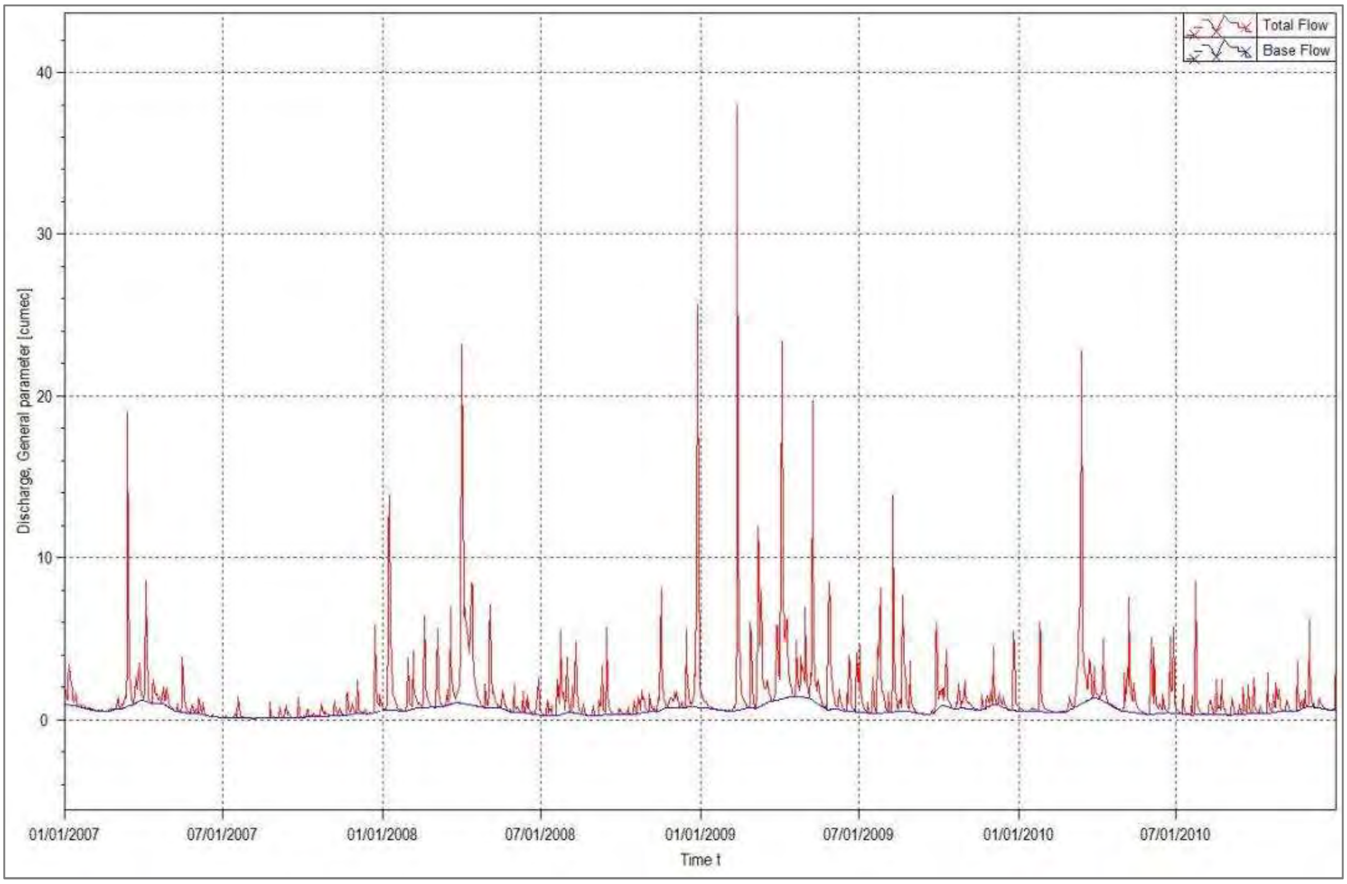


Figure 7-2: Hydrograph separation for the East Holland River using revised UKIH hydrograph separation equation.

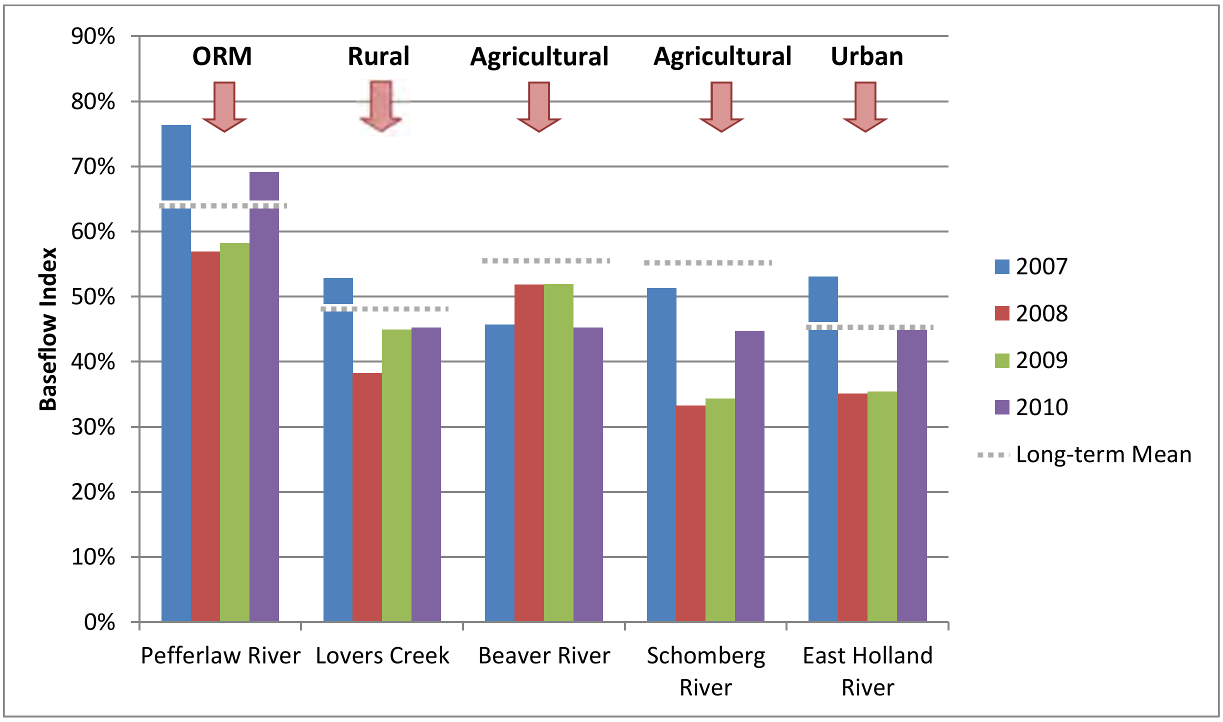


Figure 7-3: Percentage of total annual flow that is comprised of baseflow in five Lake Simcoe subwatersheds, as well as the land uses that influence baseflow contribution in the subwatersheds

