# ANNUAL WATER BALANCES AND PHOSPHORUS LOADING

# FOR LAKE SIMCOE

# (1990 - 1998)

**LAKE SIMCOE ENVIRONMENTAL MANAGEMENT STRATEGY**

**IMPLEMENTATION PHASE II**

**TECHNICAL REPORT NO. Imp. A. 4**

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## Executive Summary

One of the primary objectives of Phase II of the Lake Simcoe Environmental Management Strategy was to estimate the total phosphorus loading upon the Lake Simcoe catchment. This report presents methods and results relating to that objective, based on the hydrologic water year of June 1st to May 31st of the subsequent year 1990 - 1998 . A three-stage analysis of annual water balances was performed on the hydrological data collected throughout the study period . An annual summary of total phosphorus loads (kg $yr^{-1}$) to Lake Simcoe is presented in which five point source categories are proportionally described. The atmospheric and tributary sources constitute the greatest overall contribution. Atmospheric contribution ranged from 23% (1996-97) to 56% (1993-1994) while tributaries accounted for 17% (1994-95) to 48% (1992-93) of total phosphorus loads. Urban non-point sources were the third largest source, ranging from 9% (1990-91) to 22% (1994-95 & 1997-98). Urban point sources (sewage treatment plants) and vegetable polders contributed the least with very similar proportions of total phosphorus load to Lake Simcoe. The urban point source ranged from 3% (1990-91, & 1992-93) to 8% (1994-95) and the vegetable polders were from 2% (1994-95) to 8% (1995-96 & 1996-97) of total phosphorus loads.

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## INTRODUCTION

The Lake Simcoe Environmental Management Strategy (LSEMS) is a joint program with MOE, MNR, OMAFRA, the Lake Simcoe Region Conservation Authority (LSRCA) and the Regional Municipalities of York, Durham and Simcoe County as participating agencies. Phase I of the LSEMS was implemented in 1990 - 1994, and was followed by Phase II which operated over the period 1995 - 1999. The goal of LSEMS is to restore a self sustaining cold-water fishery in Lake Simcoe. The cold-water fish community is the focus of the goal statement because it is an excellent indicator of water quality and overall ecosystem health. Lake Simcoe has seen a decline in these fish species, along with an increase in algal blooms and aquatic weed growth. These problems stem from an excess amount of the nutrient phosphorus entering Lake Simcoe as a result of human activities.

A Memorandum of Understanding outlines the roles and responsibilities of each of the partners involved in implementing the Lake Simcoe Environmental Management Strategy. Objectives include reducing phosphorus input associated with urban development and inputs originating from rural agricultural activities.(LSEMS 1995)

A major component of these studies is the development of phosphorus mass balance models to predict the impact of phosphorus input on lake water quality. Quantitative hydrological information is required to construct catchment and lake water balances, and as input to the phosphorus mass balance models. This report presents data needed to construct the hydrological balances together with TP loading data for the period 1990 to 1998.

### Description of the Study Area

The Lake Simcoe watershed (latitude 44$^{o}$ 25' longitude 79$^{o}$ 20') is located 50 km north of Toronto between Lake Ontario and Georgian Bay on Lake Huron . The watershed occupies a total surface area of 3634 km$^2$, of which

79 % or 2914 km$^2$ is terrestrial. Lake Simcoe has a surface area of 720 km$^2$. The watershed consists of 35 sub-catchments. Five major tributaries (Talbot connected to the Trent Severn Waterway , Beaver, Black, Pefferlaw and Holland Rivers) account for 58 % of the terrestrial watershed area. The lake drains into Lake Couchiching through the Atherley Narrows and into Georgian Bay through the Trent Severn Waterway.

Nine sub-catchments have been monitored and sampled routinely since 1990 for stream flow and water quality parameters. A further three stations (chemistry only) were added in 1993. Meteorological parameters and precipitation chemistry data were routinely sampled at two stations since 1995. The location of all monitoring stations and meteorological sampling sites are shown in Figures 1& 2. Drainage basin areas for each sub-catchment within the watershed are listed in Table 1. Detailed information describing surficial geology underlying the study catchment is described elsewhere (LSEMS 1995).

## METHODS

Agencies contributing data and the period of operation of hydrological and meteorological stations used for the study are summarized in Table 2a. Analysis of the hydrologic data, including estimation of mean daily flow for each of the sub-catchments and meteorological data, allowed for the calculation of catchment water balances which are discussed in the section entitled ANNUAL WATERBALANCE . Monthly and annual summaries of total phosphorus inputs to Lake Simcoe are described in the section entitled TOTAL PHOSPHORUS LOADING FROM SUB-WATERSHEDS.

### Hydrometeorologic Network

Monitoring of streams within the Lake Simcoe area began in 1982. Each sub-catchment was identified with a specific alphabetic abbreviation (e.g., HL = "Holland River at Holland Landing" Lake Simcoe catchment,) presented in Tables 2A and 2B. In 1995, two meteorological stations were established within the study area. These stations were identified with a specific alphabetical abbreviation (e.g., SCP = Scanlon Creek, precipitation). The meteorological data prior to 1995 were obtained from Environment Canada's Meteorological Services, Ontario Climate Centre .

### Mean Daily Discharge from Inlets

The mean daily discharge is defined as channelized stream flow measured at hydrological gauging stations (open flow gauges). Values of mean daily discharge for the gauged watersheds (l $sec^{-1}$) have been computed for each tributary using automated stream flow procedure (Environment Canada Water Resources Branch 1974). In the event that flow data were missing, flow estimates were created by (1) straight line interpolation between proximal values, or (2) by modeling stream flow as a function of flow at other gauged streams in the Lake Simcoe catchment. Stage discharge relationships for five study sites (Beaver River, Pefferlaw River, Holland River at Holland Landing, Black River at Baldwin and Upper Schomberg) were obtained from Environment Canada, Water Survey Branch. Two study sites have more than one relationship (Kettleby and North Schomberg). Initial relationships established in 1985 were used between 1990 and 1993,with further refinements made in 1999 with the inclusion of 1993-1998 data. Expressing monthly discharge as unit areal runoff (total monthly discharge ($m^3$ $mo^{-1}$ ) / watershed area {Table 1($m^2$ )} factors out sub-catchment area and facilitates between sub-catchment comparison of monthly discharge. Figures 3 and 4 show areal runoff for watersheds on the eastern and southern aspects. The annual discharge data are further standardized by expressing unit runoff as Yield (annual areal runoff {Table 4(m $yr^{-1}$)} / annual precipitation depth {Table 5 (m $yr^{-1}$ )}. Yield is the fraction of the annual precipitation which is lost from the sub-catchment as stream flow.

### Total Urban Point Source Discharge

Total discharge from sewage treatment plants ($m^3$) was collated by the Ministry of the Environment Central Region on an annual basis. Stations included in the water balance were (BR WPCP, OR WPCP, LG WPCP, BD WPCP and HL LG) Table 2a. These municipalities obtain their potable water source from ground water, and as such, their discharge is considered as supply to the lake.

The nine stations excluded (Table 2a) were omitted for two reasons.

(1) Mount Albert, Beaver River Lagoons 1 & 2, Uxbridge Brook and Schomberg Lagoon discharges were accounted for by our gauging stations located below these facilities.

(2) Keswick, Innisfil (Alcona), the Lake Simcoe Lagoon Beaverton and the Sutton WPCP discharges as potential inputs to the lake, were assumed to equate to the volume of water pumped through municipal water intakes drawing directly from the lake.

### Total Daily Discharge from Outlet

Total daily discharge is defined as channelized stream flow measured at a hydrological gauging station. As no hydrologic gauging station is present at the Atherley Narrows, values of mean daily discharge for Lake Simcoe (l $sec^{-1}$) have been prorated from the gauge at Washago. In order to estimate the flows at the Atherley Narrows, numerous sources of data were collected and reviewed. These included :

**1** Daily flow records from Water Survey Branch for stations 02EC017 Lake Couchiching outflow at Washago, 02EC002 Black River near Washago, 02EC003 Swift Rapids Severn River.

Data Source: Environment Canada (June 1990 - 1998)

**2** Daily Precipitation records from the Ontario Weather Centre (1990-1995) Environment Canada and Ministry of the Environment, Dorset Environmental Science Centre (1996-1998).

**3** Daily Lake evaporation calculated by the Dorset Environmental Science Centre from data collected at Egbert , Ontario Weather Centre (1990-1995) Environment Canada and Scanlon Creek, Ministry of the Environment, Dorset Environmental Science Centre (1996-1998).

**4** Daily water level records for two stations, Lake Simcoe at Jacksons Point and Lake Couchiching at Washago from Environment Canada, Parks Branch (June 1990 - 1998) .

**5** Watershed delineation for Lake Simcoe and Lake Couchiching, from South Lake Simcoe Conservation Authority and Environment Canada Water Survey Branch .

The method used to estimate flows at Atherley Narrows makes adjustments for flows at the outlet of Lake Couchiching, prorated by difference in drainage basin size, evaporation losses, precipitation and changes in lake storage.

The equation is described in Cumming Cockburn Ltd.(1987):

QA = QW (PRO) ± ª S-PRE+EVAP.

where QA = Flow at Atherley (inlet to Lake Couchiching)

Qw = Recorded flow at Washago (outlet of Lake Couchiching)

PRO =Proration factor based on difference in drainage areas between Washago and Atherley

ªS = Changes in lake Storage

PRE = Precipitation

EVAP = Evaporation

To verify that the data used in this equation were valid, an assumption was made that the Lake Simcoe and Couchiching watersheds could be combined and considered as a single basin. Based on this assumption, the flow data from Lake Couchiching outlet at Washago was designated as the outlet for the basin. Precipitation inputs, evaporative losses, lake level changes, and the ungauged terrestrial components were calculated on the combined sums of the two lake areas.

**Precipitation**

Daily precipitation depths were measured at (EGB, BRWPCP 1990 - Dec 1995 ) and SCP, RM1P Dec 1995 - May 1, 1998. These measurements provided a two station mean daily precipitation depth (mm) . Table 6 summarizes the two station mean monthly (mm) and mean annual (m) precipitation for the Lake Simcoe area. Annual amounts ($m^3$ $yr^{-1}$) of precipitation falling on the lake surface (Table 7) is calculated as lake area ($m^2$) x annual depth of precipitation (m $yr^{-1}$).

### Unmeasured Terrestrial Runoff

It is assumed that the annual runoff from the ungauged sub-catchments and the vegetable polder areas will respond to atmospheric inputs in a similar manner to that of the gauged sub-catchments within the same drainage basin. Therefore unmeasured terrestrial runoff is calculated as the sum of the measured inflows ($m^3$ ) divided by the sum of their watershed areas ($m^2$ ) and then multiplied by the area of the ungauged component ($m^2$ ).

### Urban Non-point Runoff Coefficent

Annual urban non-point runoff ($m^3$ / yr) was calculated as (1) total depth of precipitation (m) multiplied by a mean standard runoff coefficient of 0.45 ( a modeled result provided by the SWAMP program), (2) the percent of precipitation (m) is multiplied by the sum of the urban areas ($m^2$) (Table 35).

### Evaporation

A climatologically based model (Morton 1979) was employed to estimate evaporation for the study period June 1, 1990 to May 31, 1998. The model requires data input of elevation, latitude, longitude, temperature, relative humidity, solar radiation, vapour pressure and dew point temperature. An elevation of approximately 219 m, latitude 44° 25' and longitude 79° 20' were obtained from a 1: 50,000 topographical map Table 2b. describes the location of the other required parameters. Annual lake evaporation ( $m^3$ $yr^{-1}$ ) was calculated as a loss from the water balance as lake area ($m^2$ ) x annual depth of evaporation.

### Lake Levels (Storage)

No measurements were made of ground water storage in the terrestrial component of the catchment. Lake level gauges were in place for the 1990-1998 study period. Data were obtained from the Trent Severn Waterway for two stations, Lake Simcoe at Jacksons Point and Lake Couchiching at Washago. A mean staff gauge was calculated based on 16 days extending 8 days on either side of the hydrological year (June 01 to May 31). This mean was required as the gauge at Washago is located close to water control dams and is subject to rapid deflections not observed over the rest of Lake Couchiching.

## Annual Water Balances

The lake catchment water balance is an expression of the principle of conservation of mass. It assumes that the water inputs to a catchment equal the sum of the outputs. The model used for the period 1990 to 1998 is described in Ward (1967).

The model is expressed as:

$$\sum I_G + \sum I_U + P_{LA} + G_I = E + O \pm \Delta L + G_O \qquad \textbf{(1)}$$

The Input terms are:

(1) the sum of inflows from the gauged area of the watershed ($\sum I_G$) and includes five water pollution control plants.

(2) the sum of inputs from the ungauged areas ($\sum I_U$)utilize prorated flows from Washago, this assumes that the entire Lake Couchiching terrestrial component is ungauged.

(3) the precipitation falling on the lake surface ($P_{LA}$)

(4) the groundwater seepage into the catchment ($G_I$) No measurements were made of ground water storage in the terrestrial component of the catchment.

The loss terms are:

(1) the outflow (O), this component is calculated from the outlet at Swift Rapids and then prorated from Washago to the Atherley Narrows using the Cumming Cockburn equation described in the METHODS section.

(2) the change in lake storage or volume ($\Delta L$). Note that the change in lake level is entered as a loss, but can be either positive or negative, depending upon whether water is added or removed over the time period for which the balance is performed.

(3) loss from the lake by evaporation (E)

(4) groundwater loss from the lake catchment ($G_O$ ).

It is assumed that the majority of ground water passing through the catchment, originates along the southern boundary of the Lake Simcoe watershed from the northern edge of the Oak Ridges Moraine . Accurate estimates of ground water contributions are not available, therefore it will not be included in the terms of this equation. Available monthly areal runoff (Figure 3 & 4) provides evidence that a large portion of ground water contribution may be accounted for in the six major monitored tributaries draining 37% of this land area.

Equation 1 can be rearranged to provide an estimate of the accuracy of the measured water balance for a catchment. This balance term is expressed as a percentage. Accuracies of ± 10% are considered acceptable.

$$B = \frac{(O + E + \Delta L + G_O) - (\Sigma I_G + \Sigma I_U + P_{LA} + G_I)}{O + E + \Delta L + G_O} \; x \; 100\% \qquad \textbf{(2)}$$

The methods used to measure the components of the water balance have been described in Scheider et al. (1983) and more recently in Hutchinson et al. (1994a). In computing these balances, each supply and loss term was measured or estimated individually and calculated on an annual basis for all study catchments.

**Supply Terms:**

$P_{LA}$ An estimated component expressed as ($m^3$) direct contribution to the lake surface. The term is defined as lake area ($m^2$) x mean annual precipitation depth (m).

$\Sigma I_G$ A measured component expressed as $m^3$.

$\Sigma I_U$ An estimated component expressed as ($m^3$) unmeasured terrestrial runoff. The term is defined as the sum of the measured inflows ($m^3$)/sum of their watershed areas ($m^2$ ) x the area of the ungauged component ($m^2$ ).

$G_I$ Groundwater contribution is not available as no measurements were made of ground water discharge in the terrestrial component of the catchment.

**Loss Terms:**

O A measured component expressed as $m^3$.

E An estimated component further defined in Scheider et al. (1983) and expressed as ($m^3$) direct loss from the lake surface. The term is defined as lake area ($m^2$) x estimated evaporation rate (m).

ÄL A measured component ($m^3$) based on the hydrologic year further defined in Scheider et al. (1983). The term is defined as lake area ($m^2$) x measured loss (m) and can be positive or negative.

$G_O$ Groundwater contribution is not available as no measurements were made of ground water discharge in the terrestrial component of the catchment.

The balance term is expressed as the net sum of the errors of the individual loss term minus the supply term divided by the loss term which may be positive or negative .

**Sampling Methods**

Tributary sampling frequency was on a storm event basis 1990 - 1993 , while weekly samples were collected 1993 - 1997 followed by bi-monthly samples 1997 - 1998 . Tributary sampling methodologies are described in Locke and Scott. 1986a and subsequent hydrology database storage is described in Futter et al. 1993. Precipitation was collected when accumulation was greater than 10mm. Description of field meteorological methodology may be found in Locke and de Grobois 1986b, and subsequent database storage is described in Hutchinson et al. 1994b. Chemical sample analysis methods are described in Ontario Ministry of the Environment 1983.

## RESULTS AND DISCUSSION

### Annual Water Balance Supply Terms

#### Precipitation

Annual lake precipitation volumes ranged from 4.5 18x$10^8$ $m^3$ $yr^{-1}$ [(1997-1998)] to 7.5 00x$10^8$ $m^3$ $yr^{-1}$ [(1995-1996)], with a mean of 5.882 x$10^8$ $m^3$ $yr^{-1}$ [(1990-1998)] (Table 7, Figure 5), with a resultant percent contribution to the total supply of 40.9 % [(1990-1998)] . The average depth of precipitation (for the 4 main stations, BWPP, EGB, SCP and RM1P) per month was 67.6 mm with a minimum and maximum amount of 21.1[Feb. 1998] and 167.6 mm [Nov. 1995)] over the eight-year period ( Table 6). Generally the wettest consecutive months over the eight-year period were July to September (86.9, 78.8 and 81.5 mm respectively) with the least precipitation occurring through February and March (40.0 and 46.0 mm respectively).

### Mean Daily Discharge From Gauged Areas

Table 8 summarizes watershed minimum, maximum and mean discharge values (l $sec^{-1}$). Histograms showing monthly discharge ($m^3$) for all monitored inlet sub-catchments over eight hydrologic years are presented in Figure 6 and 7 (Lake Simcoe inflow tributaries eastern and southern aspects). Values of annual yield are summarized in Table 9 as annual units and as overall site mean, maximum and minimum results. The mean yield for the 1990-1998 period was 0.327 with mean values for the eight gauged watersheds and the calculated Atherley Narrows ranging from 0.201 [North Schomberg] to 0.571 [Kettleby Creek] (Table 9). Seasonal distribution of runoff ( Table 5 ) is such that peak runoff occurs in March, April and May in response to snow melt. Secondary peaks occur in October, November and December in response to increased precipitation and less interception by the terrestrial component. Residual runoff occurs in June, July and August due to terrestrial uptake and in January and February since precipitation is stored as accumulated snow. The percentage of annual flow that occured in peak runoff periods ranged from 16.9 % [Bradford pump house] to 80.8 % [Bradford pump house] with a mean value of 48.1 %. The percentage of annual flow occurring in secondary runoff periods ranged from 4.5 % [North Schomberg] to 53.9 % [Bradford pump house] with a mean value of 20.4 %. The percent of annual flow that occured as residual runoff periods ranged from 9.7 % [Bradford pump house] to 48.4 % [Kettleby Creek] with a mean value of 31.5 %. Annual values of percent seasonal distribution are described in Table 5.