The highest baseflow index was recorded in the Pefferlaw River subwatershed in 2007, when climatic conditions were very dry, which was 76.3%. The Pefferlaw River headwaters are located on the Oak Ridges Moraine, a well-documented reservoir and groundwater recharge feature in south-central Ontario. As a result of this connection with the Oak Ridges Moraine, stream flow was augmented by large inputs of groundwater, thus maintaining stream flow volumes during extended periods without precipitation. The Pefferlaw River also has the largest proportion of natural land cover (~ 42% based on Ecological Land Classification) of the five river systems analyzed, which typically contributes to higher baseflow than other land uses. During 2008 and 2009, the annual baseflow indices for Pefferlaw were much lower than in 2007 and also lower than the long-term average baseflow index with values of 56.9 and 58.2%, respectively. This is expected in years with so many large precipitation events; particularly the rain-on-snow events described above, which produce a lot of run-off due to frozen soils that do not permit infiltration and lower transpiration by vegetation. Pefferlaw River had a slightly increased baseflow in 2010, with the higher precipitation levels in 2008-09 having recharged the watershed's storage.

Lovers Creek, and the Schomberg, East Holland, and Beaver Rivers had baseflow index values of 52.8, 53.0, 51.3 and 45.7%, respectively, in 2007. Despite having similar baseflow indices in 2007, each of these systems is very different. These subwatersheds are described in the paragraphs below.

Lovers Creek has a fairly high proportion of natural cover (~35%) most of which is contained in the large wetland complex located in its headwaters. Typically, wetlands help to recharge groundwater, moderate peak flows, and augment baseflow. However, Lovers Creek hydrograph separations and baseflow indices show that a large proportion of the annual flow is generated by quick or event flow; this could be due to the steep topography and naturally straight drainage of the subwatershed, and it is also possible that the drainage canals located within the headwater wetland are preventing the wetlands from performing the functions discussed above. In 2008, the baseflow index was low due to numerous large rainfall events that quickly saturated the available storage, resulting in higher quickflow volumes. The Lovers Creek's baseflow index returned to more normal long-term values in 2009 and 2010.

The Schomberg River also drains a relatively small watershed, but also has a large proportion of agricultural land use (~60%), with drainage canals and cleared agricultural lands that can increase run-off during precipitation events. In 2007 the Schomberg River had a high baseflow index, at 51.3%, but it also had extremely low flow with an average daily minimum flow of 0.005 m^3/s or 432 m^3/day, less than one-fifth of the volume of an Olympic-sized swimming pool. During 2008 and 2009 the Schomberg River had much lower baseflow indices despite having headwater reaches located on the Oak Ridges Moraine; this could be the result of factors including agricultural drainage, subwatershed size and slope, or that the subwatershed may not receive strong groundwater discharge from the Oak Ridges Moraine. In 2010 the baseflow index was still lower than the long-term baseflow index despite a return to more typical climatic conditions.

The East Holland River has the highest level of urban land use of the five river systems analyzed, with 44% of its watershed being comprised of urban land use. Similar to the Schomberg River the East Holland had extremely low flows during the summer of 2007 with a high baseflow index that was more related to low yield than strong groundwater contribution from the Moraine. During the wet conditions of 2008 and 2009 the impervious surfaces and engineered drainage associated with urban land use produced high stormwater run-off volumes and consequently low baseflow indices of 35.1% and 35.4%, respectively. The East Holland returned to more typical flow regime in 2010 with a baseflow index (45.3%), consistent with the long-term average of 45.5%.

In 2007 the Beaver River had the lowest baseflow index of the five systems, at 45.7%. The Beaver River is a large subwatershed with a high level of storage, similar to the Pefferlaw River. The Beaver has the most agricultural land use of the five river systems analyzed, at approximately 64%. The Beaver River also contains large wetland complexes throughout the watershed (~18%) that help to moderate flow during storm events but also tend to store water during prolonged dry conditions, resulting in abnormally low flow conditions. In 2008 and 2009 baseflow index values increased but were still below the long-term average, which is expected during extremely wet years (two greatest annual discharges in back-to-back years for a 41-year record), with large rain-on-snow events that produce a lot of quickflow. In 2010 the Beaver River had a baseflow index of 45.2% which is low compared to the long-term baseflow index of 55.7%. Unlike the Pefferlaw River (a much more groundwater-dominated system, long term baseflow index = 64.2%), which had greater baseflow following the extremely wet 2008 and 2009 period, the Beaver had lower baseflow. This is likely due to the saturation of the Beaver River's surface/shallow soil storage during 2008-09, which increased quickflow during precipitation events in 2010.

TRENDS

Changing Winter and Spring Flows

Monthly average discharges were calculated for the four gauges in the Lake Simcoe watershed with the longest and most complete period of record. For each gauge, yearly seasonal average discharges were calculated and their trends were determined, as shown in Table 7-2 below. While very little change is evident in the summer and fall flow regimes, notable change is obvious in both the winter and spring flows. For each gauge the average winter discharge appears to be increasing and conversely spring discharges are decreasing. Possible causes of this apparent shift in the seasonal flow regimes include land use change, particularly increasing urban areas; increased winter salt application, which results in a greater amount of snow melt; urban heat pollution; and climate change. To further investigate the role of land use change on the shifting flow regimes that we have been seeing, this analysis was also performed on the hydrometric gauge data for a gauge near Washago. This gauge was selected because of its close proximity to Lake Simcoe, its robust period of record (97 years), and because it has undergone very little urbanization. The Washago hydrometric gauge also exhibits an increase in winter flows and consequently lower spring flows, indicating that climate change is the most likely cause of the shifting flow regime.

Most recently this shifting trend in winter flows has resulted in some of the highest winter flows being recorded on a number of rivers. In 2008 the East Holland and Schomberg Rivers observed the second greatest monthly discharge for December in their respective histories. The Beaver and Pefferlaw Rivers observed their greatest recorded December discharges; due to a combination of warmer than average daily air temperatures and 20.8 mm of rain over a four-day period on a substantial snow pack. Again in February 2009, 36.9 mm of rain fell on snow over a period of six days, which produced the second greatest winter average flow for the East Holland River gauge (almost twice the 45 year average), the third greatest winter average flow for the Schomberg River gauge, and the greatest winter flow recorded for the Beaver and Pefferlaw River in 44 and 37 years respectively. Moreover, the Beaver and Pefferlaw Rivers' average winter flows in 2009 were twice as great as their respective long-term average winter flows. As significant as the winter flows were in these two years, their removal from the period of record did not change the increasing trend in winter flows.

Extreme winter melts impact the magnitude of the following spring freshet by depleting the snow pack that would typically melt during March, a key component of the hydrologic regime for this region. An increase in the frequency of winter melts presents a number of additional problems. Winter melt events are more prone to flooding than events during ice free seasons. Ice cover breaks up as water levels increase, causing ice floes that can cause damming, resulting in streams overtopping their banks. Furthermore, because winter soils are typically frozen they are much less pervious and water cannot infiltrate and recharge groundwater stores, which are critical for augmenting stream flow during extended dry periods. As water demands are typically highest in summer, a trend of increasing winter flows and decreasing spring and summer flows may result in water shortages during the times it is needed most.

Table 7-2: Trends for winter and spring flows for four long term flow stations in the Lake Simcoe watershed, and the Washago flow station, which lies just to the north of Lake Simcoe

River flow station	Period of record (years)	Winter flow	Spring flow
East Holland River	44	↑	↓
Beaver River	41	↑	↓
Pefferlaw River	35	↑	↓
Schomberg River	35	↑	↓
Washago Gauge	97	↑	↓

Legend

↑ Increasing Trend

↓ Decreasing Trend

GROUNDWATER LEVELS

Water levels have been continuously monitored since 2003 in each of the 14 Provincial Groundwater Monitoring Network (PGMN) wells and recorded hourly. Daily water levels from 2003 to 2010 have been recently analysed and compared to climatic and seasonal trends. With the exception of four wells (Durham forest [deep well], Ballantrae [deep well], and Oro-Medonte [intermediate and deep wells]), which show influences of nearby pumping, all of the wells tend to reflect background groundwater level conditions. Long-term monitoring of baseline groundwater levels can provide insights on seasonal influences; long term trends; and issues, including drought and climate change assessments.

TRENDS

Long Term Trends

The majority of wells show consistent, long-term water levels over the entire period of record. These wells provide good baseline groundwater levels that can be used to monitor changes in climatic and seasonal conditions over the long term.

However, three of the 14 wells exhibit an upward trend over the period of record. The deep well in Durham forest shows an increase on the order of 2.5 m, the deep well at Ballantrae has increased approximately 1.5 m, and the intermediate well at Aurora has increased 0.7 m. Since the Durham and Ballantrae wells are influenced by pumping, it is unclear whether the upward trend is a result of climatic conditions or from a decrease in the rates and/or volume being pumped (groundwater levels for the Ballantrae well are shown in Figure 7-4). A longer period of record and comparison with nearby pumping rates may provide additional insights into these observed trends.

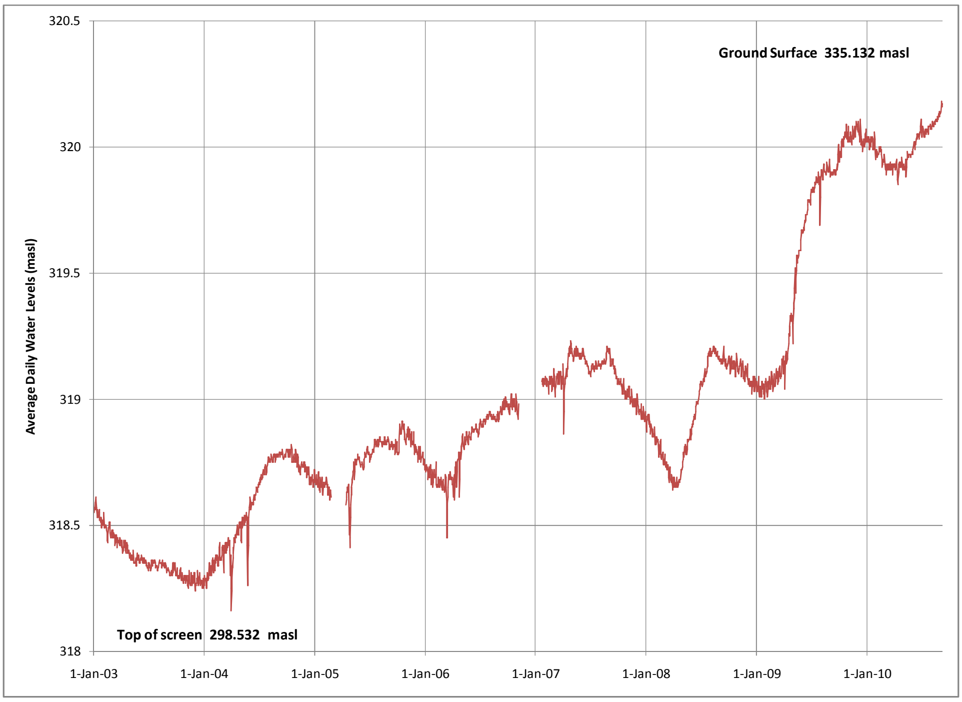


Figure 7-4: Daily groundwater levels for the Ballantrae monitoring well, which shows an upward trend of approximately 1.5 m over the period of record.

Short-Term Trends

Where long-term water level trends in a well may provide an indication of significant climatic shifts and/or local land use changes, short-term water level trends can provide insight into the sustainability of the aquifer on a seasonal basis. For example, shallow wells or wells screened in an unconfined aquifer (an aquifer that is open to receive water from the surface, with no overlying layers of low permeability) may fluctuate significantly more than deep wells during seasonal events/changes. The magnitude of water level changes within the well can provide some indication of the susceptibility of the aquifer to withstand drought and local water taking activities. These trends can also provide insight on the response of the well or aquifer to local precipitation events and whether recharge occurs after a significant delay.

The short term water level trends displayed by the wells are generally influenced by seasonal precipitation and recharge events. All wells, with the exception of those influenced by pumping (Durham forest [deep well], Ballantrae [deep well], and Oro-Medonte [intermediate and deep wells]), display seasonal water level patterns. Water levels that are influenced by nearby pumping activities may still exhibit seasonal effects; however, it is generally more difficult to isolate these trends without additional monitoring data.

In general, higher groundwater levels are observed during the spring and winter in response to snow melt and precipitation events. The lowest groundwater levels are observed during the summer and fall when precipitation is commonly at its lowest. The change in observed water levels due to seasonal fluctuations range from 0.5 m to 3 m between the highest and lowest points.

Figure 7-5 displays precipitation from the Environment Canada Black River flow station compared to daily groundwater levels for the Baldwin shallow, intermediate, and deep wells. Seasonal fluctuations are observed on the order of 1 to 2 m, over the period of record. Groundwater levels peak in the winter/spring and are at their lowest during the summer/fall, which is fairly typical for wells that are influenced by seasonal recharge patterns. In comparison, precipitation peaks in the late summer, indicating that there is a lag between the time that higher levels of precipitation fall and when it seeps into groundwater stores.