### Unmeasured Terrestrial Runoff

The contribution of runoff from the ungauged catchment area to the total input to Lake Simcoe ranged from 28.9 % [1993 / 94] to 37.6 % [1996 / 97]. Table 12 summarizes the ungauged discharges for 1990-1998.

### Ground Water

Groundwater contribution in excess of that measured as a component of stream flow is not available as no direct measurements were made of ground water discharge in the terrestrial component of the catchment.

## Annual Water Balance Loss Terms

### Mean Daily Discharge from Outlet

A water balance was generated for the combined Lake Simcoe - Lake Couchiching catchment (Table 10 ). The water balance shows a consistent positive balance for all years, ranging from a minimum of 5.2 % [1992-1993] to a maximum of 20.9 % (1996-1997) , with an overall eight year mean of 12.5 %. Given that precipitation inputs and evaporative losses can be considered approximately balanced, this implies that a consistent error in measurement may be occurring in inlets where the flow is under -estimated, or the outlet is overestimated. Comparison of monthly unit yields of both the inlets and outlets showed an overestimation in the outlet data. Based on these observations and after consultation with Parks Canada, Swift Rapids was designated as the outlet for the basin. The ungauged terrestrial component and the daily flows from the Black River at Washago were calculated and subtracted from the Swift Rapids daily flows. The Lake Simcoe outflow utilizing the two stage proration on (1) Swift Rapids to Lake Couchiching (Table 11) and (2) Lake Couchiching to Atherley Narrows is presented in Table 12 as monthly total flows ($m^3$) . An annual water balance was generated for the combined watershed (Table 11) and shows a consistent positive balance for all years excluding 1995-1996 [-1.1%] ranging from a minimum of 2.0 % [1990-1991] and a maximum of 11.1 % (1994-1995) , with an overall eight year mean of 4.2 %. These flows were accepted and subsequently adjusted by the net effects of precipitation, evaporation, and storage to estimate the daily flows at Atherley Narrows. A water balance was generated for the combined watershed ( Table 12 ) and shows a consistent positive balance for all years excluding 1990-1991 [-0.8%] and 1995-1996 [-2.2 %] ranging from a minimum of 1.7 % [1991-1992] and a maximum of 10.5 % (1994-1995) , with an overall mean of 3.2 %. Slight differences in the overall balances between Table 11 and Table 12 were attributed to long periods of no precipitation and an increase in evaporation due to hot dry summers.

### Evaporation

Mean annual values ranged from 0.646 m $yr^{-1}$ in 1996-1997 to 0.829 m $yr^{-1}$ in 1991-1992 (Table 13).
The 1990 -1998 mean annual value was 0.664 m $yr^{-1}$ , comparing well with the Scheider et al. (1983) figure of

0.660 m $yr^{-1}$ and the long term estimate of 0.70 m $yr^{-1}$ (Hydrologic Atlas of Canada 1978).
Table 14, and Figure 12 summarize the annual lake evaporation $(m^3)^{1990-1998}$ ranging from a minimum of $4.654 \times 10^8$ $(m^3)$ $^{1996-1997}$ and a maximum of $5.974 \times 10^8$ $(m^3)^{1991-1992}$ with an eight-year mean lake evaporation of $5.372 \times 10^8$ $(m^3)$.

### Lake Level (Storage)

Changes in lake level are summarized on an annual basis in Table 15. Deviations of annual lake levels are generally small ranging from -0.040 m $^{1997-1998}$ to 0.033 m $^{1991-1992}$. Over the eight years of this study period, a mean change in lake level of -0.002m occurred in Lake Simcoe, indicating a degree of artificial control by the Trent -Severn Waterway. The change in lake storage ranged from a minimum of $-3.060 \times 10^7$ $m^3$ in 1997-1998 and a maximum of $2.525 \times 10^7$ $m^3$ in 1991-1992 with a mean of $-1.702 \times 10^7$ $m^3$ (Table 16).

### Water Balance Tables

The terms of the water balance model were described in Section 3.0. The balance term is expressed as the net sum of the errors of the individual loss term minus the supply term / loss term. All annual budgets balanced to within 10% excluding 1994-1995 (10.5 %) with the mean balance +3.2 % over the 8 study years. There was a consistent positive pattern excluding (1990-1991), (1995-1996) in the error term of the balance, with a positive error indicating that either the loss was too great or the supply too small. Terrestrial runoff (1990-1998) supplies 56.6 % of the water to the lake, while precipitation directly to the lake surface correspondingly supplies 41.8 % . Loss via outflow was the most significant export at 61.9 %, while evaporation directly off the lake surface correspondingly exported 38.3 %. Individual supply and loss terms for each study catchment are presented in Table 12.

### Residence and Flushing Time for Lake Simcoe

Residence time is calculated as lake volume / total loss of water from the lake. Table 17 summarizes the data ( in years) with an annual minimum of 5.39 $^{1996-1997}$ and a maximum of 9.70 $^{1991-1992}$ with an eight-year mean value of

7.23 years. Flushing time is calculated as lake volume / lake outflow and is longer than residence time because the water loss to evaporation is not included. Table 17 summarizes the data ( in years ) with an annual minimum of 7.14 [1996-1997] and a maximum of 23. 57 [1991-1992] with an eight-year mean value of 12.48 years .

## TOTAL PHOSPHORUS LOADING FROM SUB-WATERSHEDS

Measured total phosphorus (TP) concentrations and flow data were used to calculate total annual loads for water years 1990-1991 to 1997-1998 for monitored tributaries (Figure 13). Daily phosphorus concentrations were modeled using the ‘around’ method (Scheider et al. 1979). Measured phosphorus values were matched with stream flows for the dates on which chemistry samples were collected. The midpoints between chemistry sampling dates at each station were determined, and the measured phosphorus concentration assigned to dates between the midpoints. Phosphorus loads were calculated by multiplying stream flow by the measured or assigned phosphorus concentrations. Monthly loads were calculated by summing the daily loads (Tables 18 to 25, Figure 14). Where necessary, loads were then scaled to account for the entire sub-watershed, such that the area between the chemistry station and the lake was included. Three tributary chemical sampling locations were located down stream of the hydrologic gauging stations (Black River[1990-1998] Figure 8, Beaver River[1993-1998] Figure 9 and the Pefferlaw River[1993-1998] Figure 10). Stream flow was scaled up to include the sub-catchment area between these two points. Prorated flows were not used in calculating the water balance.

Discharge was prorated for ungauged areas where only water chemistry was measured (ungauged and monitored sub-watersheds), ( Table 27). Two methods of proration were compared: 1) using an overall average discharge per unit area from all gauged sub-watersheds for each water year, and 2) using the annual discharge per unit area for the gauged sub-watershed most similar to the ungauged catchment in terms of land cover. Similarity between all sub-watersheds in terms of 1993 land cover (% of various land-use types, data supplied by the Lake Simcoe Regional Conservation Authority from their GIS, Table 36) was determined using correspondence analysis (CA). Watersheds were considered most similar to those with the closest CA scores. Total phosphorus loads were calculated using discharge data derived from these calculations. The results of the two methods were closely related ($r^2 = 0.92$, $P = 0.002$) and very similar (slope = 1.2), and the results presented in this report were calculated using method 1, an overall average discharge per unit area.

The export of phosphorus per unit area for each tributary for each year was calculated, where data were available.

The phosphorus load from any sewage treatment plants (STP) upstream of chemistry stations (for the Beaver, Black, Pefferlaw and Upper Schomberg rivers) was subtracted from the total load for this calculation (Table 34). Upstream STP loads are included in the total phosphorus load for the gauged and monitored calculations (Table 29). No chemistry data were available from: 1990-1994 for White's and Hawkstone Creek, and the Talbot River, 1993-1994 for Lover's Creek, 1993-1995 for Pottageville, 1994-1995 (Table 30) and for the Bradford pump house 1996-1998 (Table 29). Bold italics were used in the tables for calculated total phosphorus for monitored and ungauged sub-watersheds.

The TP export data (mass flux/area; $kg/km^2$) were standardized by calculating Z-scores, to look at relationships over time between the TP export from various sub-watersheds, using the equation:

$$\text{Z-score} = \frac{(X - m)}{s}$$

where X is the value to be standardized, m is the mean of the distribution and s is the standard deviation of the distribution.

Over the years for which data were available, sub-watersheds except for the Bradford pump house showed similar patterns in TP export per unit area. Regression analysis was then used to generate equations relating the phosphorus export from sub-watersheds with missing data to sub-watersheds showing a similar pattern of TP export over time and with a full set of data. TP export (E) was calculated for the sub-watersheds with missing years based on the best of these relationships.

The relationships used were:

$E_{Hawkstone} = 0.279\ E_{Pefferlaw} + 2.618$ ($r^2 = 0.92$, $P = 0.028$)

$E_{Talbots} = 0.447\ E_{Black} + 2.038$ ($r^2 = 0.64$, $P = 0.2$)

$E_{Whites} = 0.988\ E_{Beaver} - 1.518$ ($r^2 = 0.86$, $P = 0.047$)

$E_{Lovers} = 0.371\ E_{Upper\ Schomberg} + 1.957$ ($r^2 = 0.84$, $P = 0.002$)

$E_{Pottageville} = 0.091\ E_{North\ Schomberg} + 12.128$ ($r^2 = 0.52$, $P = 0.1$)

For the Bradford pump house, a mean TP concentration was calculated from measured values (1990 - 1996). The mean value was used in conjunction with measured discharge to calculate the load for missing years (1996 - 97 and 1997 - 98) .

Annual export coefficients (TP export kg/km$^2$) from the most similar catchment in terms of land use, determined using correspondence analysis, were used to calculate the export from each of the unmonitored / ungauged areas (Table 28).

Total loads from Lake Simcoe sub-watersheds (tributaries) were calculated by adding loads from gauged and monitored areas (Table 26), ungauged and monitored areas (Table 27), and ungauged and unmonitored areas (Table 28). Inputs from several urban areas were considered as separate inputs to the lake: Barrie, Orillia, Keswick and Bradford (Table 28). The inputs from other urban areas are included in the sub-watershed loads (Table 31). Sewage treatment plant inputs (Table 2b) are also considered as separate inputs to the lake (urban point source) (Table 34). Annual flow from the tributaries (m$^3$) was calculated as (total flow of the gauged inlets including the polder area (Holland Marsh) m$^3$, minus urban non-point source, polders and urban point sources above the

gauging stations). This flow represents the combined land use categories of forested, wetland, cultivated, scrubland and barren pastures.

### Total phosphorus loading from precipitation (Atmospheric)

Daily precipitation loads from Scanlon Creek (SCP) and Ramara (RM1P) were determined by multiplying bulk phosphorus concentration in the samples collected by daily precipitation depth over the collection period.

Monthly loads were determined by summing calculated daily loads. Daily phosphorus concentrations were not available from 1990 - 1995. Annual loads for this time period were calculated by utilizing a mean monthly total phosphorus concentration of the 1995-96 to 1997-98 data set. The procedure used to calculate total precipitation falling on the lake surface as (m$^3$) are discussed in the METHODS section.

### Urban point source loads

Point source loads (mg/mo$^{-1}$) of total phosphorus and discharge rates (m$^3$ mo$^{-1}$) for each sewage treatment plant are obtained from district Ministry of the Environment monthly monitoring reports, which are submitted as part of the Municipal Utilities monitoring program. These data are collated by the Ministry of the Environment, Central

Region and monthly totals in kilograms of total phosphorus and cubic metres of discharge. These data are then summarized on an annual basis (Table 34).

### Urban non-point source load calculations

Urban expansion within the watershed was obtained from areal photographic interpretations of 1985 and 2000 low level photographs. A linear increase in urban growth was assumed and interpolated annual areal values of urban land forms were calculated (Table 35). To calculate total phosphorus load, these areas were then multiplied by (132 kg / $km^2$ / yr) a modeled result provided by the SWAMP program ( MOE Storm water analysis and monitoring program unpublished data: Beak Consultants Limited 1993) . It is assumed that the amount of urban non point source runoff is dependant on the annual amount of precipitation and the rate of infiltration. For other land uses, 1993 satellite imagery was used for all data except the urban areas, for which 1998 values were used from the extrapolation (Table 35) . Urban expansion was subtracted from barren pasture and cultivated categories proportionally.

### Phosphorus loading from vegetable polders

Vegetable polder areas were determined by digital orthophotographic interpretation and include the inner Holland Marsh ( PP see Table 1.**)** The phosphorus loads from the Bradford pump house were extrapolated to include the polder areas outside of the inner marsh. The inner Holland Marsh plus the outer vegetable polders under vegetable production were combined for the annual summary of kg/yr total phosphorus exported (Table 34). It is assumed that the annual runoff from the ungauged polder areas (Bradford, Keswick and Colbar marshes) will respond to atmospheric inputs in a similar manner to that of the gauged sub-catchment (Holland Marsh).

## TECHNICAL SUMMARY

1. Data to construct annual water balances for Lake Simcoe for the 8 year period June 1990 - May 1998 are presented . Supply terms are: gauged inflows, ungauged inflows, Water Pollution Control Plants and precipitation directly to the lake's surfac. Loss terms are: lake outlet, evaporation and change in storage.

Groundwater flux was not measured.

2. All annual water budgets balanced to within 10% except for 1994 - 95 (10.5%). The mean balance over the 8 year period was 3.2%, thus giving a high degree of confidence in the overall hydrological data.
3. Total phosphorus loading data for Lake Simcoe for the 8 year period 1990 - 1998 are presented. Sources of TP to the lake are catagorized as : precipitation input, gauged and ungauged terrestrial watersheds, urban point sources, urban non-point sources and vegetable polders.
4. The average annual TP load to Lake Simcoe over the 8 year period was 114.3m tons / yr, with a range of 85.4 - 156.5 m tons / yr. Current mean annual TP load to Lake Simcoe for the LSEMS Phase II period is estimated from the 1994 - 95 to 1997 - 98 data as 102.2m tons / yr

## GLOSSARY

In order to facilitate the use of this report, some basic hydrologic terms as defined herein:

Catchment — Describes the total area within a watershed boundary.

Correspondence Analysis (CA) – is an ordination technique.
Ordination is the collective term for mathematical techniques that arrange sites (in this case sub-watersheds) along axes on the basis of data collected for them (in this case land cover). The result of ordination is a diagram in which sites are represented by points in two dimensions. The aim of ordination is to arrange points such that points that are close together correspond to sites that are similar, in this case in terms of land cover, and points far apart correspond to sites that are dissimilar.

Discharge — The volume of water that passes a particular reference section in a unit of time.

Flushing Time — Flushing time or replenishment time is calculated as lake volume / lake out flow.

Hydrologic Water Year — A one year length beginning with June 1st. in the initial year and May 31st. in the subsequent year.

| | |
|---|---|
| Lake Level | The gauge height reading corresponding to the change in depth relative to a geodetic survey elevation. |
| Mean Daily Discharge | An estimate of the mean daily flow from a sub-catchment stream or river usually measured through a calibrated gauging structure. |
| Residence Time | The length of time required to displace a volume of water equivalent to the lake volume. This term is calculated as lake volume / total annual loss of water from the lake. |
| Runoff | Is water draining the terrestrial portion of a lake's catchment or drainage from upstream lakes; operationally, it includes channelized stream flow measured at hydrological gauging stations. |
| Stage-discharge relationships | The relationship between the measured stage (height) and channelized stream flow measured at hydrologic gauging stations. |
| Sub-catchment | Describes the area drained by a tributary stream. |
| Vegetable polders | A tract of peat land below lake level, which has been reclaimed for agricultural use and is protected by dikes and drained by pumping. |
| Watershed | The outer boundary around a catchment. It is the point of elevation where flows divide. All points inside the boundary flow into the catchment, while no points outside the watershed flow into the catchment. The watershed extends around the line of break in flow, and the gauging structure on the outflow stream of the catchment. |
| Yield | The fraction of the annual precipitation (m $yr^{-1}$) which is lost from the sub-catchment as stream flow. |