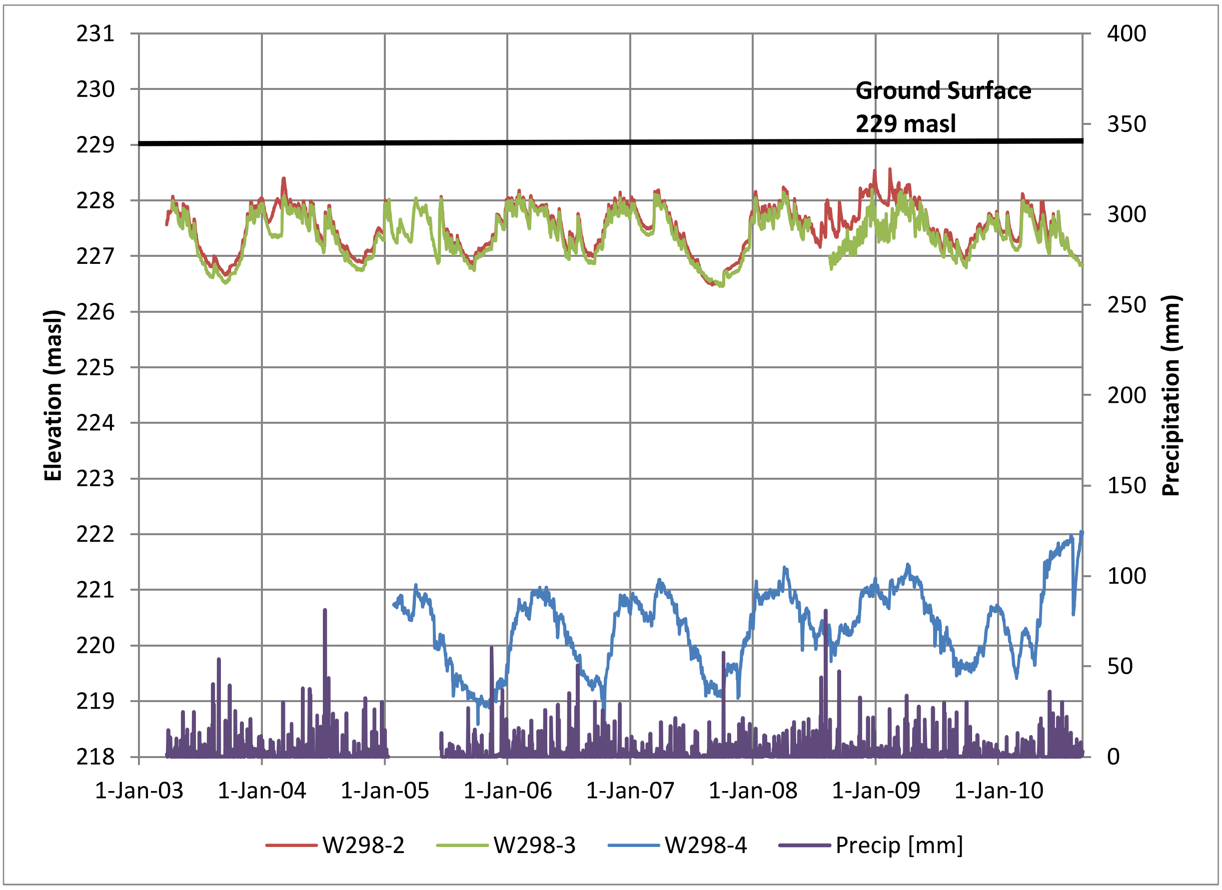


Figure 7-5: Precipitation from the Environment Canada Black River flow station compared to daily groundwater levels for the Baldwin shallow, intermediate, and deep wells (W0000298-2, W0000298-3, & W0000298-4), shows seasonal fluctuations on the order of 1 to 2 m, over the period of record.

Additional insights can be gained by monitoring multiple intervals (depths) at the same location. As seen from Figure 7-5, the shallow and intermediate wells at Baldwin show the same water levels. Although these screens are separated by more than 20 metres and some till units, the water levels indicate that the screens are located in the same water bearing zone (i.e. aquifer). The deep bedrock well (W0000298-4) displays lower water levels with the same pattern, indicating that there is a connection between the overlying sediment and the bedrock aquifer. Knowledge of this connection can be useful in undertaking groundwater modelling and mapping exercises that can be used in the management of groundwater resources.

FISH

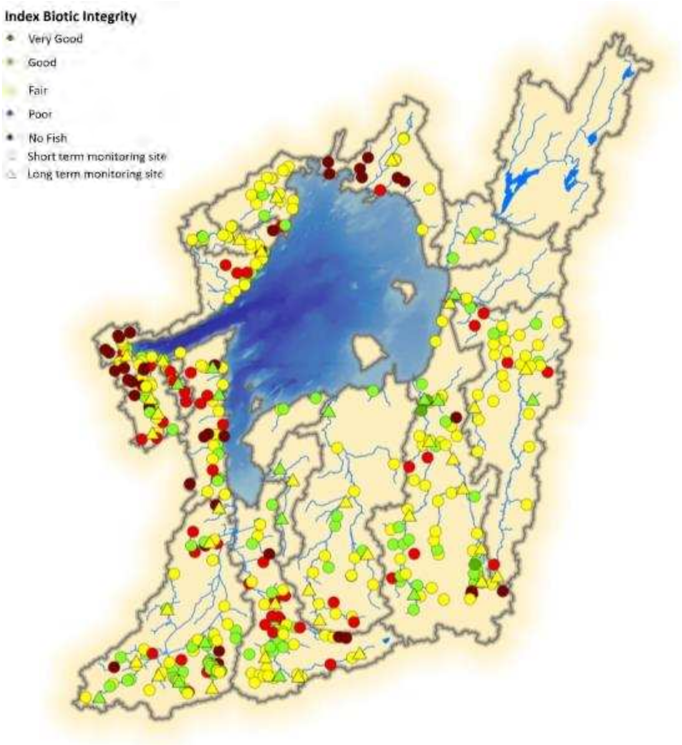


Figure 8-1: Index of biotic integrity scores at fisheries monitoring sites throughout the Lake Simcoe watershed

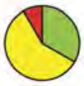
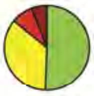
Fish are sensitive to a great number of stresses including degraded water quality, increasing temperatures, changing flow regimes, and the removal of instream or bankside habitat. While they are able to move quickly in response to a sudden change in conditions (e.g. a release of a chemical into the system) and are therefore not a good indicator of these types of issues, prolonged stresses will eventually cause a shift in the fish community from one that is sensitive and requires clean, cool water to survive to one that is more tolerant of degraded conditions. A fish Index of Biotic Integrity is used to evaluate the ecological integrity of the fish communities within the Lake Simcoe watershed. There are varying numbers of monitoring sites in each subwatershed, with the West Holland River subwatershed having the most at 85, and the Whites Creek subwatershed having the least, with only two (Figure 8-1). This needs to be taken into consideration when comparing subwatershed results.

Three monitoring sites were rated as 'Very Good', all located in the Pefferlaw (Uxbridge) River subwatershed. The Georgina Creeks and Maskinonge River subwatersheds share the highest percentage (67%) of 'Good' sites, however since they both only have three monitoring sites, these results may not be fully representative of the entire system. Nine of the 17 monitored subwatersheds had fish caught at every monitoring site; possible issues at the eight sites where no fish were captured include barriers or lack of flow.

The Barrie Creeks and Ramara Creeks subwatersheds have the lowest scores with a large percentage of sites having no fish (42% and 38%, respectively) and a small percentage of sites having a rating of "Good' or better (13% and 15%, respectively). Results for each subwatershed are summarized in Table 8-1

LSRCA electrofishing crew collecting fisheries samples

Table 8-1: Proportion of sites with each Index of Biotic Integrity rating in each Lake Simcoe subwatershed

Subwatershed	% of sites per rating	# of Sites	Subwatershed	% of sites per rating	# of Sites
Barrie Creeks		24	**Maskinonge River**		3
Beaver River		36	**Oro Creeks North**		20
Black River		24	**Oro Creeks South**		11
East Holland River		55	**Pefferlaw/ Uxbridge**		74
Georgina Creeks		3	**Ramara Creeks**		13
Hawkestone Creek		26	**Talbot River**		4
Hewitt's Creek		14	**West Holland River**		85
Innisfil Creeks		31	**Whites Creek**		2
Lovers Creek		26			

IBI Ratings

🟩 Very Good	🟥 Poor
🟩 Good	🟥 No Fish
🟨 Fair	

Trends

The trends of the 30 long term fish monitoring stations in the Lake Simcoe watershed were looked at over a 10 year period (2002-2011) to determine if there had been any significant changes. Significance was evaluated using regression analysis on the IBI scores calculated over the 10 year period. This analysis identified seven sites showing a significant trend, while the other 23 long term sites in the watershed are in various states (slight decline, slight improvement, or static) but are not showing statistically significant changes. Of the seven sites showing trends (Table 8-2), six show a declining IBI score (indicating there are fewer coldwater species, less species diversity, and/or an increase of invasive species), with only one site in the West Holland River (WH-21) subwatershed showing a significant improvement (indicating an increase in coldwater species, increased species diversity, and/or fewer invasive species).

Site WH-21, located in a well-buffered section of Pottageville Creek in the upper portion of the West Holland River subwatershed, is the site showing a significant improvement. In comparison to the 2003 and 2006 sampling season when no brook trout were captured and there was low species diversity, the 2008 and 2010 sampling seasons had several adult brook trout caught and great species diversity, resulting in a significant increase in the IBI scores.

In the Pefferlaw River subwatershed there are four sites that are showing a significant declining IBI score, all of which are in the mid to lower portions of the subwatershed. These declining scores are associated with the loss of brook trout and/or mottled sculpin over the past several years, and, at site PF1-01 in the lower reaches, due to the increasing presence of round goby (invasive) that is displacing native species.

Table 8-2: Long term fish monitoring sites showing significant trends, and causes of these trends.

Subwatershed	Site	Trend	Cause
West Holland River	WH-21	↑	New brook trout
Pefferlaw River (includes Uxbridge Brook)	PF1-01	↓	Round goby
	PF1-18	↓	
	PF1-26	↓	
	UX1-04	↓	
Beaver River	BVRV-02	↓	Loss of diversity
East Holland River	EH-03	↓	Lack of brook trout, loss of diversity

Brook trout (*Salvelinus fontinalis*)

BENTHIC INVERTEBRATES

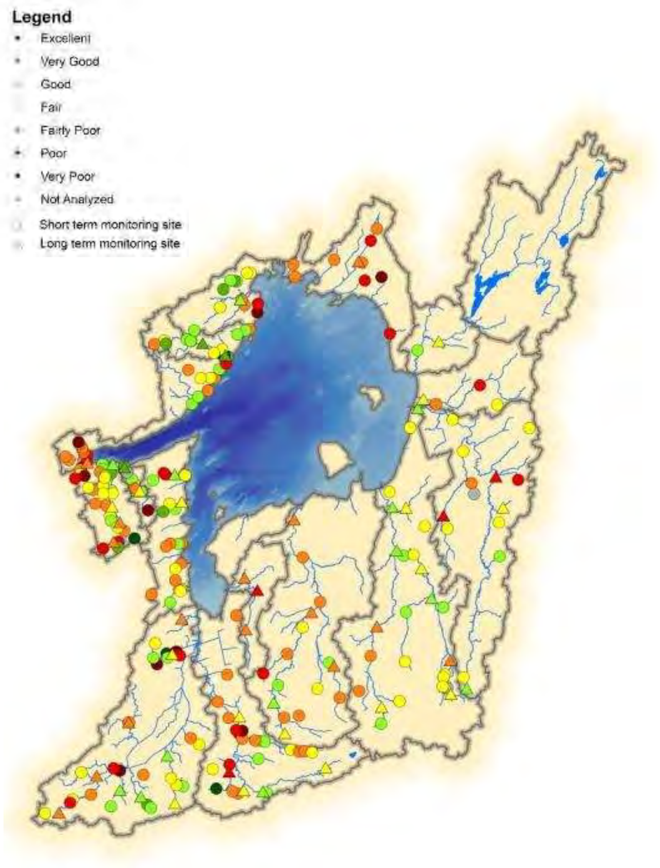


Figure 8-2: Hilsenhoff index of Biotic Integrity scores for Lake Simcoe benthic invertebrate stations

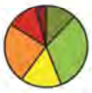
Benthic invertebrates, the aquatic insects, crustaceans, molluscs, and worms that dwell on the stream bottom, are an ideal indicator of water quality as different species have different tolerances to factors such as nutrient enrichment, dissolved solids, oxygen, and temperature. The presence or absence of a certain species can be used to help determine water quality at a given site.

Unlike fish, benthic invertebrates are not able to move quickly in response to a sudden change in conditions (e.g. a release of a chemical into the system) and are therefore a good indicator of these types of issues. Long term changes also impact benthic communities, causing them to shift from one that is sensitive and requires clean, cool water to survive, to one that is more tolerant of lower quality conditions.