## Table 1. Watershed area of gauged and ungauged catchments, total watershed areas and % watershed gauged and ungauged for Lake Simcoe

| DESCRIPTION | STN | WATERSHED AREA m$^2$ | GAUGED AREA m$^2$ | UNGAUGED AREA m$^2$ | % GAUGED | % UNGAUGED | URBAN AREAS (m$^2$) 1985 | URBAN AREAS (m$^2$) 2000 |
|---|---|---|---|---|---|---|---|---|
| AURORA | AA | 49,460,000 | | | | | 9,200,000 | 49,460,000 |
| BARRIE | LSBEU | 44,360,000 | | 44,360,000 | | 100.0 | 15,450,000 | 44,360,000 |
| BEAVERTON | BVTN | 1,610,000 | | | | | 263,000 | 1,610,000 |
| BEAVER RIVER | BV | 322,871,510 | 288,650,000 | 34,221,510 | 89.4 | 10.6 | | |
| BLACK RIVER | BL | 344,103,090 | 257,256,000 | 86,847,090 | 74.8 | 25.2 | | |
| BRADFORD | BD | 5,000,000 | | | | | 2,830,000 | 5,000,000 |
| BRADFORD PUMP | PP | 28,367,303 | 28,367,303 | | 100.0 | | | |
| BRADFORD MARSH | BM | 11,300,000 | | 11,300,000 | | 100.0 | | |
| BRECHIN | LSBRU | 141,406,061 | | 141,406,061 | | 100.0 | | |
| CANNINGTON | | 3,110,000 | | | | | 980,000 | 3,110,000 |
| COLBAR MARSH | CM | 4,000,000 | | 4,000,000 | | 100.0 | | |
| COUCHICHING | CD | 64,440,000 | | 64,440,000 | | 100.0 | | |
| EAST HOLLAND RIVER | HL | 266,219,180 | 182,872,000 | 83,347,180 | 68.7 | 31.3 | | |
| FOX ISLAND | LSFXU | 189,639 | | 189,639 | | 100.0 | | |
| GEORGINA ISLAND | LSGAU | 12,889,789 | | 12,889,789 | | 100.0 | | |
| GRAND ISLAND | LSGDU | 393,661 | | 393,660.50 | | 100.0 | | |
| GLENVILLE CR | LSGEU | 22,930,306 | | 22,930,306 | | 100.0 | | |
| GOFFATT ISLAND | LSGOU | 55,855 | | 55,855 | | 100.0 | | |
| HOLLAND LANDING | | 5,150,000 | | | | | 2,110,000 | 5,150,000 |
| HAWKSTONE | HS | 85,056,755 | | 85,056,755 | | 100.0 | | |
| ISLAND | LSGRU | 1,118,399 | | 1,118,399 | | 100.0 | | |
| INNISFIL | LSILU | 107,708,790 | | 107,708,790 | | 100.0 | | |
| KESWICK | | 5,890,000 | | | | | 3,430,000 | 5,890,000 |
| KESWICK MARSH | KM | 5,500,000 | | 5,500,000 | | 100.0 | | |
| KETTLEBY | KB | 42,333,050 | 31,135,000 | 11,198,050 | 73.5 | 26.5 | | |
| LAKE COUCHICHING | LC | 44,750,000 | | | | | | |
| LAKE SIMCOE (Surface) | LS | 720,307,070 | | | | | | |
| LOVERS CREEK | LV | 54,379,331 | | 54,379,331 | | 100.0 | | |
| MASKINONGE | LSMEU | 119,584,160 | | 119,584,160 | | 100.0 | | |
| MT. ALBERT | MA | 1,650,000 | | | | | 940.000 | 1,650,000 |
| NEWMARKET | NMT | 38,500,000 | | | | | 11,000,000 | 38,500,000 |
| NORTH SCHOMBERG | NS | 73,442,260 | 44,986,000 | 28,456,260 | 61.3 | 38.7 | | |
| O'DONNELL CREEK | LSODU | 11,161,512 | | 11,161,512 | | 100.0 | | |
| ORILLIA | | 22,480,000 | | | | | 12,400,000 | 22,480,000 |
| ORO STATION | LSORU | 35,373,590 | | 35,373,590 | | 100.0 | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PEFFERLAW RIVER | PFR | 396,727,500 | 321,143,000 | 75,584,500 | 80.9 | 19.1 | | |
| PORT BOLSTER | LSPBU | 30,247,876 | | 30,247,876 | | 100.0 | | |
| POTTAGEVILLE | PT | 48,343,315 | | 48,343,315 | | 100.0 | | |
| RED CAP ISLAND | LSRCU | 691,331 | | 691,330.70 | | 100.0 | | |
| SCANLON CREEK | LSSCU | 25,217,133 | | 25,217,133 | | 100.0 | | |
| SCHOMBERG | | 1,280,000 | | | | | 910,000 | 1,280,000 |
| SHANTY BAY | LSSBU | 58,153,723 | | 58,153,723 | | 100.0 | | |
| SHARON | | 1,610,000 | | | | | 930,000 | 1,610,000 |
| SNAKE ISLAND | LSSNU | 1,408,080 | | 1,408,080 | | 100.0 | | |
| STROUD | LSSDU | 17,142,460 | | 17,142,460 | | 100.0 | | |
| STRAWBERRY ISLAND | LSSTU | 127,095 | | 127,095 | | 100.0 | | |
| SUNDERLAND | | 920,000 | | | | | 710,000 | 920,000 |
| SUTTON | | 3,550,000 | | | | | 2,950,000 | 3,550,000 |
| SWIFT RAPIDS | SW | 651,000,000 | | 651,000,000 | | 100.0 | | |
| TALBOT | LSTAU | 321,338,680 | | 321,338,680 | | 100.0 | | |
| THORAH ISLAND | LSTHU | 4,409,198 | | 4,409,198 | | 100.0 | | |
| UXBRIDGE | | 5,690,000 | | | | | 2,010,000 | 5,690,000 |
| VIRGINIA BEACH | LSVAU | 49,364,090 | | 49,364,090 | | 100.0 | | |
| WILLIAM NEELY CREEK | LSWNU | 12,774,735 | | 12,774,735 | | 100.0 | | |
| WHITES CREEK | LSWTU | 106,692,030 | | 106,692,030 | | 100.0 | | |
| UPPER SCHOMBERG | US | 69,080,560 | 41,996,000 | 27,084,560 | 60.8 | 39.2 | | |

**Table 1. cont'd Watershed area of gauged and ungauged catchments, total watershed areas and % watershed gauged and ungauged for Lake Simcoe.**

| DESCRIPTION | WATERSHED AREA $m^2$ | GAUGED AREA $m^2$ | UNGAUGED AREA $m^2$ | % GAUGED | % UNGAUGED | URBAN AREAS ($m^2$) 1985 | URBAN AREAS ($m^2$) 2000 |
|---|---|---|---|---|---|---|---|
| TOTAL TERRESTRIAL | 2,914,313,417 | 1,196,405,303 | 1,712,119,485 | 41.1 | 58.9 | 68,480,000 | 190,260,000 |
| MONITORED | 1,543,144,543 | 1,196,405,303 | 346,739,150.0 | 77.5 | 22.5 | | |
| LAKE AREA $m^2$ | 720,307,070 | | | | | | |
| CATCHMENT AREA $m^2$ | 3,634,620,487 | | | | | | |

**Table 2a. Location description for the water balance supply and loss terms.**

| Supply Descriptions | Abbrev. | Source Data | Location Description | Sub-watershed Unit | Easting | Northing |
|---|---|---|---|---|---|---|
| Beaver River | BV | (1, 4[1990-93])(5[1993-98]) | Beaverton Museum | 02EC011 | 646500 | 4921100 |
| Black River | BL | (1, 4[1990-93])(5[1993-98]) | Baldwin at Hwy 12 | 02EC008 | 630700 | 4906850 |
| Black River | BLW | (1[1990-98]) | Black R. at Washago | 02EC002 | 633050 | 4956850 |
| Pefferlaw River | PFR | (1, 4[1990-98]) | Pefferlaw | 02EC018 | 643500 | 4908300 |
| Holland Landing | HL | (1, 4[1990-98]) | Holland Landing | 02EC009 | 620875 | 4883275 |
| Upper Schomberg R. | US | (1, 4[1990-98]) | Schomberg | 02EC118 | 605350 | 4873850 |
| North Schomberg R. | NS | (5[1993-98])(6[1990-92]) | 5th Conc. W. Gwillimbury | 02EC118 | 609475 | 4880700 |
| Kettleby Creek | KB | (5[1993-98])(6[1990-92]) | Hwy 9 W. of Cardinal G&.C.C. | 02EC117 | 614450 | 4876450 |
| Bradford Pump House | PP | (7[1990-98]) | W. Canal Bank Rd. off Hwy 11 | 02EC(121, 122) | 616300 | 4884975 |
| North Pump House | North Pump | (7[1990-98]) | North Canal / Holland R. | | 614000 | 4882000 |
| Barrie WPCP & (Meteorological Site) | Br WPCP | (3[1990-95])(8[1991-98]) | Point of discharge Lake Simcoe | | 627000 | 4999350 |
| Orillia WPCP | Or WPCP | (8[1991-98]) | Point of discharge Lake Simcoe | | 626000 | 4938600 |
| Lagoon City WPCP | LGn WPCP | (8[1991-98]) | Point of discharge Lake Simcoe | | 642000 | 4935750 |
| Bradford WPCP | BD WPCP | (8[1991-98]) | Holland R. below quantity / quality station | | 615600 | 4886500 |
| Holland Landing Lagoon | HL LG | (8[1991-98]) | East Holland R. below quantity / quality station | | 621500 | 4886000 |
| Scanlon Creek Meteorological Site | SCP | (5[1996-98]) | Hwy 11 North of Bradford | | 614450 | 4889100 |
| Ramara Meteorological Site RM1P | | (5[1996-98]) | West of Hwy 12/48 on Conc. 2 | | 645000 | 4931300 |
| Egbert Meteorological Site | EGB | (3[1990-Dec 1995]) | W. of Hwy 27 & N. of Hwy 89 | | 597350 | 4898200 |
| Lagoon City Meteorological Site | BRWP | (3[1990-Dec 1995]) | Lagoon City | | 641600 | 4934400 |
| Lake Staff Gauges | Lsg | Ä storage(2[June 1990-98]) | Jacksons Point (Simcoe), Washago (Couchiching) | | 630100, 631350 | 4909400, 4956100 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Loss Descriptions** | | | | | | |
| Atherley Narrows (Simcoe Outlet) | ATH | | Hwy 12 at Atherley | | 629350 | 4940000 |
| Lake Couchiching Outlet | LCW OF | (1 June, 1990-98) | Hwy 11 & 169 at Washago | 631500 | 4956000 | |
| Swift Rapids | SW Outlet | (1 June, 1990-98) | Swift Rapids on Severn River | 02EC003 | 615400 | 4967900 |
| **Excluded From Water Balance** | | | | | | |
| Keswick WPCP | KW WPCP | (8 1991-98) | Point of discharge Lake Simcoe | | 620850 | 4901100 |
| Innisfil (Alcona) WPCP | IF WPCP | (8 1991-98) | Point of discharge Lake Simcoe | | 615000 | 4911000 |
| Lake Simcoe Lagoon (Beaverton) | BV LG | (8 1991-98) | Point of discharge Lake Simcoe | | 646400 | 4920000 |
| Sutton WPCP | SN WPCP | (8 1991-98) | Black R. below quantity / quality station | | 631800 | 4907300 |
| Mount Albert WPCP | | | Black River above Baldwin quantity / quality station | | 635600 | 4889400 |
| Beaver River 1 Lagoon (Sunderland) | | | Beaver River above quantity / quality station | | 655000 | 4904000 |
| Beaver River 2 Lagoon (Cannington) | | | Beaver River above quantity / quality station | | 657000 | 4913300 |
| Uxbridge Brook WPCP | | | Pefferlaw River above quantity station | | 650500 | 4886000 |
| Schomberg Lagoon | | | Schomberg River above quantity / quality station | | 605000 | 4873300 |

**Data Source Collaborators:**

1. Environment Canada, Water Survey Brch. (Susan Saunders)
2. Environment Canada, Parks Brch. (Bruce Kitchen)
3. Environment Canada, Ontario Weather Centre (Jim Cook)
4. M.O.E. Environmental Monitoring and Reporting Brch. (Brian Whitehead)
5. M.O.E. Dorset Environmental Science Centre (Wolfgang Scheider)
6. South Lake Simcoe Conservation Authority (Mike Walters, Geoff. Pete)
7. Bradford West Gwillimbury (Municipality) (Art Janse)
8. M.O.E. Central Region (Steve Maude)

## Table 2b. Locations with measured Chemistry (C), modeled chemistry (MC) and meteorological (M) location descriptions (see Table 2a for data source codes)

| Description | Abbrev. | Data Type | Data Source | Location Description |
|---|---|---|---|---|
| Monitored & Gauged | | | | |
| Beaver River | BV | C | (5 1993-98) | Beaverton Museum |
| Beaver River | BV | C | (6 1990-93) | Conc.1 West of Cannington |
| Black River | BL | C | (6 1990-93 5 1993-98) | Sutton |
| Pefferlaw River | PFU | C | (6 1990-93) | Udora |
| Pefferlaw River | PFR | C | (5 1993-98) | Pefferlaw |
| Holland Landing | HL | C | (6 1990-93 5 1993-98) | Holland River at Holland Landing |
| Upper Schomberg River | US | C | (6 1990-93 5 1993-98) | Schomberg Conc. 20 |
| North Schomberg River | NS | C | (6 1990-93 5 1993-98) | 5th Conc. W. Gwillimbury |
| Kettleby Creek | KB | C | (6 1990-93 5 1993-98) | Hwy 9 W. of Cardinal GCC |
| Bradford pump house | PP | C | (6 1990-96) | Bradford, Hwy 11 |
| Sewage Treatment Plants | | | | |
| Bradford WPCP | BD WPCP | C | (8 1991-98) | Bradford below HWY 11 |
| Holland Landing Lagoon | HL LG | C | (8 1991-98) | Holland R. below Holland Landing |
| Innisfil (Alcona) WPCP | IF WPCP | C | (8 1991-98) | Innisfil near Alcona |
| Keswick WPCP | KW WPCP | C | (8 1991-98) | Keswick |
| Lagoon City | BR LG | C | (8 1991-98) | Brechin |
| Beaverton Lagoon | BV LG | C | (8 1991-98) | Beaverton |
| Orillia WPCP | OR WPCP | C | (8 1991-98) | Orillia |

| | | | | |
|---|---|---|---|---|
| Barrie WPCP | Br WPCP | C | (8 $^{1991-98}$) | Barrie |
| Sutton WPCP | SN WPCP | C | (8 $^{1991-98}$) | Sutton |
| Monitored & Ungauged | | | | |
| Hawkstone Creek | HS | C | (5 $^{1993-98}$) | Hawkstone |
| Lovers Creek | LV | C | (5 $^{1993-98}$) | Barrie |
| Talbot River | LSTAL | C | (5 $^{1993-98}$) | Gambridge |
| Whites Creek | LSWT | C | (5 $^{1993-98}$) | Beaverton |
| Pottageville Creek | PT | C | (5 $^{1993-98}$) | Pottageville |
| Unmonitored & Ungauged | | | | |
| Stroud | LSSD | MC | (5 $^{1990-98}$) | Stroud |
| Innisfil | LSIL | MC | (5 $^{1990-98}$) | Innisfil |
| Brechin | LSBR | MC | (5 $^{1990-98}$) | Brechin |
| Maskinonge | LSME | MC | (5 $^{1990-98}$) | Maskinonge |
| Oro Station | LSOR | MC | (5 $^{1990-98}$) | Oro |
| Shanty Bay | LSSB | MC | (5 $^{1990-98}$) | Shanty Bay |
| Remaining Ungauged | | MC | (5 $^{1990-98}$) | |

| Meteorological Stations | Abbrev. | Precipitation | Relative Humidity | Temperature | Solar Radiation | Vapour Pressure |
|---|---|---|---|---|---|---|
| Barrie WPCP | Br WPCP | 1990-95 | | | | |
| Egbert | EGB | 1990-95 | 1990-95 | 1990-95 | 1990-95 | 1990-95 |
| Scanlon Creek | SCP | 1995-98 | 1995-98 | 1995-98 | 1995-98 | 1995-98 |
| Ramara | RM1P | 1995-98 | 1995-98 | 1995-98 | | |

**Table 3. Total annual discharge ($m^3$ $yr^{-1}$x $10^6$) for the eight gauged watersheds and the calculated Atherley Narrows 1990 - 1998.**

| Watershed | 1990-91 | 1991-92 | 1992-93 | 1993-94 | 1994-95 | 1995-96 | 1996-97 | 1997-98 |
|---|---|---|---|---|---|---|---|---|
| BV | 104.0 | 47.8 | 96.8 | 59.5 | 49.8 | 122.0 | 111.0 | 70.7 |
| BL | 85.6 | 45.3 | 86.2 | 50.3 | 46.1 | 72.7 | 101.0 | 54.6 |
| PFR | 132.0 | 76.3 | 101.0 | 77.6 | 75.1 | 117.0 | 145.0 | 104.0 |
| HL | 64.0 | 28.7 | 56.5 | 31.4 | 30.5 | 54.4 | 73.2 | 41.0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| US | 9.4 | 3.6 | 11.0 | 5.1 | 6.2 | 13.8 | 12.6 | 7.2 |
| NS | 9.3 | 3.9 | 7.4 | 6.4 | 6.2 | 11.6 | 9.5 | 5.9 |
| KB | 16.3 | 12.6 | 21.2 | 9.1 | 8.4 | 21.0 | 16.6 | 12.3 |
| PP | 7.7 | 3.9 | 4.2 | 1.9 | 4.5 | 12.6 | 7.0 | 5.0 |
| ATH | 1120.0 | 434.0 | 1140.0 | 717.0 | 692.0 | 1240.0 | 1440.0 | 753.0 |

**Table 4. Annual areal runoff (m $yr^{-1}$) for the eight gauged watersheds and the calculated Atherley Narrows 1990 - 1998 calculated as total annual discharge ($m^3$ $yr^{-1}$) / watershed area ($m^2$)**

| | | | | | | | | | Mean | Maximum | Minimum |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Watershed | 1990-91 | 1991-92 | 1992-93 | 1993-94 | 1994-95 | 1995-96 | 1996-97 | 1997-98 | 1990-98 | | |
| BV | 0.361 | 0.166 | 0.335 | 0.206 | 0.173 | 0.423 | 0.384 | 0.245 | 0.287 | 0.423 | 0.166 |
| BL | 0.333 | 0.176 | 0.336 | 0.196 | 0.179 | 0.282 | 0.392 | 0.212 | 0.263 | 0.392 | 0.176 |
| PFR | 0.412 | 0.238 | 0.314 | 0.242 | 0.234 | 0.365 | 0.451 | 0.323 | 0.322 | 0.451 | 0.234 |
| HL | 0.350 | 0.157 | 0.310 | 0.172 | 0.167 | 0.297 | 0.400 | 0.224 | 0.259 | 0.400 | 0.157 |
| US | 0.224 | 0.087 | 0.263 | 0.120 | 0.147 | 0.328 | 0.300 | 0.171 | 0.205 | 0.328 | 0.087 |
| NS | 0.206 | 0.088 | 0.164 | 0.141 | 0.138 | 0.257 | 0.211 | 0.131 | 0.167 | 0.257 | 0.088 |
| KB | 0.522 | 0.405 | 0.680 | 0.292 | 0.269 | 0.674 | 0.533 | 0.393 | 0.471 | 0.680 | 0.269 |
| PP | 0.272 | 0.136 | 0.148 | 0.065 | 0.157 | 0.443 | 0.248 | 0.175 | 0.206 | 0.443 | 0.065 |
| ATH | 0.314 | 0.122 | 0.238 | 0.201 | 0.194 | 0.347 | 0.402 | 0.211 | 0.254 | 0.402 | 0.122 |
| Mean | 0.333 | 0.175 | 0.310 | 0.182 | 0.184 | 0.380 | 0.369 | 0.232 | | | |
| Maximum | 0.522 | 0.405 | 0.680 | 0.292 | 0.269 | 0.674 | 0.533 | 0.393 | | | |
| Minimum | 0.206 | 0.087 | 0.148 | 0.065 | 0.138 | 0.257 | 0.211 | 0.131 | | | |

**Table 5. Seasonal distribution of runoff from each gauged watershed as a % of annual runoff for the eight gauged watersheds and the calculated Atherley Narrows 1990 - 1998.**

| Stn | Peak runoff (Mar - May) Mean | Peak runoff (Mar - May) Maximum | Peak runoff (Mar - May) Minimum | Secondary runoff (Oct - Dec) Mean | Secondary runoff (Oct - Dec) Maximum | Secondary runoff (Oct - Dec) Minimum | Residual runoff (Jun-Sep & Jan-Feb) Mean | Residual runoff (Jun-Sep & Jan-Feb) Maximum | Residual runoff (Jun-Sep & Jan-Feb) Minimum |
|---|---|---|---|---|---|---|---|---|---|
| BV | 51.57 | 78.64 | 39.28 | 20.42 | 29.83 | 10.52 | 28.00 | 42.68 | 10.84 |
| BL | 50.10 | 65.50 | 39.54 | 20.26 | 26.08 | 13.49 | 29.64 | 40.51 | 21.01 |
| PFR | 43.35 | 54.11 | 37.12 | 21.68 | 27.43 | 17.54 | 34.96 | 43.02 | 25.49 |
| HL | 45.29 | 56.59 | 34.51 | 19.81 | 28.56 | 13.67 | 34.91 | 45.62 | 25.23 |
| US | 53.46 | 70.11 | 39.55 | 18.40 | 29.83 | 8.84 | 28.13 | 36.54 | 17.39 |
| NS | 55.85 | 79.80 | 36.11 | 17.11 | 33.46 | 4.52 | 27.04 | 43.76 | 14.71 |
| KB | 36.15 | 42.01 | 30.05 | 21.58 | 26.09 | 15.34 | 42.28 | 48.35 | 37.11 |
| PP | 48.72 | 80.77 | 16.89 | 24.16 | 53.87 | 5.28 | 27.12 | 38.05 | 9.69 |
| ATH | 31.65 | 43.42 | 16.49 | 20.99 | 36.25 | 10.31 | 47.36 | 58.80 | 30.67 |
| mean [1] | 48.06 | 65.94 | 34.13 | 20.43 | 31.89 | 11.15 | 31.51 | 42.32 | 20.18 |
| maximum [1] | 55.85 | 80.77 | 39.55 | 24.16 | 53.87 | 17.54 | 42.28 | 48.35 | 37.11 |
| minimum [1] | 36.15 | 42.01 | 16.89 | 17.11 | 26.08 | 4.52 | 27.04 | 36.54 | 9.69 |

1. Without outflow (Atherley Narrows)

**Table 6. Mean Monthly (mm) and Mean Annual (m) summaries of precipitation depth in the Lake Simcoe area by hydrologic year (June 01 - May 31), (Hy Yr) (for the four stations BWPP, EGB, SCP and RM1P)**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Hy Yr | Annual Precip. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | | | | | | 78.5 | 69.9 | 36.6 | 93.2 | 103.9 | 83.2 | 92.8 | 1990-91 | 0.868 |
| 1991 | 34.4 | 33.6 | 65.6 | 118.1 | 58.5 | 30.1 | 121.7 | 46.1 | 43.3 | 67.7 | 49.4 | 54.1 | 1991-92 | 0.662 |
| 1992 | 45.4 | 38.4 | 41.7 | 70.3 | 53.7 | 36.8 | 95.7 | 118.1 | 110.4 | 47.4 | 117.8 | 70.6 | 1992-93 | 0.923 |
| 1993 | 99.6 | 50.3 | 29.0 | 76.7 | 70.2 | 105.6 | 53.5 | 86.1 | 114.2 | 62.0 | 52.7 | 25.1 | 1993-94 | 0.814 |
| 1994 | 79.4 | 31.2 | 39.0 | 63.5 | 102.1 | 56.4 | 46.2 | 68.6 | 73.1 | 56.3 | 60.4 | 51.2 | 1994-95 | 0.727 |
| 1995 | 92.1 | 48.2 | 31.7 | 86.4 | 56.7 | 103.1 | 119.2 | 115.0 | 60.0 | 122.1 | 167.6 | 94.1 | 1995-96 | 1.041 |
| 1996 | 28.3 | 42.5 | 39.9 | 76.1 | 73.4 | 106.7 | 126.3 | 83.3 | 116.4 | 58.7 | 60.6 | 52.7 | 1996-97 | 0.871 |
| 1997 | 56.4 | 54.9 | 60.2 | 33.7 | 60.8 | 59.8 | 62.7 | 76.8 | 41.9 | 63.0 | 55.4 | 27.6 | 1997-98 | 0.627 |
| 1998 | 79.1 | 21.1 | 61.0 | 35.3 | 43.5 | | | | | | | | | |
| Mean | 64.3 | 40.0 | 46.0 | 70.0 | 64.9 | 72.1 | 86.9 | 78.8 | 81.5 | 72.6 | 76.0 | 58.5 | Mean | 0.817 |
| Maximum | 99.6 | 54.9 | 61.0 | 118.1 | 102.1 | 105.6 | 126.3 | 118.1 | 116.4 | 122.1 | 167.6 | 94.1 | Max. | 1.041 |
| Minimum | 28.3 | 21.1 | 29.0 | 33.7 | 43.5 | 30.1 | 46.2 | 36.6 | 41.9 | 47.4 | 49.4 | 25.1 | Min. | 0.627 |

**Table 7. Annual lake precipitation ($m^3 yr^{-1} x10^8$) for Lake Simcoe 1990 - 1998 calculated as lake area ( $m^2$ ) x annual precipitation ($m yr^{-1}$)**

| Year | 1990-91 | 1991-92 | 1992-93 | 1993-94 | 1994-95 | 1995-96 | 1996-97 | 1997-98 | 1990-1998 Mean | 1990-1998 Total Sum |
|---|---|---|---|---|---|---|---|---|---|---|
| Lake Simcoe | 6.252 | 4.765 | 6.644 | 5.864 | 5.238 | 7.500 | 6.272 | 4.518 | 5.882 | 47.053 |

**Table 8. Minimum, maximum, and mean measured values of stream discharge (l/sec) for the eight gauged watersheds, and the calculated Atherley Narrows 1990-1998.**

| Watershed | minimum discharge (l/sec) 1990-91 | 1991-92 | 1992-93 | 1993-94 | maximum discharge (l/sec) 1990-91 | 1991-92 | 1992-93 | 1993-94 | mean discharge (l/sec) 1990-91 | 1991-92 | 1992-93 | 1993-94 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BV | 188.0 | 60.0 | 29.0 | 313.0 | 37400.0 | 22000.0 | 42000.0 | 11600.0 | 3308.4 | 1510.9 | 3070.6 | 1887.6 |
| BL | 324.0 | 264.0 | 396.0 | 364.0 | 25000.0 | 14800.0 | 38500.0 | 11300.0 | 2712.8 | 1432.2 | 2737.9 | 1594.9 |
| PFR | 713.0 | 644.0 | 795.0 | 968.0 | 41211.4 | 21000.0 | 29000.0 | 13000.0 | 4198.5 | 2412.3 | 3195.7 | 2462.4 |
| HL | 173.0 | 111.0 | 132.0 | 192.0 | 20388.2 | 12600.0 | 25400.0 | 10200.0 | 2028.5 | 908.6 | 1795.5 | 994.9 |
| US | 2.6 | 1.0 | 13.0 | 6.0 | 4220.0 | 2570.0 | 6920.0 | 3100.0 | 298.9 | 115.0 | 350.2 | 160.0 |
| NS | 0.0 | 0.0 | 0.0 | 0.0 | 5730.3 | 5270.0 | 4880.1 | 1700.0 | 293.5 | 124.5 | 233.9 | 201.8 |
| KB | 146.0 | 102.0 | 64.0 | 32.3 | 3230.0 | 5100.0 | 5080.0 | 4553.9 | 515.7 | 398.6 | 671.2 | 287.9 |
| PP | 0.0 | 0.0 | 0.0 | 0.0 | 8039.0 | 2500.5 | 1343.4 | 1206.1 | 244.4 | 122.4 | 132.9 | 58.5 |
| ATH | 0.0 | 0.0 | 5.2 | 0.0 | 125638.6 | 54498.1 | 71388.3 | 53184.9 | 35569.3 | 13758.2 | 36267.0 | 22731.9 |

| Watershed | minimum discharge (l/sec) 1994-95 | 1995-96 | 1996-97 | 1997-98 | maximum discharge (l/sec) 1994-95 | 1995-96 | 1996-97 | 1997-98 | mean discharge (l/sec) 1994-95 | 1995-96 | 1996-97 | 1997-98 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BV | 366.1 | 517.0 | 718.8 | 483.0 | 19478.1 | 14386.5 | 32274.9 | 16100.0 | 1580.4 | 3863.1 | 3513.1 | 2241.4 |
| BL | 235.0 | 185.0 | 371.0 | 169.6 | 17696.1 | 13800.0 | 31500.0 | 17800.0 | 1461.2 | 2297.8 | 3198.2 | 1731.0 |
| PFR | 691.0 | 515.0 | 1130.0 | 921.0 | 29100.0 | 17100.0 | 42000.0 | 29900.0 | 2380.3 | 3713.7 | 4592.2 | 3285.8 |
| HL | 124.0 | 135.0 | 180.0 | 128.0 | 20800.0 | 16215.9 | 39900.0 | 14400.0 | 965.9 | 1718.6 | 2320.6 | 1299.8 |
| US | 10.0 | 15.0 | 25.0 | 8.0 | 3940.0 | 4410.0 | 4900.0 | 3250.0 | 196.4 | 435.4 | 399.9 | 227.3 |
| NS | 0.0 | 2.0 | 1.8 | 0.0 | 2200.0 | 3120.0 | 4122.1 | 3899.2 | 196.4 | 366.2 | 300.6 | 186.7 |
| KB | 0.0 | 63.9 | 73.4 | 121.0 | 2140.0 | 6526.1 | 4242.7 | 1770.0 | 265.2 | 664.3 | 526.1 | 388.4 |
| PP | 0.0 | 0.0 | 0.0 | 0.0 | 1703.2 | 2942.8 | 3364.9 | 1999.0 | 141.7 | 397.6 | 223.3 | 157.8 |
| ATH | 0.0 | 0.0 | 0.0 | 0.0 | 47112.2 | 79150.1 | 91542.0 | 59853.2 | 21953.9 | 39324.8 | 45563.7 | 23863.7 |

**Table 9. Annual yield for the eight gauged watersheds and the calculated Atherley Narrows 1990 - 1998 calculated as areal unit runoff ( m yr $^{-1}$) / precipitation depth (m yr $^{-1}$).**

| Watershed | 1990-91 | 1991-92 | 1992-93 | 1993-94 | 1994-95 | 1995-96 | 1996-97 | 1997-98 | 1990-98 Mean | 1990-98 Maximum | 1990-98 Minimum |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BV | 0.416 | 0.250 | 0.363 | 0.253 | 0.238 | 0.406 | 0.441 | 0.391 | 0.345 | 0.441 | 0.238 |
| BL | 0.383 | 0.266 | 0.364 | 0.240 | 0.246 | 0.271 | 0.450 | 0.338 | 0.320 | 0.450 | 0.240 |
| PFR | 0.475 | 0.359 | 0.340 | 0.297 | 0.322 | 0.351 | 0.518 | 0.515 | 0.397 | 0.518 | 0.297 |
| HL | 0.403 | 0.237 | 0.335 | 0.211 | 0.229 | 0.285 | 0.459 | 0.357 | 0.315 | 0.459 | 0.211 |
| US | 0.259 | 0.131 | 0.285 | 0.148 | 0.203 | 0.315 | 0.345 | 0.272 | 0.245 | 0.345 | 0.131 |
| NS | 0.237 | 0.132 | 0.178 | 0.174 | 0.189 | 0.247 | 0.242 | 0.209 | 0.201 | 0.247 | 0.132 |
| KB | 0.602 | 0.611 | 0.737 | 0.358 | 0.369 | 0.647 | 0.612 | 0.627 | 0.571 | 0.737 | 0.358 |
| PP | 0.313 | 0.206 | 0.160 | 0.080 | 0.217 | 0.425 | 0.285 | 0.280 | 0.246 | 0.425 | 0.080 |
| ATH | 0.362 | 0.184 | 0.258 | 0.247 | 0.267 | 0.333 | 0.462 | 0.336 | 0.306 | 0.462 | 0.184 |
| Mean | 0.383 | 0.264 | 0.336 | 0.223 | 0.253 | 0.365 | 0.424 | 0.370 | 0.327 | 0.737 | 0.080 |
| Maximum | 0.602 | 0.611 | 0.737 | 0.358 | 0.369 | 0.647 | 0.612 | 0.627 | | | |
| Minimum | 0.237 | 0.131 | 0.160 | 0.080 | 0.189 | 0.247 | 0.242 | 0.209 | | | |

**Table 10. Annual water balance for Lake Simcoe - Lake Couchiching 1990 -1998. Individual supply and loss terms in $m^3 yr^{-1}$ and as % total supply or total loss June 1, 1990 to May 31, 1998.**

| | 1990/91 | % | 1991/92 | % | 1992/93 | % | 1993/94 | % | 1994/95 | % | 1995/96 | % | 1996/97 | % | 1997/98 | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Precip [1] | 6.641e+08 | 38.35 | 5.061e+08 | 47.35 | 7.057e+08 | 42.43 | 6.229e+08 | 50.57 | 5.563e+08 | 49.26 | 7.966e+08 | 42.89 | 6.662e+08 | 36.02 | 4.798e+08 | 38.89 |
| BV | 1.043e+08 | 6.02 | 4.778e+07 | 4.47 | 9.684e+07 | 5.82 | 5.953e+07 | 4.83 | 4.984e+07 | 4.41 | 1.222e+08 | 6.58 | 1.108e+08 | 5.99 | 7.069e+07 | 5.73 |
| BL | 8.555e+07 | 4.94 | 4.529e+07 | 4.24 | 8.621e+07 | 5.18 | 5.030e+07 | 4.08 | 4.608e+07 | 4.08 | 7.266e+07 | 3.91 | 1.009e+08 | 5.45 | 5.459e+07 | 4.42 |
| PFR | 1.324e+08 | 7.65 | 7.628e+07 | 7.14 | 1.008e+08 | 6.06 | 7.765e+07 | 6.30 | 7.507e+07 | 6.65 | 1.174e+08 | 6.32 | 1.448e+08 | 7.83 | 1.036e+08 | 8.40 |
| HL | 6.397e+07 | 3.69 | 2.873e+07 | 2.69 | 5.646e+07 | 3.39 | 3.138e+07 | 2.55 | 3.046e+07 | 2.70 | 5.435e+07 | 2.93 | 7.318e+07 | 3.96 | 4.099e+07 | 3.32 |
| US | 9.427e+06 | 0.54 | 3.638e+06 | 0.34 | 1.104e+07 | 0.66 | 5.047e+06 | 0.41 | 6.194e+06 | 0.55 | 1.377e+07 | 0.74 | 1.261e+07 | 0.68 | 7.167e+06 | 0.58 |
| NS | 9.255e+06 | 0.53 | 3.937e+06 | 0.37 | 7.363e+06 | 0.44 | 6.364e+06 | 0.52 | 6.195e+06 | 0.55 | 1.158e+07 | 0.62 | 9.481e+06 | 0.51 | 5.888e+06 | 0.48 |
| KB | 1.626e+07 | 0.94 | 1.260e+07 | 1.18 | 2.117e+07 | 1.27 | 9.079e+06 | 0.74 | 8.362e+06 | 0.74 | 2.101e+07 | 1.13 | 1.659e+07 | 0.90 | 1.225e+07 | 0.99 |
| PP | 7.707e+06 | 0.45 | 3.870e+06 | 0.36 | 4.190e+06 | 0.25 | 1.845e+06 | 0.15 | 4.467e+06 | 0.40 | 1.257e+07 | 0.68 | 7.042e+06 | 0.38 | 4.976e+06 | 0.40 |
| Ungauged | 6.159e+08 | 35.56 | 3.190e+08 | 29.84 | 5.514e+08 | 33.15 | 3.463e+08 | 28.12 | 3.244e+08 | 28.73 | 6.110e+08 | 32.90 | 6.826e+08 | 36.91 | 4.310e+08 | 34.94 |
| Br WPCP | 1.324e+07 | 0.76 | 1.324e+07 | 1.24 | 1.365e+07 | 0.82 | 1.373e+07 | 1.11 | 1.357e+07 | 1.20 | 1.500e+07 | 0.81 | 1.532e+07 | 0.83 | 1.419e+07 | 1.15 |
| Or WPCP | 5.657e+06 | 0.33 | 5.657e+06 | 0.53 | 5.559e+06 | 0.33 | 5.379e+06 | 0.44 | 5.658e+06 | 0.50 | 6.207e+06 | 0.33 | 6.867e+06 | 0.37 | 5.604e+06 | 0.45 |
| LGn WPCP | 3.483e+05 | 0.02 | 3.483e+05 | 0.03 | 3.834e+05 | 0.02 | 2.396e+05 | 0.02 | 2.927e+05 | 0.03 | 1.451e+05 | 0.01 | 3.066e+05 | 0.02 | 3.664e+05 | 0.03 |
| BD WPCP | 1.753e+06 | 0.10 | 1.753e+06 | 0.16 | 1.990e+06 | 0.12 | 1.838e+06 | 0.15 | 1.930e+06 | 0.17 | 2.109e+06 | 0.11 | 2.133e+06 | 0.12 | 2.121e+06 | 0.17 |
| HL LG | 4.057e+05 | 0.02 | 4.057e+05 | 0.04 | 3.335e+05 | 0.02 | 7.299e+04 | 0.01 | 4.516e+05 | 0.04 | 6.086e+05 | 0.03 | 4.724e+05 | 0.03 | 4.329e+05 | 0.04 |
| North Pump | 1.514e+06 | 0.09 | 2.815e+05 | 0.03 | 2.806e+05 | 0.02 | 0.000e+00 | 0.00 | 0.000e+00 | 0.00 | 1.227e+05 | 0.01 | 1.169e+05 | 0.01 | 0.000e+00 | 0.00 |
| Total Supply | 1.732e+09 | 100.00 | 1.069e+09 | 100.00 | 1.663e+09 | 100.0 | 1.232e+09 | 100.0 | 1.129e+09 | 100.00 | 1.857e+09 | 100.00 | 1.849e+09 | 100.00 | 1.234e+09 | 100.0 |
| | | | | | | | | | | | | | | | | |
| LCW OF | 1.222e+09 | 66.35 | 4.916e+08 | 42.70 | 1.206e+09 | 68.76 | 8.436e+08 | 60.38 | 7.937e+08 | 58.26 | 1.552e+09 | 73.51 | 1.841e+09 | 78.76 | 9.945e+08 | 64.56 |
| Evaporation | 6.003e+08 | 32.61 | 6.345e+08 | 55.11 | 5.586e+08 | 31.85 | 5.683e+08 | 40.68 | 5.973e+08 | 43.84 | 5.348e+08 | 25.33 | 4.943e+08 | 21.15 | 5.766e+08 | 37.43 |
| Lake | 1.911e+07 | 1.04 | 2.525e+07 | 2.19 | -1.060e+07 | -0.60 | -1.480e+07 | -1.06 | -2.870e+07 | -2.11 | 2.452e+07 | 1.16 | 2.208e+06 | 0.09 | -3.060e+07 | -1.99 |
| Total Loss | 1.841e+09 | 100.00 | 1.151e+09 | 100.00 | 1.754e+09 | 100.0 | 1.397e+09 | 100.0 | 1.362e+09 | 100.00 | 2.111e+09 | 100.00 | 2.338e+09 | 100.00 | 1.540e+09 | 100.0 |
| | | | | | | | | | | | | | | | | |
| Balance | 5.935e-02 | | 7.159e-02 | | 5.177e-02 | | 1.184e-01 | | 1.710e-01 | | 1.203e-01 | | 2.088e-01 | | 1.991e-01 | |
| Balance % | 5.935e+00 | | 7.159e+00 | | 5.177e+00 | | 1.184e+01 | | 1.710e+01 | | 1.203e+01 | | 2.088e+01 | | 1.991e+01 | |

| | 1990/98 |
|---|---|
| Balance | 1.251e-01 |
| Balance % | 1.251e+01 |

Note: Point source data not available for water year 1990-1991, Water year 1991-1992 was substituted.
Sewage Treatment plant volumes omitted from the water balance are described in Table 2a
1. Precipitation to the lake