The Hilsenhoff Biotic Index is used to evaluate the ecological integrity of the benthic invertebrate communities within the Lake Simcoe watershed. In total, 234 sites were monitored for benthic invertebrate species from 2002 to 2011 (Figure 8-2). However, the number of monitoring sites in each subwatershed varies, with the West Holland River subwatershed having the most with 37, and the Georgina Creeks subwatershed having the least, with no monitoring sites. This needs to be taken into consideration when comparing subwatershed results.

Both the Hawkestone Creek and the Hewitt’s Creek subwatersheds have the highest percentage of ‘Excellent’ sites (35% and 31%, respectively). The Barrie Creeks subwatershed has the lowest rankings with 23% of its sites ranked as ‘Very Poor’ and no sites being ranked ‘Good’ or better. The results for each subwatershed are summarized in Table 8-3.

Table 8-3: Number of sites with each Hilsenhoff Biotic Index score in each Lake Simcoe subwatershed

Subwatershed	% of sites per rating	# of Sites	Subwatershed	% of sites per rating	# of Sites
Barrie Creeks		22	**Maskinonge River**		3
Beaver River		14	**Oro Creeks North**		14
Black River		16	**Oro Creeks South**		10
East Holland River		27	**Pefferlaw/ Uxbridge**		25
Georgina Creeks	N/A	0	**Ramara Creeks**		1
Hawkestone Creek		17	**Talbot River**		2
Hewitt's Creek		13	**West Holland River**		37
Innisfil Creeks		22	**Whites Creek**		4
Lovers Creek		21			

Hilsenhoff Ratings

- ■ Excellent
- ■ Very Good
- ■ Good
- ■ Fair
- ■ Fairly Poor
- ■ Poor
- ■ Very Poor

Trends

The trends of the 19 long term benthic monitoring sites within the Lake Simcoe watershed were looked at over a 10-year period (2002-2011) to determine if there had been any significant changes. Significance was evaluated using regression analysis on the HBI scores calculated over the 10-year period. This analysis shows three of the 19 sites had significant long-term trends (Table 8-4), while the other 16 sites within the watershed are in various states (slight decline, slight improvement, or static) and are not showing a significant change.

Site WH-35 in the West Holland River subwatershed is located near the outlet of Kettleby Creek (a headwater tributary), with a wide buffer area in a mainly agricultural setting. The long term trend for this site indicated a significant improvement over the sampling period. The greatest change was seen between 2007 and 2009, with Hilsenhoff scores significantly decreasing (a higher quality environment reflects a lower score, while more degraded sites will have a higher Hilsenhoff score) from 4.04 to 3.67. This was a result of fewer midges (4.84% to 1.52%), which are pollution tolerant, and an increase in sensitive shredder species (from the Ephemeroptera, Plecoptera and Trichoptera – or EPT – orders; see Figure 8-3) from 67.74% to 70.45%. Site WHI1-01 in White's Creek subwatershed is also surrounded by agricultural landuses, but with little to no buffer at the outlet of White's Creek. Despite minimal riparian area, WHI-01 went from a Hilsenhoff rating of Good to Very Good between 2007 and 2009. This is a result of a decrease in midges (17.89% to 6.03%) and an increase in EPT species (27.37% to 68.10%).

The only site to show a significantly increasing Hilsenhoff score (which corresponds to declining community health) is located within the Beaver River subwatershed; Site BVRV-02 is located in Vrooman Creek in a generally marshy area with large buffer areas. Again, between the years of 2007 to 2009 there was a change in the Hilsenhoff scores from a rating of Fair to Fairly Poor. This significant decline is a result of an increase in worm species (6.45% to 21.14%) and crustacean species (4.30% to 40.54%), both of which have a higher tolerance to organic pollution and increase the Hilsenhoff scores for a poorer rating.

Table 8-4: Long term benthic invertebrate monitoring sites showing significant trends

Subwatershed	Site	Trend	Cause
West Holland River	WH-35	↑	Fewer pollution tolerant species, increase in EPT species
White's Creek	WHI1-01	↑	Fewer pollution tolerant species, increase in EPT species
Beaver River	BVRV-02	↓	Increase in pollution tolerant worm and crustacean species

Figure 8-4: Benthic invertebrate orders of note - (A) Ephemeroptera (mayfly), (B)Plecoptera (stonefly), and (C) Trichoptera (caddisfly)

TEMPERATURE

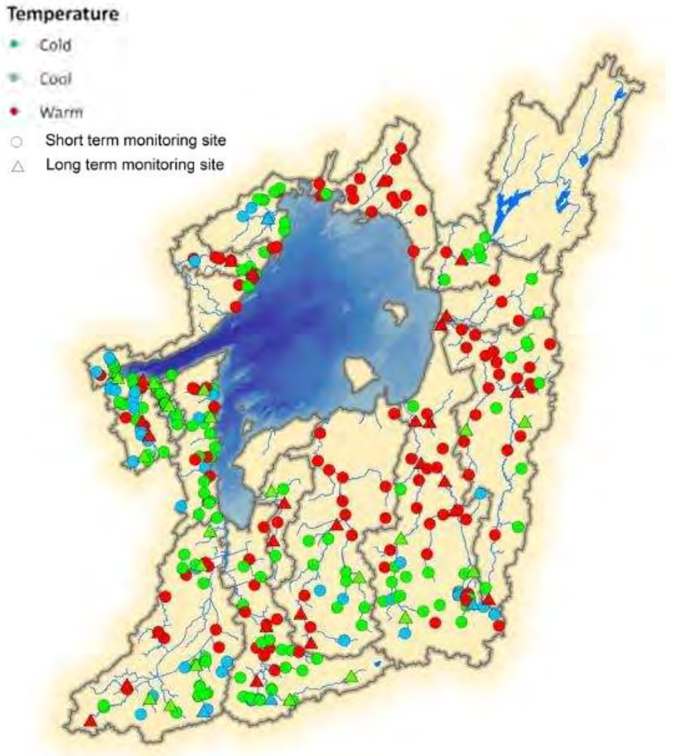


Figure 8-5: Water temperature classifications at Lake Simcoe monitoring sites

The water temperature of a system can dictate the composition of the aquatic communities, as well as determine how systems are managed. Water temperature is affected by natural conditions such as precipitation, groundwater inputs, and natural features such as wetlands. Anthropogenic alterations to watercourses and the surrounding landscape can negatively impact the water temperature of a system. For example, creating online ponds, removing stream bank vegetation, and creating impervious surfaces can all increase the water temperature in a stream, resulting in adverse effects on fish and benthic invertebrate populations.

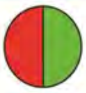
Temperature monitoring was undertaken at 338 sites within the Lake Simcoe watershed between 2003 and 2011. Of these, 53 sites recorded cold water temperatures, 151 were recorded as cool water, and 134 sites recorded warm water temperatures (Figure 8-5). It should be noted that the temperature loggers collect data at a single point and only represent the temperatures at that location (cannot be extrapolated to a reach, tributary, or watershed).