**Table 11. Annual water balance for Lake Couchiching using prorated Swift Rapids outflow data 1990 -1998. Individual supply and loss terms in $m^3$ $yr^{-1}$ and as % total supply or total loss June 1, 1990 to May 31, 1998.**

| | 1990/91 | % | 1991/92 | % | 1992/93 | % | 1993/94 | % | 1994/95 | % | 1995/96 | % | 1996/97 | % | 1997/98 | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Precip [1] | 6.641e+08 | 38.35 | 5.061e+08 | 47.35 | 7.057e+08 | 42.43 | 6.229e+08 | 50.57 | 5.563e+08 | 49.26 | 7.966e+08 | 42.89 | 6.662e+08 | 36.02 | 4.798e+08 | 38.89 |
| BV | 1.043e+08 | 6.02 | 4.778e+07 | 4.47 | 9.684e+07 | 5.82 | 5.953e+07 | 4.83 | 4.984e+07 | 4.41 | 1.222e+08 | 6.58 | 1.108e+08 | 5.99 | 7.069e+07 | 5.73 |
| BL | 8.555e+07 | 4.94 | 4.529e+07 | 4.24 | 8.621e+07 | 5.18 | 5.030e+07 | 4.08 | 4.608e+07 | 4.08 | 7.266e+07 | 3.91 | 1.009e+08 | 5.45 | 5.459e+07 | 4.42 |
| PFR | 1.324e+08 | 7.65 | 7.628e+07 | 7.14 | 1.008e+08 | 6.06 | 7.765e+07 | 6.30 | 7.507e+07 | 6.65 | 1.174e+08 | 6.32 | 1.448e+08 | 7.83 | 1.036e+08 | 8.40 |
| HL | 6.397e+07 | 3.69 | 2.873e+07 | 2.69 | 5.646e+07 | 3.39 | 3.138e+07 | 2.55 | 3.046e+07 | 2.70 | 5.435e+07 | 2.93 | 7.318e+07 | 3.96 | 4.099e+07 | 3.32 |
| US | 9.427e+06 | 0.54 | 3.638e+06 | 0.34 | 1.104e+07 | 0.66 | 5.047e+06 | 0.41 | 6.194e+06 | 0.55 | 1.377e+07 | 0.74 | 1.261e+07 | 0.68 | 7.167e+06 | 0.58 |
| NS | 9.255e+06 | 0.53 | 3.937e+06 | 0.37 | 7.363e+06 | 0.44 | 6.364e+06 | 0.52 | 6.195e+06 | 0.55 | 1.158e+07 | 0.62 | 9.481e+06 | 0.51 | 5.888e+06 | 0.48 |
| KB | 1.626e+07 | 0.94 | 1.260e+07 | 1.18 | 2.117e+07 | 1.27 | 9.079e+06 | 0.74 | 8.362e+06 | 0.74 | 2.101e+07 | 1.13 | 1.659e+07 | 0.90 | 1.225e+07 | 0.99 |
| PP | 7.707e+06 | 0.45 | 3.870e+06 | 0.36 | 4.190e+06 | 0.25 | 1.845e+06 | 0.15 | 4.467e+06 | 0.40 | 1.257e+07 | 0.68 | 7.042e+06 | 0.38 | 4.976e+06 | 0.40 |
| Ungauged | 6.159e+08 | 35.56 | 3.190e+08 | 29.84 | 5.514e+08 | 33.15 | 3.463e+08 | 28.12 | 3.244e+08 | 28.73 | 6.110e+08 | 32.90 | 6.826e+08 | 36.91 | 4.310e+08 | 34.94 |
| BR WPCP | 1.324e+07 | 0.76 | 1.324e+07 | 1.24 | 1.365e+07 | 0.82 | 1.373e+07 | 1.11 | 1.357e+07 | 1.20 | 1.500e+07 | 0.81 | 1.532e+07 | 0.83 | 1.419e+07 | 1.15 |
| OR WPCP | 5.657e+06 | 0.33 | 5.657e+06 | 0.53 | 5.559e+06 | 0.33 | 5.379e+06 | 0.44 | 5.658e+06 | 0.50 | 6.207e+06 | 0.33 | 6.867e+06 | 0.37 | 5.604e+06 | 0.45 |
| LG WPCP | 3.483e+05 | 0.02 | 3.483e+05 | 0.03 | 3.834e+05 | 0.02 | 2.396e+05 | 0.02 | 2.927e+05 | 0.03 | 1.451e+05 | 0.01 | 3.066e+05 | 0.02 | 3.664e+05 | 0.03 |
| BD WPCP | 1.753e+06 | 0.10 | 1.753e+06 | 0.16 | 1.990e+06 | 0.12 | 1.838e+06 | 0.15 | 1.930e+06 | 0.17 | 2.109e+06 | 0.11 | 2.133e+06 | 0.12 | 2.121e+06 | 0.17 |
| HL LG | 4.057e+05 | 0.02 | 4.057e+05 | 0.04 | 3.335e+05 | 0.02 | 7.299e+04 | 0.01 | 4.516e+05 | 0.04 | 6.086e+05 | 0.03 | 4.724e+05 | 0.03 | 4.329e+05 | 0.04 |
| North Pump | 1.514e+06 | 0.09 | 2.815e+05 | 0.03 | 2.806e+05 | 0.02 | 0.000e+00 | 0.00 | 0.000e+00 | 0.00 | 1.227e+05 | 0.01 | 1.169e+05 | 0.01 | 0.000e+00 | 0.00 |
| Total Supply | 1.732e+09 | 100.00 | 1.069e+09 | 100.00 | 1.663e+09 | 100.00 | 1.232e+09 | 100.00 | 1.129e+09 | 100.00 | 1.857e+09 | 100.00 | 1.849e+09 | 100.00 | 1.234e+09 | 100.00 |
| | | | | | | | | | | | | | | | | |
| SW Outlet | 1.148e+09 | 64.95 | 4.373e+08 | 39.86 | 1.171e+09 | 68.12 | 7.314e+08 | 56.92 | 7.023e+08 | 55.26 | 1.278e+09 | 69.56 | 1.472e+09 | 74.77 | 7.626e+08 | 58.28 |
| Evaporation | 6.00e+08 | 33.97 | 6.34e+08 | 57.84 | 5.59e+08 | 32.49 | 5.68e+08 | 44.23 | 5.97e+08 | 47.00 | 5.35e+08 | 29.10 | 4.94e+08 | 25.11 | 5.77e+08 | 44.06 |
| Lake | 1.911e+07 | 1.08 | 2.525e+07 | 2.30 | -1.060e+0 | -0.62 | -1.480e+07 | -1.15 | -2.870e+07 | -2.26 | 2.452e+07 | 1.33 | 2.208e+06 | 0.11 | -3.060e+07 | -2.34 |
| Total Loss | 1.767e+09 | 100.00 | 1.097e+09 | 100.00 | 1.719e+09 | 100.00 | 1.285e+09 | 100.00 | 1.271e+09 | 100.00 | 1.838e+09 | 100.00 | 1.968e+09 | 100.00 | 1.309e+09 | 100.00 |
| | | | | | | | | | | | | | | | | |
| Balance | 2.019e-02 | | 2.561e-02 | | 3.245e-02 | | 4.148e-02 | | 1.114e-01 | | -1.067e-02 | | 6.035e-02 | | 5.718e-02 | |
| Balance % | 2.019e+00 | | 2.561e+00 | | 3.245e+00 | | 4.148e+00 | | 1.114e+01 | | -1.067e+00 | | 6.035e+00 | | 5.718e+00 | |

| | 1990/98 |
|---|---|
| Balance | 4.225e-02 |
| Balance % | 4.225e+00 |

Note: Point source data not available for water year 1990-1991, Water year 1991-1992 was substituted.
Sewage Treatment plant volumes omitted from the water balance are described in Table 2a
1. Precipitation to the lake

**Table 12. Annual water balance for Lake Simcoe at Atherley Narrows 1990 -1998. Individual supply and loss terms in $m^3 yr^{-1}$ and as % total supply or total loss June 1, 1990 to May 31, 1998.**

| | 1990/91 | % | 1991/92 | % | 1992/93 | % | 1993/94 | % | 1994/95 | % | 1995/96 | % | 1996/97 | % | 1997/98 | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Precip [1] | 6.252e+08 | 36.93 | 4.765e+08 | 45.85 | 6.644e+08 | 40.96 | 5.864e+08 | 49.07 | 5.238e+08 | 47.75 | 7.500e+08 | 41.42 | 6.272e+08 | 34.65 | 4.518e+08 | 37.47 |
| BV | 1.043e+08 | 6.16 | 4.778e+07 | 4.60 | 9.684e+07 | 5.97 | 5.953e+07 | 4.98 | 4.984e+07 | 4.54 | 1.222e+08 | 6.75 | 1.108e+08 | 6.12 | 7.069e+07 | 5.86 |
| BL | 8.555e+07 | 5.05 | 4.529e+07 | 4.36 | 8.621e+07 | 5.31 | 5.030e+07 | 4.21 | 4.608e+07 | 4.20 | 7.266e+07 | 4.01 | 1.009e+08 | 5.57 | 5.459e+07 | 4.53 |
| PFR | 1.324e+08 | 7.82 | 7.628e+07 | 7.34 | 1.008e+08 | 6.21 | 7.765e+07 | 6.50 | 7.507e+07 | 6.84 | 1.174e+08 | 6.49 | 1.448e+08 | 8.00 | 1.036e+08 | 8.59 |
| HL | 6.397e+07 | 3.78 | 2.873e+07 | 2.76 | 5.646e+07 | 3.48 | 3.138e+07 | 2.63 | 3.046e+07 | 2.78 | 5.435e+07 | 3.00 | 7.318e+07 | 4.04 | 4.099e+07 | 3.40 |
| US | 9.427e+06 | 0.56 | 3.638e+06 | 0.35 | 1.104e+07 | 0.68 | 5.047e+06 | 0.42 | 6.194e+06 | 0.56 | 1.377e+07 | 0.76 | 1.261e+07 | 0.70 | 7.167e+06 | 0.59 |
| NS | 9.255e+06 | 0.55 | 3.937e+06 | 0.38 | 7.363e+06 | 0.45 | 6.364e+06 | 0.53 | 6.195e+06 | 0.56 | 1.158e+07 | 0.64 | 9.481e+06 | 0.52 | 5.888e+06 | 0.49 |
| KB | 1.626e+07 | 0.96 | 1.260e+07 | 1.21 | 2.117e+07 | 1.30 | 9.079e+06 | 0.76 | 8.362e+06 | 0.76 | 2.101e+07 | 1.16 | 1.659e+07 | 0.92 | 1.225e+07 | 1.02 |
| PP | 7.707e+06 | 0.46 | 3.870e+06 | 0.37 | 4.190e+06 | 0.26 | 1.845e+06 | 0.15 | 4.467e+06 | 0.41 | 1.257e+07 | 0.69 | 7.042e+06 | 0.39 | 4.976e+06 | 0.41 |
| Ungauged | 6.159e+08 | 36.38 | 3.190e+08 | 30.69 | 5.514e+08 | 34.00 | 3.463e+08 | 28.98 | 3.244e+08 | 29.58 | 6.110e+08 | 33.74 | 6.826e+08 | 37.70 | 4.310e+08 | 35.75 |
| BR WPCP | 1.324e+07 | 0.78 | 1.324e+07 | 1.27 | 1.365e+07 | 0.84 | 1.373e+07 | 1.15 | 1.357e+07 | 1.24 | 1.500e+07 | 0.83 | 1.532e+07 | 0.85 | 1.419e+07 | 1.18 |
| OR WPCP | 5.657e+06 | 0.33 | 5.657e+06 | 0.54 | 5.559e+06 | 0.34 | 5.379e+06 | 0.45 | 5.658e+06 | 0.52 | 6.207e+06 | 0.34 | 6.867e+06 | 0.38 | 5.604e+06 | 0.46 |
| LG WPCP | 3.483e+05 | 0.02 | 3.483e+05 | 0.03 | 3.834e+05 | 0.02 | 2.396e+05 | 0.02 | 2.927e+05 | 0.03 | 1.451e+05 | 0.01 | 3.066e+05 | 0.02 | 3.664e+05 | 0.03 |
| BD WPCP | 1.753e+06 | 0.10 | 1.753e+06 | 0.17 | 1.990e+06 | 0.12 | 1.838e+06 | 0.15 | 1.930e+06 | 0.18 | 2.109e+06 | 0.12 | 2.133e+06 | 0.12 | 2.121e+06 | 0.18 |
| HL LG | 4.057e+05 | 0.02 | 4.057e+05 | 0.04 | 3.335e+05 | 0.02 | 7.299e+04 | 0.01 | 4.516e+05 | 0.04 | 6.086e+05 | 0.03 | 4.724e+05 | 0.03 | 4.329e+05 | 0.04 |
| North Pump | 1.514e+06 | 0.09 | 2.815e+05 | 0.03 | 2.806e+05 | 0.02 | 0.000e+00 | 0.00 | 0.000e+00 | 0.00 | 1.227e+05 | 0.01 | 1.169e+05 | 0.01 | 0.000e+00 | 0.00 |
| Total Supply | 1.693e+09 | 100.0 | 1.039e+09 | 100.00 | 1.622e+09 | 100.00 | 1.195e+09 | 100.00 | 1.097e+09 | 100.00 | 1.811e+09 | 100.00 | 1.810e+09 | 100.00 | 1.206e+09 | 100.00 |
| | | | | | | | | | | | | | | | | |
| ATH Outlet | 1.122e+09 | 65.75 | 4.351e+08 | 41.13 | 1.144e+09 | 68.94 | 7.169e+08 | 57.95 | 6.923e+08 | 56.47 | 1.243e+09 | 70.18 | 1.437e+09 | 75.44 | 7.526e+08 | 59.50 |
| Evaporation | 5.652e+08 | 33.13 | 5.974e+08 | 56.48 | 5.260e+08 | 31.70 | 5.351e+08 | 43.25 | 5.624e+08 | 45.87 | 5.035e+08 | 28.43 | 4.654e+08 | 24.44 | 5.428e+08 | 42.92 |
| Lake | 1.911e+07 | 1.12 | 2.525e+07 | 2.39 | -1.060e+0 | -0.64 | -1.480e+0 | -1.20 | -2.870e+07 | -2.34 | 2.452e+07 | 1.38 | 2.208e+06 | 0.12 | -3.060e+07 | -2.42 |
| Total Loss | 1.706e+09 | 100.0 | 1.058e+09 | 100.00 | 1.659e+09 | 100.00 | 1.237e+09 | 100.00 | 1.226e+09 | 100.00 | 1.771e+09 | 100.00 | 1.904e+09 | 100.00 | 1.265e+09 | 100.00 |
| | | | | | | | | | | | | | | | | |
| Balance | 7.687e-03 | | 1.739e-02 | | 2.227e-02 | | 3.391e-02 | | 1.054e-01 | | -2.248e-02 | | 4.922e-02 | | 4.676e-02 | |
| Balance % | 7.687e-01 | | 1.739e+00 | | 2.227e+00 | | 3.391e+00 | | 1.054e+01 | | -2.248e+00 | | 4.922e+00 | | 4.676e+00 | |

| | 1990 / 98 |
|---|---|
| Balance | 3.215e-02 |
| Balance % | 3.215e+00 |

Note: Point source data not available for water year 1990-1991, Water year 1991-1992 was substituted.
Sewage Treatment plant volumes omitted from the water balance are described in Table 2a
1. Precipitation to the lake