The majority of the subwatersheds with headwater streams on the Oak Ridges Moraine (Pefferlaw/Uxbridge, Black, Beaver, East Holland, and West Holland Rivers) recorded cold water temperatures in this area, mainly due to groundwater influence. Downstream of these areas, the sites tend to record warmer temperatures as the watercourses pass through wetlands, urban areas, and experience the natural warming that takes places as streams grow wider. The headwater areas in the south and west of the watershed typically have cooler systems, containing cold water fish species such as brook trout. Warmer temperatures are being seen in areas of the watershed where watercourses are being used as municipal drains and there are fewer groundwater inputs. Results are summarized in Table 8-5.

The headwaters of streams in the Oro Moraine are very similar to those on the Oak Ridges Moraine. Factors such as land use change, water taking, and the removal of bank vegetation are causing thermal degradation in the middle and lower reaches in the subwatersheds in this area. For example, Hawkestone Creek has only one of its 17 monitoring sites recording cold water temperatures, and only warm water temperatures through its middle sections.

Historically, watercourses within the Barrie Creeks subwatershed were cold water. Despite the intense urban build-up of the area, many of the creeks have remained mostly cool or cold water. The creeks in the Innisfil Creeks subwatershed were also likely cold water, supported by groundwater inputs. With the removal of streambank vegetation for agriculture and the increase in urban area, many are changing to cool and warm water systems.

Table 8-5: Proportion of sites in each subwatershed that are classified as cold, cool, and warm water

Subwatershed	% of sites per rating	# of Sites	Subwatershed	% of sites per rating	# of Sites
Barrie Creeks		19	**Maskinonge River**		6
Beaver River		32	**Oro Creeks North**		10
Black River		27	**Oro Creeks South**		2
East Holland River		38	**Pefferlaw/ Uxbridge**		58
Georgina Creeks	N/A	0	**Ramara Creeks**		8
Hawkestone Creek		17	**Talbot River**		7
Hewitt's Creek		16	**West Holland River**		44
Innisfil Creeks		29	**Whites Creek**		6
Lovers Creek		19			

Temperature Ratings

🟦 Cold 🟩 Cool 🟥 Warm

Trends

Trends for 36 of the long-term temperature monitoring sites within the Lake Simcoe watershed were evaluated (2003-2011). Significance was evaluated using regression analysis on the average daily maximum temperature for each year calculated over the nine year period. Results of this analysis show six of the 36 sites had significant long-term trends, while the other 30 sites within the watershed are in various states (slight increasing temperature, slightly decreasing temperature, or static) and are not showing a significant change. Of the six showing significant trends, four are exhibiting a significant increase in temperature over the nine year study period (Figure 8-6, Table 8-6). Two of these sites are located in the upstream reaches of the West Holland subwatershed (WH-24, WH-87), while the other two are in the middle and lower reaches of the Pefferlaw River subwatershed (PF1-36, UX1-04). The two sites that showed a decreasing temperature trend were in the upstream area of the East Holland River (EH-57) and at the mouth of White's Creek (WHI1-01) subwatersheds.

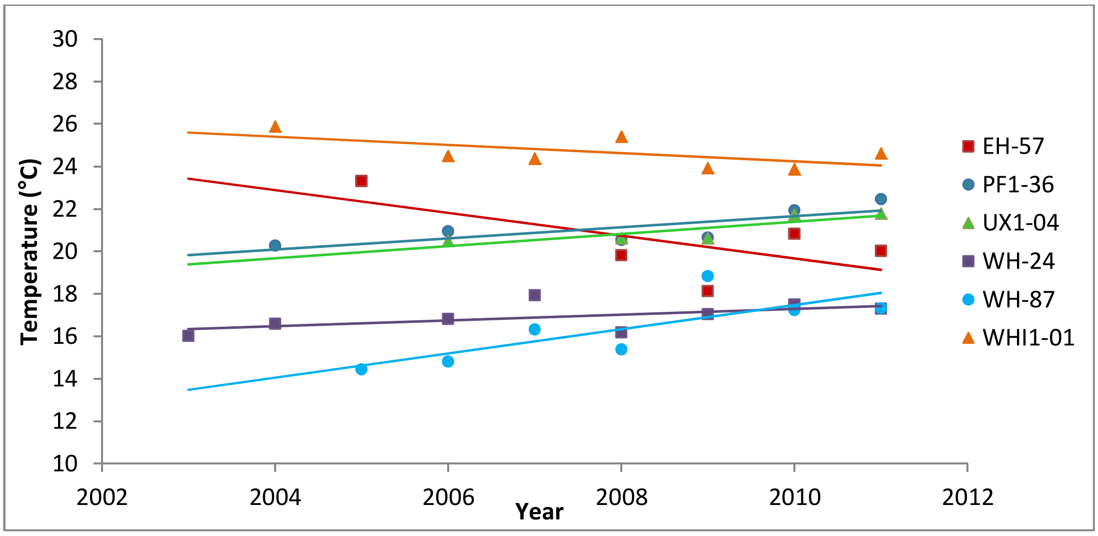
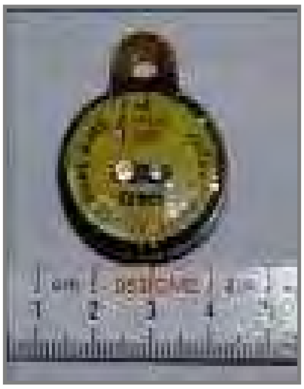


Figure 8-6: Trends in average daily maximum temperature (2003-2011).

Table 8-6: Trends in average daily maximum temperature (2003-2011).

Monitoring station	Trend (2003-2011)
PF1-36	↑
UX1-04	↑
WH-24	↑
WH-87	↑
EH-57	↓
WHI1-01	↓



Temperature Logger

DIATOMS

Diatoms (Bacillariophyceae) are single-celled algae encased in frustules of silicon dioxide that live free-floating in the water column or attached to rocks, plants, sand grains, and other substrates. As these algae have well-studied ecological optima and tolerances to most environmental variables, the species assemblages can be related to environmental conditions and used to assess and track a wide variety of changes.

As an example, Table 8-7 shows the reliability of how some key diatom-inferred environmental variables are correlated with measured water chemistry values in Lovers and Hawkestone Creeks (Figure 8-7 displays some of the diatoms found through this sampling). Diatom samples were collected along with water chemistry and benthic invertebrates from all stream habitats. After identification under a microscope, diatoms were added with water chemistry data to a "calibration set" which relates species to environmental conditions. This data set, containing information from over 115 sites in Southern Ontario, and another 1240 sites in the continental United States, was then used to infer environmental conditions at our sample sites.