**Table 13. Summary of monthly (mm mo $^{-1}$) and annual (m yr $^{-1}$) evaporation rates in the Lake Simcoe area by hydrologic year (Hy Yr)**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Hy Yr | Annual Evap.(m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | | | | | | 121.2 | 141.8 | 112.9 | 77.9 | 46.0 | 24.6 | 3.1 | 1990-91 | 0.7847 |
| 1991 | 1.3 | 22.5 | 47.1 | 65.8 | 120.5 | 155.2 | 144.1 | 125.5 | 73.6 | 42.5 | 19.2 | 4.0 | 1991-92 | 0.8293 |
| 1992 | 2.2 | 20.8 | 46.7 | 69.0 | 126.7 | 129.1 | 103.3 | 104.4 | 63.2 | 41.6 | 18.3 | 8.4 | 1992-93 | 0.7302 |
| 1993 | 9.2 | 23.8 | 49.5 | 61.9 | 117.3 | 125.0 | 147.2 | 116.5 | 57.3 | 39.5 | 19.9 | 3.3 | 1993-94 | 0.7429 |
| 1994 | -7.5 | 22.1 | 48.5 | 74.2 | 96.9 | 127.9 | 140.5 | 107.9 | 71.1 | 51.2 | 25.7 | 7.0 | 1994-95 | 0.7807 |
| 1995 | 6.4 | 19.8 | 57.5 | 59.6 | 106.0 | 128.6 | 138.0 | 120.1 | 66.0 | 37.3 | 12.3 | -2.8 | 1995-96 | 0.6991 |
| 1996 | -0.4 | 1.6 | 49.5 | 49.6 | 99.2 | 94.5 | 133.4 | 118.1 | 56.0 | 33.4 | 14.8 | 3.1 | 1996-97 | 0.6461 |
| 1997 | -0.9 | 3.4 | 39.6 | 65.1 | 85.5 | 133.0 | 137.3 | 98.3 | 68.6 | 46.1 | 20.0 | -0.5 | 1997-98 | 0.7536 |
| 1998 | 0.3 | 21.0 | 38.4 | 77.8 | 113.2 | | | | | | | | | |
| | | | | | | | | | | | | | | |
| Mean | 1.3 | 16.9 | 47.1 | 65.4 | 108.2 | 126.8 | 135.7 | 113.0 | 66.7 | 42.2 | 19.4 | 3.2 | Mean | 0.664 |
| Maximum | 9.2 | 23.8 | 57.5 | 77.8 | 126.7 | 155.2 | 147.2 | 125.5 | 73.6 | 51.2 | 25.7 | 8.4 | Max. | 0.829 |
| Minimum | -7.5 | 1.6 | 38.4 | 49.6 | 85.5 | 94.5 | 103.3 | 98.3 | 56.0 | 33.4 | 12.3 | -2.8 | Min. | 0.646 |

**Table 14. Annual lake evaporation (m$^{3}$ yr$^{-1}$ x 10 $^{8}$) for Lake Simcoe 1990 - 1998 calculated as evaporation rate ( m yr**

| | | | 1992-93 | Year 1993-94 | 1990-91 1994-95 | 1991-92 1995-96 | 1996-97 | 1997-98 | Mean |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| Lake Simcoe | 5.652 | 5.974 | 5.260 | 5.351 | 5.624 | 5.035 | 4.654 | 5.428 | 5.372 |
| | | | | | | | | | |

**Table 15. Lake Simcoe lake level (m) 1990 - 1998.**

| Hydrologic Year | 1990-91 | 1991-92 | 1992-93 | 1993-94 | 1994-95 | 1995-96 | 1996-97 | 1997-98 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jacksons Point lake storage | 0.026 | 0.032 | -0.015 | -0.020 | -0.040 | 0.034 | 0.008 | | | | |
| Washago lake storage | 0.024 | 0.034 | -0.013 | -0.019 | -0.035 | 0.030 | -0.002 | -0.040 | Mean 1990-98 | Maximum | Minimum |
| Mean lake storage | 0.025 | 0.033 | -0.014 | -0.019 | -0.038 | 0.032 | 0.003 | -0.040 | -0.002 | 0.033 | -0.040 |

**Table 16. Change in lake storage ($m^3$ $yr^{-1}$) .**

Calculation: (mean delta storage (m) * lake area ($m^2$) ) = $m^3$ volume of lake storage.

| Hydrologic Year | 1990-91 | 1991-92 | 1992-93 | 1993-94 | 1994-95 | 1995-96 | 1996-97 | 1997-98 | Mean 1990-98 | Maximum | Minimum |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lake Storage | 1.911e+07 | 2.525e+07 | -1.060e+07 | -1.480e+07 | -2.870e+07 | 2.452e+07 | 2.208e+06 | -3.060e+07 | -1.702e+06 | 2.525e+07 | -3.060e+07 |

**Table 17. Flushing time and residence time (years) for Lake Simcoe ( volume = 1.0255 * $10^{10}$ $m^3$) 1990 - 1998.**

| Hydrologic Year | 1990-91 | 1991-92 | 1992-93 | 1993-94 | 1994 -95 | 1995-96 | 1996-97 | 1997-98 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Mean 1990-98 | Maximum | Minimum |
| Flushing | 9.14 | 23.57 | 8.97 | 14.31 | 14.81 | 8.25 | 7.14 | 13.63 | 12.48 | 23.57 | 7.14 |
| | | | | | | | | | Mean1990-98 | Maximum | Minimum |
| Residence | 6.01 | 9.7 | 6.18 | 8.29 | 8.36 | 5.79 | 5.39 | 8.11 | 7.23 | 9.7 | 5.39 |

**Table 18. Monthly total phosphorus loading (kg) for the gauged watersheds 1990-91.**

| SDATE | BL PRO | BV | HL | KB | NS | PFU | US | PP | Total | Mean | Maximum | Minimum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JUN | 349.21 | 137.69 | 1301.81 | 323.82 | 11.38 | 178.25 | 19.64 | 229.18 | 2550.98 | 318.87 | 1301.81 | 11.38 |
| JUL | 313.66 | 64.21 | 706.07 | 21.20 | 4.55 | 152.90 | 11.89 | 236.61 | 1511.09 | 188.89 | 706.07 | 4.55 |
| AUG | 175.96 | 26.16 | 421.88 | 20.69 | 9.62 | 96.86 | 17.18 | 127.22 | 895.58 | 111.95 | 421.88 | 9.62 |
| SEP | 106.15 | 20.99 | 319.99 | 12.15 | 1.03 | 84.98 | 14.61 | 89.91 | 649.80 | 81.23 | 319.99 | 1.03 |
| OCT | 235.48 | 81.78 | 2180.16 | 193.11 | 27.58 | 169.39 | 52.79 | 389.73 | 3330.03 | 416.25 | 2180.16 | 27.58 |
| NOV | 198.83 | 87.30 | 680.08 | 15.97 | 34.92 | 114.84 | 41.14 | 218.26 | 1391.33 | 173.92 | 680.08 | 15.97 |
| DEC | 151.20 | 108.22 | 1065.37 | 33.26 | 27.90 | 125.29 | 75.10 | 241.04 | 1827.37 | 228.42 | 1065.37 | 27.90 |
| JAN | 109.20 | 65.02 | 261.91 | 18.63 | 7.52 | 84.14 | 27.35 | 140.57 | 714.34 | 89.29 | 261.91 | 7.52 |
| FEB | 224.75 | 650.94 | 668.71 | 332.07 | 63.69 | 504.05 | 171.58 | 153.91 | 2769.69 | 346.21 | 668.71 | 63.69 |
| MAR | 948.35 | 1743.89 | 11030.42 | 740.21 | 738.43 | 1127.03 | 356.94 | 1033.83 | 17719.09 | 2214.89 | 11030.42 | 356.94 |
| APR | 1200.99 | 2175.16 | 8648.79 | 838.31 | 2973.06 | 1238.39 | 250.76 | 1214.23 | 18539.69 | 2317.46 | 8648.79 | 250.76 |
| MAY | 206.55 | 178.97 | 771.71 | 91.46 | 6.84 | 307.24 | 15.50 | 146.72 | 1724.99 | 215.62 | 771.71 | 6.84 |
| | | | | | | | | | | | | |
| Total | 4220.34 | 5340.32 | 28056.90 | 2640.87 | 3906.51 | 4183.37 | 1054.48 | 4221.21 | 53624.00 TP in | | | |
| Mean | 351.69 | 445.03 | 2338.07 | 220.07 | 325.54 | 348.61 | 87.87 | 351.77 | | | | |
| Maximum | 1200.99 | 2175.16 | 11030.42 | 838.31 | 2973.06 | 1238.39 | 356.94 | 1214.23 | | | | |
| Minimum | 106.15 | 20.99 | 261.91 | 12.15 | 1.03 | 84.14 | 11.89 | 89.91 | | | | |

**Table 19. Monthly total phosphorus loading (kg) for the gauged watersheds 1991-92.**

| SDATE | BL PRO | BV | HL | KB | NS | PFU | US | PP | Total | Mean | Maximum | Minimum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JUN | 179.82 | 31.92 | 402.56 | 21.79 | 0.30 | 95.25 | 9.14 | 84.26 | 825.04 | 103.13 | 402.56 | 0.30 |
| JUL | 120.94 | 20.16 | 533.10 | 36.60 | 1.63 | 89.03 | 8.40 | 8.12 | 817.98 | 102.25 | 533.10 | 1.63 |
| AUG | 76.19 | 7.43 | 180.78 | 6.70 | 0.06 | 69.17 | 3.80 | 24.95 | 369.07 | 46.13 | 180.78 | 0.06 |
| SEP | 55.31 | 5.99 | 108.68 | 6.12 | 0.07 | 54.33 | 1.86 | 0.00 | 232.36 | 29.04 | 108.68 | 0.00 |
| OCT | 54.20 | 19.08 | 391.48 | 8.51 | 1.58 | 95.84 | 6.37 | 39.99 | 617.05 | 77.13 | 391.48 | 1.58 |
| NOV | 41.43 | 20.70 | 300.38 | 10.86 | 2.01 | 53.94 | 7.27 | 5.86 | 442.44 | 55.31 | 300.38 | 2.01 |
| DEC | 52.12 | 26.65 | 383.13 | 15.05 | 8.97 | 69.62 | 8.56 | 139.08 | 703.18 | 87.90 | 383.13 | 8.56 |
| JAN | 43.22 | 27.91 | 276.79 | 14.69 | 15.31 | 44.41 | 6.29 | 66.01 | 494.65 | 61.83 | 276.79 | 6.29 |
| FEB | 61.70 | 34.78 | 745.55 | 125.41 | 96.80 | 72.74 | 31.60 | 87.49 | 1256.06 | 157.01 | 745.55 | 31.60 |
| MAR | 1035.40 | 1590.66 | 2636.87 | 509.81 | 567.07 | 1284.71 | 86.94 | 1269.27 | 8980.75 | 1122.59 | 2636.87 | 86.94 |
| APR | 665.20 | 322.98 | 3209.13 | 753.71 | 145.04 | 451.59 | 67.38 | 795.91 | 6410.94 | 801.37 | 3209.13 | 67.38 |
| MAY | 748.28 | 197.43 | 472.67 | 37.21 | 7.32 | 262.20 | 21.48 | 118.33 | 1864.92 | 233.11 | 748.28 | 7.32 |
| | | | | | | | | | | | | |
| Total | 3133.81 | 2305.69 | 9641.13 | 1546.47 | 846.17 | 2642.83 | 259.08 | 2639.26 | 23014.43 TP in kg | | | |
| Mean | 261.15 | 192.14 | 803.43 | 128.87 | 70.51 | 220.24 | 21.59 | 219.94 | | | | |
| Maximum | 1035.40 | 1590.66 | 3209.13 | 753.71 | 567.07 | 1284.71 | 86.94 | 1269.27 | | | | |
| Minimum | 41.43 | 5.99 | 108.68 | 6.12 | 0.06 | 44.41 | 1.86 | 0.00 | | | | |

## Table 20. Monthly total phosphorus loading (kg) for the gauged watersheds 1992-93.

| SDATE | BL PRO | BV | HL | KB | NS | PFU | US | PP | Total | Mean | Maximum | Minimum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JUN | 123.49 | 22.00 | 160.00 | 11.18 | 0.52 | 100.40 | 6.70 | 0.00 | 424.30 | 53.04 | 160.00 | 0.00 |
| JUL | 96.70 | 9.53 | 1049.55 | 49.24 | 3.46 | 141.93 | 15.82 | 815.74 | 2181.96 | 272.74 | 1049.55 | 3.46 |
| AUG | 186.23 | 44.16 | 6170.35 | 553.21 | 19.31 | 436.89 | 36.73 | 409.66 | 7856.54 | 982.07 | 6170.35 | 19.31 |
| SEP | 275.08 | 238.35 | 783.49 | 176.56 | 13.61 | 324.84 | 21.21 | 158.88 | 1992.02 | 249.00 | 783.49 | 13.61 |
| OCT | 115.98 | 50.97 | 240.05 | 120.39 | 3.63 | 110.31 | 14.37 | 366.15 | 1021.85 | 127.73 | 366.15 | 3.63 |
| NOV | 409.94 | 538.98 | 2301.00 | 571.53 | 386.55 | 306.42 | 72.00 | 678.16 | 5264.59 | 658.07 | 2301.00 | 72.00 |
| DEC | 132.14 | 72.41 | 1580.24 | 277.49 | 282.29 | 120.63 | 92.54 | 237.03 | 2794.78 | 349.35 | 1580.24 | 72.41 |
| JAN | 272.85 | 170.27 | 2867.70 | 864.05 | 195.52 | 158.73 | 143.78 | 80.80 | 4753.71 | 594.21 | 2867.70 | 80.80 |
| FEB | 78.82 | 94.18 | 323.88 | 36.15 | 3.30 | 89.55 | 12.16 | 47.72 | 685.76 | 85.72 | 323.88 | 3.30 |
| MAR | 927.19 | 2602.89 | 2995.97 | 421.98 | 714.50 | 919.56 | 938.65 | 78.81 | 9599.54 | 1199.94 | 2995.97 | 78.81 |
| APR | 3638.26 | 2090.68 | 1871.83 | 595.83 | 280.23 | 1218.55 | 407.17 | 338.60 | 10441.15 | 1305.14 | 3638.26 | 280.23 |
| MAY | 590.66 | 330.56 | 997.09 | 1102.83 | 42.89 | 302.13 | 75.93 | 178.78 | 3620.89 | 452.61 | 1102.83 | 42.89 |
| | | | | | | | | | | | | |
| Total | 6847.34 | 6264.98 | 21341.15 | 4780.44 | 1945.81 | 4229.95 | 1837.06 | 3390.34 | 50637.07 TP in kg | | | |
| Mean | 570.61 | 522.08 | 1778.43 | 398.37 | 162.15 | 352.50 | 153.09 | 282.53 | | | | |
| Maximum | 3638.26 | 2602.89 | 6170.35 | 1102.83 | 714.50 | 1218.55 | 938.65 | 815.74 | | | | |
| Minimum | 78.82 | 9.53 | 160.00 | 11.18 | 0.52 | 89.55 | 6.70 | 0.00 | | | | |

## Table 21. Monthly total phosphorus loading (kg) for the gauged watersheds 1993-94.

| SDATE | BL PRO | BV | BV | HL | KB | NS | PFR | PFU | US | PP | Total | Mean | Maximum | Minimum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JUN | 343.89 | 129.91 | | 1292.36 | 782.15 | 32.88 | | 361.45 | 83.48 | 138.85 | 3164.95 | 395.62 | 1292.36 | 32.88 |
| JUL | 123.17 | 41.21 | | 276.18 | 459.57 | 2.43 | | 131.84 | 8.61 | 45.50 | 1088.52 | 136.06 | 459.57 | 2.43 |
| AUG | 78.61 | | 43.70 | 221.38 | 77.99 | 1.29 | | 129.75 | 3.72 | 81.62 | 638.05 | 79.76 | 221.38 | 1.29 |
| SEP | 65.78 | | 46.69 | 182.97 | 2.83 | 0.52 | | 111.68 | 4.25 | 84.90 | 499.62 | 62.45 | 182.97 | 0.52 |
| OCT | 76.40 | | 73.61 | 381.24 | 4.89 | 2.17 | 159.83 | | 11.77 | 66.50 | 776.41 | 97.05 | 381.24 | 2.17 |
| NOV | 89.19 | | 60.30 | 472.78 | 5.37 | 2.75 | 146.95 | | 11.94 | 99.13 | 888.42 | 111.05 | 472.78 | 2.75 |
| DEC | 110.86 | | 68.69 | 132.73 | 6.23 | 2.61 | 146.15 | | 11.35 | 134.10 | 612.72 | 76.59 | 146.15 | 2.61 |
| JAN | 50.76 | | 32.17 | 32.43 | 6.10 | 3.94 | 58.83 | | 8.93 | 46.13 | 239.28 | 29.91 | 58.83 | 3.94 |
| FEB | 399.27 | | 126.44 | 750.70 | 106.60 | 30.91 | 897.72 | | 135.50 | 58.24 | 2505.38 | 313.17 | 897.72 | 30.91 |
| MAR | 538.91 | | 691.35 | 1229.85 | 113.44 | 333.79 | 687.90 | | 188.85 | 91.75 | 3875.84 | 484.48 | 1229.85 | 91.75 |
| APR | 406.74 | | 391.81 | 518.97 | 50.20 | 86.01 | 510.64 | | 67.39 | 308.15 | 2339.91 | 292.49 | 518.97 | 50.20 |
| MAY | 476.01 | | 301.30 | 625.21 | 27.78 | 51.40 | 395.86 | | 44.11 | 100.64 | 2022.31 | 252.79 | 625.21 | 27.78 |
| | | | | | | | | | | | | | | |
| Total | 2759.57 | 171.12 | 1836.0 | 6116.79 | 1643.1 | 550.70 | 3003.8 | 734.72 | 579.90 | 1255.5 | 18651.4 TP in | | | |
| Mean | 229.96 | 85.56 | 183.61 | 509.73 | 136.93 | 45.89 | 375.49 | 183.68 | 48.32 | 104.63 | | | | |
| Maximum | 538.91 | 129.91 | 691.35 | 1292.36 | 782.15 | 333.79 | 897.72 | 361.45 | 188.85 | 308.15 | | | | |
| Minimum | 50.76 | 41.21 | 32.17 | 32.43 | 2.83 | 0.52 | 58.83 | 111.68 | 3.72 | 45.50 | | | | |

**Table 22. Monthly total phosphorus loading (kg) for the gauged watersheds 1994-95.**

| SDATE | BL PRO | BV PRO | HL | KB | NS | PFR PRO | US | PP | Total | Mean | Maximum | Minimum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JUN | 189.53 | 132.27 | 202.63 | 8.12 | 7.18 | 167.86 | 18.88 | 24.92 | 751.40 | 93.92 | 202.63 | 7.18 |
| JUL | 146.28 | 66.03 | 123.75 | 6.91 | 12.84 | 183.56 | 6.51 | 14.17 | 560.04 | 70.01 | 183.56 | 6.51 |
| AUG | 88.82 | 43.41 | 112.65 | 4.17 | 2.23 | 127.71 | 9.29 | 16.08 | 404.36 | 50.54 | 127.71 | 2.23 |
| SEP | 60.46 | 42.35 | 109.26 | 3.09 | 3.61 | 108.16 | 6.31 | 0.00 | 333.25 | 41.66 | 109.26 | 0.00 |
| OCT | 68.76 | 56.12 | 89.86 | 1.75 | 3.09 | 100.06 | 5.59 | 56.21 | 381.43 | 47.68 | 100.06 | 1.75 |
| NOV | 93.41 | 140.14 | 173.75 | 13.63 | 6.98 | 262.64 | 12.92 | 160.58 | 864.05 | 108.01 | 262.64 | 6.98 |
| DEC | 90.00 | 36.92 | 130.26 | 16.72 | 4.50 | 123.23 | 11.47 | 72.05 | 485.15 | 60.64 | 130.26 | 4.50 |
| JAN | 958.67 | 1027.35 | 849.53 | 63.96 | 77.17 | 1189.96 | 96.90 | 152.42 | 4415.96 | 551.99 | 1189.96 | 63.96 |
| FEB | 46.82 | 33.38 | 70.25 | 39.24 | 6.00 | 67.08 | 9.92 | 109.15 | 381.85 | 47.73 | 109.15 | 6.00 |
| MAR | 761.47 | 758.18 | 802.14 | 142.94 | 165.03 | 989.11 | 210.50 | 274.29 | 4103.66 | 512.96 | 989.11 | 142.94 |
| APR | 346.42 | 150.42 | 470.25 | 34.07 | 61.86 | 331.22 | 61.17 | 173.79 | 1629.19 | 203.65 | 470.25 | 34.07 |
| MAY | 292.10 | 166.57 | 441.48 | 39.20 | 27.93 | 311.89 | 30.29 | 93.55 | 1402.99 | 175.37 | 441.48 | 27.93 |
| | | | | | | | | | | | | |
| Total | 3142.72 | 2653.14 | 3575.8 | 373.80 | 378.42 | 3962.48 | 479.74 | 1147.21 | 15713.32 TP in kg. | | | |
| Mean | 261.89 | 221.09 | 297.98 | 31.15 | 31.54 | 330.21 | 39.98 | 95.60 | | | | |
| Maximum | 958.67 | 1027.35 | 849.53 | 142.94 | 165.03 | 1189.96 | 210.50 | 274.29 | | | | |
| Minimum | 46.82 | 33.38 | 70.25 | 1.75 | 2.23 | 67.08 | 5.59 | 0.00 | | | | |

**Table 23. Monthly total phosphorus loading (kg) for the gauged watersheds 1995-96.**

| SDATE | BL PRO | BV PRO | HL | KB | NS | PFR PRO | US | PP | Total | Mean | Maximum | Minimum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JUN | 238.55 | 199.30 | 278.55 | 20.10 | 13.74 | 354.63 | 26.96 | 989.96 | 1883.24 | 269.03 | 989.96 | 13.74 |
| JUL | 139.60 | 89.06 | 696.20 | 26.84 | 19.05 | 290.33 | 29.30 | 204.59 | 1355.37 | 193.62 | 696.20 | 19.05 |
| AUG | 87.66 | 71.44 | 304.30 | 15.19 | 11.76 | 167.45 | 18.87 | 131.63 | 720.65 | 102.95 | 304.30 | 11.76 |
| SEP | 61.72 | 85.28 | 143.06 | 18.12 | 5.39 | 212.43 | 4.37 | 48.39 | 517.04 | 73.86 | 212.43 | 4.37 |
| OCT | 181.37 | 254.38 | 462.78 | 9.16 | 20.78 | 305.31 | 20.68 | 194.03 | 1267.12 | 181.02 | 462.78 | 9.16 |
| NOV | 468.32 | 509.28 | 851.80 | 34.69 | 56.89 | 455.71 | 69.06 | 568.76 | 2546.19 | 363.74 | 851.80 | 34.69 |
| DEC | 96.07 | 139.23 | 162.80 | 13.63 | 12.06 | 150.43 | 19.61 | 105.55 | 603.31 | 86.19 | 162.80 | 12.06 |
| JAN | 519.04 | 339.02 | 691.94 | 147.40 | 306.42 | 634.27 | 279.25 | 447.29 | 2845.57 | 406.51 | 691.94 | 147.40 |
| FEB | 463.26 | 335.49 | 838.49 | 312.31 | 194.16 | 362.20 | 182.13 | 320.81 | 2545.58 | 363.65 | 838.49 | 182.13 |
| MAR | 405.70 | 493.02 | 976.94 | 200.80 | 96.18 | 499.21 | 111.47 | 682.78 | 3060.40 | 437.20 | 976.94 | 96.18 |
| APR | 626.92 | 596.74 | 1129.4 | 179.30 | 75.70 | 666.47 | 110.38 | 1690.24 | 4448.26 | 635.47 | 1690.24 | 75.70 |
| MAY | 470.99 | 496.33 | 658.71 | 91.02 | 23.58 | 479.43 | 62.88 | 518.89 | 2330.85 | 332.98 | 658.71 | 23.58 |
| | | | | | | | | | | | | |
| Total | 3759.22 | 3608.56 | 7195.0 | 1068.5 | 835.71 | 4577.88 | 934.94 | 5902.92 | 27882.80 TP in kg. | | | |
| Mean | 313.27 | 300.71 | 599.58 | 89.05 | 69.64 | 381.49 | 77.91 | 491.91 | | | | |
| Maximum | 626.92 | 596.74 | 1129.4 | 312.31 | 306.42 | 666.47 | 279.25 | 1690.24 | | | | |
| Minimum | 61.72 | 71.44 | 143.06 | 9.16 | 5.39 | 150.43 | 4.37 | 48.39 | | | | |

## Table 24. Monthly total phosphorus loading (kg) for the gauged watersheds 1996-97.

| SDATE | BL PRO | BV PRO | HL | KB | NS | PFR PRO | US | PP | Total | Mean | Maximum | Minimum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JUN | 311.85 | 229.61 | 831.39 | 25.14 | 19.51 | 320.64 | 43.06 | 218.34 | 1687.68 | 241.10 | 831.39 | 19.51 |
| JUL | 432.52 | 222.19 | 971.92 | 21.50 | 14.52 | 467.25 | 37.63 | 88.70 | 1823.70 | 260.53 | 971.92 | 14.52 |
| AUG | 401.14 | 220.64 | 383.55 | 20.94 | 12.58 | 392.98 | 19.04 | 8.51 | 1058.26 | 151.18 | 392.98 | 8.51 |
| SEP | 552.96 | 556.73 | 725.92 | 20.21 | 13.99 | 629.64 | 24.18 | 29.14 | 1999.81 | 285.69 | 725.92 | 13.99 |
| OCT | 321.44 | 161.13 | 596.61 | 25.67 | 22.44 | 328.46 | 32.30 | | 1167.94 | 166.85 | 596.61 | 1.35 |
| NOV | 204.12 | 93.53 | 394.36 | 15.16 | 19.55 | 192.11 | 24.03 | | 738.74 | 123.12 | 394.36 | 15.16 |
| DEC | 320.88 | 390.87 | 841.66 | 77.26 | 60.98 | 474.80 | 98.23 | | 1943.79 | 323.97 | 841.66 | 60.98 |
| JAN | 281.55 | 152.94 | 473.19 | 67.10 | 34.66 | 394.24 | 61.55 | | 1183.68 | 197.28 | 473.19 | 34.66 |
| FEB | 989.21 | 645.19 | 3087.54 | 73.47 | 85.33 | 1721.60 | 101.02 | | 5714.15 | 952.36 | 3087.54 | 73.47 |
| MAR | 746.44 | 692.52 | 2848.06 | 334.64 | 344.98 | 1093.62 | 371.28 | | 5685.10 | 947.52 | 2848.06 | 334.64 |
| APR | 531.96 | 559.57 | 1019.90 | 60.11 | 65.21 | 704.67 | 57.66 | | 2467.13 | 411.19 | 1019.90 | 57.66 |
| MAY | 288.93 | 239.84 | 576.60 | 40.61 | 21.03 | 327.02 | 31.60 | | 1236.71 | 206.12 | 576.60 | 21.03 |
| | | | | | | | | | | | | |
| Total | 5383.00 | 4164.76 | 12750.69 | 781.82 | 714.77 | 7047.04 | 901.58 | 346.03 | 32089.70 TP in | | | |
| Mean | 448.58 | 347.06 | 1062.56 | 65.15 | 59.56 | 587.25 | 75.13 | 69.21 | | | | |
| Maximum | 989.21 | 692.52 | 3087.54 | 334.64 | 344.98 | 1721.60 | 371.28 | 218.34 | | | | |
| Minimum | 204.12 | 93.53 | 383.55 | 15.16 | 12.58 | 192.11 | 19.04 | 1.35 | | | | |

## Table 25. Monthly total phosphorus loading (kg) for the gauged watersheds 1997-98.

| SDATE | BL PRO | BV PRO | HL | KB | NS | PFR PRO | US | PP | Total | Mean | Maximum | Minimum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JUN | 380.45 | 512.87 | 1138.52 | 29.86 | 58.46 | 586.53 | 19.18 | | 2345.42 | 390.90 | 1138.52 | 19.18 |
| JUL | 107.24 | 84.75 | 244.69 | 22.90 | 4.79 | 260.35 | 9.31 | | 626.78 | 104.46 | 260.35 | 4.79 |
| AUG | 73.48 | 73.54 | 274.06 | 17.53 | 13.89 | 228.69 | 11.99 | | 619.70 | 103.28 | 274.06 | 11.99 |
| SEP | 102.58 | 94.72 | 414.78 | 16.64 | 20.38 | 289.84 | 16.08 | | 852.46 | 142.08 | 414.78 | 16.08 |
| OCT | 145.28 | 106.76 | 329.18 | 27.42 | 15.39 | 304.74 | 19.34 | | 802.83 | 133.80 | 329.18 | 15.39 |
| NOV | 464.42 | 511.76 | 320.50 | 57.48 | 47.72 | 496.30 | 27.42 | | 1461.18 | 243.53 | 511.76 | 27.42 |
| DEC | 325.41 | 401.46 | 200.41 | 60.41 | 4.04 | 395.73 | 18.35 | | 1080.40 | 180.07 | 401.46 | 4.04 |
| JAN | 643.10 | 827.48 | 387.38 | 65.55 | 20.69 | 735.84 | 50.59 | | 2087.53 | 347.92 | 827.48 | 20.69 |
| FEB | 516.99 | 643.28 | 507.77 | 63.13 | 50.51 | 586.82 | 81.08 | | 1932.58 | 322.10 | 643.28 | 50.51 |
| MAR | 881.99 | 1001.99 | 1225.53 | 85.01 | 101.41 | 1351.83 | 126.77 | | 3892.54 | 648.76 | 1351.83 | 85.01 |
| APR | 623.66 | 460.76 | 878.38 | 71.91 | 37.06 | 938.02 | 72.14 | | 2458.26 | 409.71 | 938.02 | 37.06 |
| MAY | 173.47 | 110.58 | 254.37 | 76.82 | 12.46 | 356.30 | 23.98 | | 834.50 | 139.08 | 356.30 | 12.46 |
| | | | | | | | | | | | | |
| Total | 4438.07 | 4829.95 | 6175.55 | 594.66 | 386.79 | 6531.00 | 476.23 | | 23432.24 TP in kg | | | |
| Mean | 369.84 | 402.50 | 514.63 | 49.55 | 32.23 | 544.25 | 39.69 | | | | | |
| Maximum | 881.99 | 1001.99 | 1225.53 | 85.01 | 101.41 | 1351.83 | 126.77 | | | | | |
| Minimum | 73.48 | 73.54 | 200.41 | 16.64 | 4.04 | 228.69 | 9.31 | | | | | |

**Table 26. Total phosphorus (TP) loads for Lake Simcoe gauged and monitored sub-watersheds scaled up to include the whole area up to the lake shore, and subtracting urban areas modeled separately. Numbers in bold italics were calculated using methods described in the text.**

| GAUGED AND MONITORED | Year | TP load at monitoring station (kg) including STP upstream of chemistry monitoring stations | Watershed area at monitoring station ($km^2$) | TP export ($kg/km^2$) minus STP | Total watershed area ($km^2$) | TP load total (kg) including STP upstream of chemistry monitoring stations |
|---|---|---|---|---|---|---|
| **Black River (BL)** | 1990-91 | 4220 | 344.1 | 12.2 | 402.7 | 4939 |
| | 1991-92 | 3134 | 344.1 | 9.1 | 402.7 | 3668 |
| | 1992-93 | 6847 | 344.1 | 19.9 | 402.7 | 8014 |
| | 1993-94 | 2760 | 344.1 | 6.7 | 402.7 | 3230 |
| | 1994-95 | 3143 | 344.1 | 9.1 | 402.7 | 3678 |
| | 1995-96 | 3759 | 344.1 | 10.8 | 402.7 | 4400 |
| | 1996-97 | 5383 | 344.1 | 15.6 | 402.7 | 6300 |
| | 1997-98 | 4438 | 344.1 | 12.8 | 402.7 | 5194 |
| **Beaver River (BV)** | 1990-91 | 5340 | 288.7 | 18.4 | 322.9 | 5973 |
| | 1991-92 | 2306 | 288.7 | 7.9 | 322.9 | 2579 |
| | 1992-93 | 6265 | 288.7 | 21.6 | 322.9 | 7008 |
| | 1993-94 | 2027 | 322.9 | 5.5 | 322.9 | 2027 |
| | 1994-95 | 2653 | 322.9 | 8.0 | 322.9 | 2653 |
| | 1995-96 | 3609 | 322.9 | 10.8 | 322.9 | 3609 |
| | 1996-97 | 4165 | 322.9 | 12.7 | 322.9 | 4165 |
| | 1997-98 | 4830 | 322.9 | 14.9 | 322.9 | 4830 |
| **Pefferlaw River (PFR)** | 1990-91 | 4183 | 321.1 | 10.7 | 425.7 | 5546 |
| | 1991-92 | 2643 | 321.1 | 6.6 | 425.7 | 3504 |
| | 1992-93 | 4230 | 321.1 | 11.5 | 425.7 | 5608 |
| | 1993-94 | 3912 | 396.7 | 9.0 | 425.7 | 4198 |
| | 1994-95 | 3962 | 396.7 | 9.4 | 425.7 | 4252 |
| | 1995-96 | 4578 | 396.7 | 11.2 | 425.7 | 4913 |
| | 1996-97 | 7047 | 396.7 | 17.7 | 425.7 | 7562 |
| | 1997-98 | 6531 | 396.7 | 16.0 | 425.7 | 7009 |
| **East Holland River at Holland** | 1990-91 | 28057 | 182.9 | 153.4 | 256.7 | 39387 |
| **Landing (HL)** | 1991-92 | 9641 | 182.9 | 52.7 | 256.7 | 13534 |
| **minus Keswick and COLBAR** | 1992-93 | 21341 | 182.9 | 116.7 | 256.7 | 29959 |
| **polders** | 1993-94 | 6117 | 182.9 | 33.4 | 256.7 | 8587 |
| | 1994-95 | 3576 | 182.9 | 19.6 | 256.7 | 5020 |
| | 1995-96 | 7195 | 182.9 | 39.3 | 256.7 | 10100 |
| | 1996-97 | 12751 | 182.9 | 69.7 | 256.7 | 17900 |
| | 1997-98 | 6176 | 182.9 | 33.8 | 256.7 | 8669 |
| **Kettleby Creek (KB)** | 1990-91 | 2641 | 31.1 | 84.8 | 65.3 | 5536 |
| **Scaled up to include Grenville** | 1991-92 | 1546 | 31.1 | 49.7 | 65.3 | 3242 |
| **Creek** | 1992-93 | 4780 | 31.1 | 153.5 | 65.3 | 10020 |
| | 1993-94 | 1643 | 31.1 | 52.8 | 65.3 | 3444 |
| | 1994-95 | 374 | 31.1 | 12.0 | 65.3 | 784 |
| | 1995-96 | 1069 | 31.1 | 34.3 | 65.3 | 2240 |
| | 1996-97 | 782 | 31.1 | 25.1 | 65.3 | 1639 |
| | 1997-98 | 595 | 31.1 | 19.1 | 65.3 | 1246 |