Table 8-7: Comparison of diatom-inferred and measured data for key environmental indicators at Lovers and Hawkestone Creeks.

Limnological Variable	Lovers Creek		Hawkestone	
	Diatom inferred	Measured	Diatom inferred	Measured
pH	8.1	8.1	7.9	8.1
Temperature (°C)	18.9	17.9	19.5	17.9
Dissolved oxygen (mg·L^{-1})	9.3	9.1	9.4	9.0
Total phosphorus (mg·L^{-1})	0.03	0.03	0.02	0.02
Total nitrogen (TKN) (mg·L^{-1})	0.74	0.50	0.71	0.60

Continuation of this study in future years will provide a low-cost method of tracking environmental changes in the Lake Simcoe watershed.

Figure 8-7: Photograph of diatom assemblage (mounted on a microscope slide) collected from Lovers Creek. White scale bar is 10 µm (0.01 mm) in length

INVASIVE SPECIES

The traits possessed by invasive species, including aggressive feeding, rapid growth, prolific reproduction, and the ability to tolerate and adapt to a wide range of habitat conditions, enable them to outcompete native species for food, water, sunlight, nutrients, and space. The replacement of native species with introduced affects the balance of the ecosystem, as species that relied on the native species for food, shelter, and other functions now either have to move to another area, or must utilize another source that is less desirable. Ecosystems that are already under stress are particularly vulnerable to invasion by non-native species, as the existing ecosystem is not typically robust enough to maintain viable population of native species as the invasive species becomes more established.

In the Lake Simcoe watershed, there are a total of 13 aquatic invasive species, consisting of fish (five), aquatic invertebrates (five) and aquatic plants (three), as well as two aquatic diseases (Table 8-7).

Table 8-7: Aquatic invasive species in the Lake Simcoe watershed (source: LSRCA, MNR and www.fishingsimcoe.com).

Common Name	Scientific Name	Year of first Capture
Fish		
Common carp	*Cyprinus carpo*	1896
Rainbow smelt	*Osmerus mordax*	1962
Black crappie	*Pomoxis nigromaculatus*	1987
Bluegill	*Lepomis macrochirus*	2000
Round goby	*Neogobius melanostomus*	2004
Aquatic invertebrates		
Zebra mussels	*Dreissena polymorpha*	Early 1990s
Spiny waterflea	*Bythotrephes longimanus*	1993
Quagga mussels	*Dreissena rostriformis bugensis*	2004
Rusty crayfish	*Oronectes rusticus*	2004
Eurasian amphipod	*Echinogammarus ischnus*	2005
Submergent aquatic plants		
Curly-leaf pondweed	*Potamogeton crispus*	1961-1984
Eurasian watermilfoil	*Myriophillum spicatum*	1984
Red algae	*Bangia atropurpurea*	1980
Starry Stonewort	*Nitellopsis obtusa*	2010
Aquatic diseases		
Koi Herpes Virus (KHV)		2008
Viral Hemorrhagic Septicemia (VHS)		2011

The round goby (*Neogobius melanostomus*) is the species that is currently of greatest concern in the watershed. Round gobies are native to Europe and were released into Canadian waters via ballast from international ships. They are an aggressive and fertile sculpin-like species that can out-compete native species for space and food. The round goby was first discovered in the Pefferlaw River in 2004 by an astute angler, and their presence was confirmed in June 2005 by the LSRCA and OMNR. In October 2005, efforts were made to eradicate the gobies by application of the pesticide Rotenone by licensed applicators and dead fish were removed from the system.

Round goby
Photo Credit: Gary Blight

Unfortunately, the gobies survived/rebounded and spread to the lake. In 2009, round gobies were captured at the mouths of the Black River and Beaver River, and in 2011 were captured at the mouths of Lovers Creek and Hewitt's Creek (Figure 8-8). They have also been captured in the vicinity of Georgina and Thorah Islands. LSRCA and MNR will continue to monitor the spread of this species; however, it would appear that their establishment throughout the lake and its tributaries is inevitable.

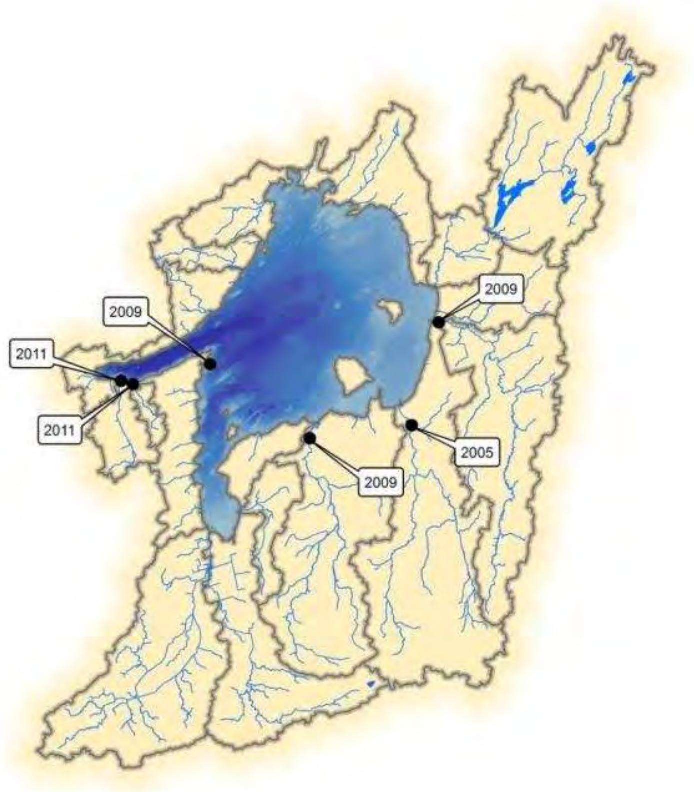


Figure 8-8: The spread of round goby around the Lake Simcoe watershed since their discovery in 2005 using LSRCA data set

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Period of record for Lake Simcoe water quality stations

Station Name	Year of station initiation	Station Name	Year of station initiation
Upper Schomberg	1977	Beaver	1972
North Schomberg	1993	Whites	1994
Kettleby	1993	Talbot	1993
West Holland	1965	Ramara	2009
East Holland	1993	Bluffs	2008
Tannery	1965	Hawkestone	1993
Maskinonge	1985	Hotchkiss	2008
Mount Albert	1971	Lovers	1974
Black	1993	Hewitt’s	2008
Pefferlaw	1973	Leonards	2008
Uxbridge	2002		

For more information, or for a copy of this guide in an alternative format, please contact LSRCA at 905-895-1281.

Lake Simcoe Region
conservation authority