**Table 26 cont'd.**

**Total phosphorus (TP) loads for Lake Simcoe gauged and monitored sub-watersheds scaled up to include the whole area up to the lake shore, and subtracting urban areas modeled separately. Numbers in bold italics were calculated using methods described in the text.**

| GAUGED AND MONITORED | Year | TP load at monitoring station (kg) including STP upstream of chemistry monitoring stations | Watershed area at monitoring station ($km^2$) | TP export ($kg / km^2$) minus STP | Total watershed area ($km^2$) | TP load total (kg) including STP upstream of chemistry monitoring stations |
|---|---|---|---|---|---|---|
| **North Schomberg River (NS)** | 1990-91 | 3907 | 45.0 | 86.8 | 111.30 | 9665 |
| **Scaled up to include** | 1991-92 | 846 | 45.0 | 18.8 | 111.30 | 2093 |
| **Scanlon and William Neely Creek** | 1992-93 | 1946 | 45.0 | 43.3 | 111.30 | 4814 |
| **minus Bradford polder** | 1993-94 | 551 | 45.0 | 12.2 | 111.30 | 1362 |
| | 1994-95 | 378 | 45.0 | 8.4 | 111.30 | 936 |
| | 1995-96 | 836 | 45.0 | 18.6 | 111.30 | 2068 |
| | 1996-97 | 715 | 45.0 | 15.9 | 111.30 | 1768 |
| | 1997-98 | 387 | 45.0 | 8.6 | 111.30 | 957 |
| **Upper Schomberg River (US)** | 1990-91 | 1054 | 42.0 | 25.0 | 69.1 | 1735 |
| | 1991-92 | 259 | 42.0 | 6.1 | 69.1 | 426 |
| | 1992-93 | 1837 | 42.0 | 43.7 | 69.1 | 3022 |
| | 1993-94 | 580 | 42.0 | 13.7 | 69.1 | 954 |
| | 1994-95 | 480 | 42.0 | 11.3 | 69.1 | 789 |
| | 1995-96 | 935 | 42.0 | 22.0 | 69.1 | 1538 |
| | 1996-97 | 902 | 42.0 | 21.0 | 69.1 | 1483 |
| | 1997-98 | 476 | 42.0 | 11.1 | 69.1 | 783 |
| **Bradford Pump house (PP)** | 1990-91 | 4221 | 28.4 | 148.8 | 48.8 | 7262 |
| **Scaled up to include other** | 1991-92 | 2639 | 28.4 | 93.0 | 48.8 | 4540 |
| **vegetable polders** | 1992-93 | 3390 | 28.4 | 119.5 | 48.8 | 5832 |
| **(Bradford, Keswick and Colbar** | 1993-94 | 1256 | 28.4 | 44.3 | 48.8 | 2160 |
| **polders)** | 1994-95 | 1147 | 28.4 | 40.4 | 48.8 | 1974 |
| | 1995-96 | 5903 | 28.4 | 208.1 | 48.8 | 10155 |
| | 1996-97 | ***4640*** | 28.4 | ***163.6*** | 48.8 | ***7982*** |
| | 1997-98 | ***3279*** | 28.4 | ***115.6*** | 48.8 | ***5641*** |

**Table 27. Total phosphorus (TP) loads for Lake Simcoe ungauged and monitored sub-watersheds scaled up to include the whole area up to the lake shore, and subtracting urban areas modeled separately.**
**Numbers in bold italics were calculated using methods described in the text.**

| UNGAUGED AND MONITORED | Year | TP load at monitoring station (kg) | Watershed area at monitoring station ($km^2$) | TP export ($kg/km^2$) | Total watershed area ($km^2$) | TP load total (kg) |
|---|---|---|---|---|---|---|
| **Pottageville Creek (PT)** | 1990-91 | 1112 | 48.3 | 23.0 | | 1112 |
| | 1991-92 | 409 | 48.3 | 8.5 | | 409 |
| | 1992-93 | 781 | 48.3 | 16.2 | | 781 |
| | 1993-94 | | | ***13.2*** | 48.3 | ***640*** |
| | 1994-95 | | | ***12.9*** | 48.3 | ***623*** |
| | 1995-96 | 880 | 48.3 | 18.2 | | 880 |
| | 1996-97 | 843 | 48.3 | 17.4 | | 843 |
| | 1997-98 | 463 | 48.3 | 9.6 | | 463 |
| **Lovers Creek (LV)** | 1990-91 | 547 | 54.4 | 10.1 | 54.9 | 552 |
| | 1991-92 | 388 | 54.4 | 7.1 | 54.9 | 392 |
| | 1992-93 | 947 | 54.4 | 17.4 | 54.9 | 956 |
| | 1993-94 | | | ***7.1*** | 54.9 | ***387*** |
| | 1994-95 | 264 | 54.4 | 4.8 | 54.9 | 266 |
| | 1995-96 | 470 | 54.4 | 8.6 | 54.9 | 474 |
| | 1996-97 | 593 | 54.4 | 10.9 | 54.9 | 599 |
| | 1997-98 | 439 | 54.4 | 8.1 | 54.9 | 443 |
| **Hawkstone Creek (HS)** | 1990-91 | | | ***5.6*** | 62.6 | ***350*** |
| **Scaled down to subtract Orillia** | 1991-92 | | | ***4.4*** | 62.6 | ***278*** |
| | 1992-93 | | | ***5.8*** | 62.6 | ***365*** |
| | 1993-94 | | | ***5.1*** | 62.6 | ***320*** |
| | 1994-95 | 310 | 62.6 | 5.0 | 62.6 | 310 |
| | 1995-96 | 381 | 62.6 | 6.1 | 62.6 | 381 |
| | 1996-97 | 469 | 62.6 | 7.5 | 62.6 | 469 |
| | 1997-98 | 442 | 62.6 | 7.1 | 62.6 | 442 |
| **Talbot River (LSTAU)** | 1990-91 | | | ***7.5*** | 322.4 | ***2419*** |
| | 1991-92 | | | ***6.1*** | 322.4 | ***1964*** |
| | 1992-93 | | | ***10.9*** | 322.4 | ***3522*** |
| | 1993-94 | | | ***5.0*** | 322.4 | ***1623*** |
| | 1994-95 | 1660 | 321.3 | 5.2 | 322.4 | 1666 |
| | 1995-96 | 2644 | 321.3 | 8.2 | 322.4 | 2653 |
| | 1996-97 | 2827 | 321.3 | 8.8 | 322.4 | 2836 |
| | 1997-98 | 2403 | 321.3 | 7.5 | 322.4 | 2411 |
| **Whites Creek (LSWT)** | 1990-91 | | | *16.6* | 106.7 | ***1775*** |
| | 1991-92 | | | ***6.2*** | 106.7 | ***666*** |
| | 1992-93 | | | ***19.8*** | 106.7 | ***2117*** |
| | 1993-94 | | | ***3.9*** | 106.7 | ***418*** |
| | 1994-95 | 722 | 106.7 | 6.8 | 106.7 | 722 |
| | 1995-96 | 1061 | 106.7 | 9.9 | 106.7 | 1061 |
| | 1996-97 | 1059 | 106.7 | 9.9 | 106.7 | 1059 |
| | 1997-98 | 1492 | 106.7 | 14.0 | 106.7 | 1493 |

**Table 28. Total phosphorus (TP) loads for Lake Simcoe ungauged and unmonitored sub-watersheds scaled up to include the whole area up to the lake shore, and subtracting urban areas modeled separately. Numbers in bold italics were calculated using methods described in the text.**

| UNGAUGED AND UNMONITORED: | Year | Total watershed area (km $^2$) | TP export (kg/km $^2$) | TP load total (kg) |
|---|---|---|---|---|
| **Remaining ungauged area + islands [a]** | 1990-91 | 126 | ***10.7*** | ***1343*** |
| **Scaled down to subtract Keswick** | 1991-92 | 126 | ***6.6*** | ***826*** |
| | 1992-93 | 126 | ***11.5*** | ***1453*** |
| | 1993-94 | 126 | ***9.0*** | ***1128*** |
| | 1994-95 | 126 | ***9.4*** | ***1186*** |
| | 1995-96 | 126 | ***11.2*** | ***1406*** |
| | 1996-97 | 126 | ***17.7*** | ***2233*** |
| | 1997-98 | 126 | ***16.0*** | ***2023*** |
| **Stroud (LSSDU) [b]** | 1990-91 | 11 | ***10.1*** | ***114*** |
| **minus Barrie expansion** | 1991-92 | 11 | ***7.1*** | ***81*** |
| | 1992-93 | 11 | ***17.4*** | ***198*** |
| | 1993-94 | 11 | ***7.1*** | ***80*** |
| | 1994-95 | 11 | ***4.8*** | ***55*** |
| | 1995-96 | 11 | ***8.6*** | ***98*** |
| | 1996-97 | 11 | ***10.9*** | ***124*** |
| | 1997-98 | 11 | ***8.1*** | ***92*** |
| **Innisfil (LSILU) [c]** | 1990-91 | 108 | ***18.4*** | ***1979*** |
| | 1991-92 | 108 | ***7.9*** | ***846*** |
| | 1992-93 | 108 | ***21.6*** | ***2330*** |
| | 1993-94 | 108 | ***5.5*** | ***592*** |
| | 1994-95 | 108 | ***8.0*** | ***867*** |
| | 1995-96 | 108 | ***10.9*** | ***1169*** |
| | 1996-97 | 108 | ***12.7*** | ***1374*** |
| | 1997-98 | 108 | ***14.9*** | ***1602*** |
| **Brechin (LSBR) [a]** | 1990-91 | 141 | ***10.7*** | ***1506*** |
| | 1991-92 | 141 | ***6.6*** | ***927*** |
| | 1992-93 | 141 | ***11.5*** | ***1629*** |
| | 1993-94 | 141 | ***9.0*** | ***1266*** |
| | 1994-95 | 141 | ***9.4*** | ***1331*** |
| | 1995-96 | 141 | ***11.2*** | ***1577*** |
| | 1996-97 | 141 | ***17.7*** | ***2505*** |
| | 1997-98 | 141 | ***16.0*** | ***2269*** |
| **Maskinonge (LSME) [d]** | 1990-91 | 67 | ***25.0*** | ***1662*** |
| | 1991-92 | 67 | ***6.1*** | ***403*** |
| | 1992-93 | 67 | ***43.7*** | ***2906*** |
| | 1993-94 | 67 | ***13.7*** | ***913*** |
| | 1994-95 | 67 | ***11.3*** | ***752*** |
| | 1995-96 | 67 | ***22.0*** | ***1461*** |
| | 1996-97 | 67 | ***21.0*** | ***1395*** |
| | 1997-98 | 67 | ***11.1*** | ***738*** |

a Pefferlaw River TP export coefficient used

b Lovers Creek TP export coefficient used

c Beaver River TP export coefficient used
d Upper Schomberg TP export coefficient used

**Table 28 cont'd. Total phosphorus (TP) loads for Lake Simcoe ungauged and unmonitored sub-watersheds scaled up to include the whole area up to the lake shore, and subtracting urban areas modeled separately.**

**Numbers in bold italics were calculated using methods described in the text.**

| UNGAUGED AND UNMONITORED: | Year | Total watershed area ($km^2$) | TP export ($kg/km^2$) | TP load total (kg) |
|---|---|---|---|---|
| Oro Station (LSOR)[a] | 1990-91 | 35 | ***10.7*** | ***377*** |
| | 1991-92 | 35 | ***6.6*** | ***232*** |
| | 1992-93 | 35 | ***11.5*** | ***408*** |
| | 1993-94 | 35 | ***9.0*** | ***317*** |
| | 1994-95 | 35 | ***9.4*** | ***333*** |
| | 1995-96 | 35 | ***11.2*** | ***395*** |
| | 1996-97 | 35 | ***17.7*** | ***627*** |
| | 1997-98 | 35 | ***16.0*** | ***568*** |
| Shanty Bay (LSSBU)[b] | 1990-91 | 58 | ***10.1*** | ***584*** |
| | 1991-92 | 58 | ***7.1*** | ***415*** |
| | 1992-93 | 58 | ***17.4*** | ***1012*** |
| | 1993-94 | 58 | ***7.1*** | ***410*** |
| | 1994-95 | 58 | ***4.8*** | ***282*** |
| | 1995-96 | 58 | ***8.6*** | ***502*** |
| | 1996-97 | 58 | ***10.9*** | ***634*** |
| | 1997-98 | 58 | ***8.1*** | ***469*** |

a Pefferlaw River TP export coefficient used
b Lovers Creek TP export coefficient used
c Beaver River TP export coefficient used
d Upper Schomberg TP export coefficient used

**Table 29. Summary of total phosphorus (TP) loads (kg) from gauged and chemically monitored sub-watersheds to Lake Simcoe. Numbers in bold italics were calculated using methods described in the text.**

| Year | Black River | Beaver River | Pefferlaw River | East Holland River at Holland Landing | Kettleby Creek | North Schomberg River | Upper Schomberg River | Vegetable polders - Bradford Pump house PP | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| 1990-91 | 4939 | 5973 | 5546 | 39387 | 5536 | 9665 | 1735 | 7262 | 80000 |
| 1991-92 | 3668 | 2579 | 3504 | 13534 | 3242 | 2093 | 426 | 4540 | 33600 |
| 1992-93 | 8014 | 7008 | 5608 | 29959 | 10020 | 4814 | 3022 | 5832 | 74300 |
| 1993-94 | 3230 | 2027 | 4198 | 8587 | 3444 | 1362 | 954 | 2160 | 26000 |
| 1994-95 | 3678 | 2653 | 4252 | 5020 | 784 | 936 | 789 | 1974 | 20100 |
| 1995-96 | 4400 | 3609 | 4913 | 10100 | 2240 | 2068 | 1538 | 10155 | 39000 |
| 1996-97 | 6300 | 4165 | 7562 | 17900 | 1639 | 1768 | 1483 | ***7982*** | 48800 |
| 1997-98 | 5194 | 4830 | 7009 | 8669 | 1246 | 957 | 783 | ***5641*** | 34300 |

**Table 30. Summary of total phosphorus (TP) loads (kg) from ungauged and chemically monitored sub-watersheds to Lake Simcoe . Numbers in bold italics were calculated using methods described in the text.**

| Year | Hawkstone Creek | Lovers Creek | Talbot River | Whites Creek | Pottageville Creek | TOTAL |
|---|---|---|---|---|---|---|
| 1990-91 | ***350*** | 552 | ***2419*** | ***1775*** | 1112 | ***5100*** |
| 1991-92 | ***278*** | 392 | ***1964*** | ***666*** | 409 | ***3300*** |
| 1992-93 | ***365*** | 956 | ***3522*** | ***2117*** | 781 | ***7000*** |
| 1993-94 | ***320*** | ***387*** | ***1623*** | ***418*** | 640 | ***2700*** |
| 1994-95 | 310 | 266 | 1666 | 722 | 623 | 3000 |
| 1995-96 | 381 | 474 | 2653 | 1061 | 880 | 4600 |
| 1996-97 | 469 | 599 | 2836 | 1059 | 843 | 5000 |
| 1997-98 | 442 | 443 | 2411 | 1493 | 463 | 4800 |

**Table 31. Summary of total phosphorus (TP) loads (kg) from ungauged and chemically unmonitored sub-watersheds to Lake Simcoe.**
**Numbers in bold italics were calculated using methods described in the text.**

| Year | Stroud LSSDU | Innisfil LSILU | Brechin LSBR | Maskinonge LSME | ORO Station LSORU | Shanty Bay LSSBU | Remaining Ungauged area | TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1990-91 | ***114*** | ***1979*** | ***1506*** | ***1662*** | ***377*** | ***584*** | ***1343*** | ***7600*** |
| 1991-92 | ***81*** | ***846*** | ***927*** | ***403*** | ***232*** | ***415*** | ***826*** | ***3700*** |
| 1992-93 | ***198*** | ***2330*** | ***1629*** | ***2906*** | ***408*** | ***1012*** | ***1453*** | ***9900*** |
| 1993-94 | ***80*** | ***592*** | ***1266*** | ***913*** | ***317*** | ***410*** | ***1128*** | ***4700*** |
| 1994-95 | ***55*** | ***867*** | ***1331*** | ***752*** | ***333*** | ***282*** | ***1186*** | ***4800*** |
| 1995-96 | ***98*** | ***1169*** | ***1577*** | ***1461*** | ***395*** | ***502*** | ***1406*** | ***6600*** |
| 1996-97 | ***124*** | ***1374*** | ***2505*** | ***1395*** | ***627*** | ***634*** | ***2233*** | ***8900*** |
| 1997-98 | ***92*** | ***1602*** | ***2269*** | ***738*** | ***568*** | ***469*** | ***2023*** | ***7800*** |

**Table 32. Overall Summary of annual total phosphorus (TP) loads (kg / yr) from sub-watersheds to Lake Simcoe 1990 - 1998.**

| Year | TOTAL PHOSPHORUS |
|---|---|
| 1990-91 | 92700 |
| 1991-92 | 40600 |
| 1992-93 | 91200 |

| | |
|---|---|
| 1993-94 | 33400 |
| 1994-95 | 27900 |
| 1995-96 | 50200 |
| 1996-97 | 62700 |
| 1997-98 | 46900 |

## Table 33. Total annual summary of total phosphorus loads (kg / yr) to Lake Simcoe from precipitation 1990 - 1998.

| MONTH | 1990-91 | 1991-92 | 1992-93 | 1993-94 | 1994-95 | 1995-96 | 1996-97 | 1997-98 | Mean | Maximum | Minimum |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jun | 10790 | 4133 | 5055 | 14525 | 7757 | 14181 | 3595 | 1538 | 7697 | 14525 | 1538 |
| Jul | 5963 | 10385 | 8170 | 4563 | 3940 | 10172 | 2092 | 8288 | 6697 | 10385 | 2092 |
| Aug | 2400 | 3020 | 7741 | 5646 | 4498 | 6847 | 3209 | 6728 | 5011 | 7741 | 2400 |
| Sep | 3421 | 1588 | 4053 | 4192 | 2685 | 694 | 3298 | 3584 | 2939 | 4192 | 694 |
| Oct | 2939 | 1915 | 1341 | 1754 | 1592 | 1293 | 2388 | 1945 | 1896 | 2939 | 1293 |
| Nov | 1788 | 1062 | 2531 | 1133 | 1297 | 606 | 1230 | 757 | 1300 | 2531 | 606 |
| Dec | 1443 | 841 | 1098 | 390 | 796 | 547 | 587 | 464 | 771 | 1443 | 390 |
| Jan | 462 | 611 | 1340 | 1067 | 1239 | 520 | 1121 | 537 | 862 | 1340 | 462 |
| Feb | 816 | 933 | 1222 | 758 | 1170 | 1170 | 523 | 105 | 837 | 1222 | 105 |
| Mar | 2390 | 1518 | 1057 | 1419 | 1155 | 4528 | 301 | 766 | 1642 | 4528 | 301 |
| Apr | 12610 | 7501 | 8190 | 6775 | 9225 | 5829 | 2856 | 8395 | 7673 | 12610 | 2856 |
| May | 8330 | 7646 | 9996 | 14538 | 8073 | 11174 | 2470 | 6976 | 8650 | 14538 | 2470 |
| **Mean** | 4446 | 3429 | 4316 | 4730 | 3619 | 4797 | 1972 | 3340 | | | |
| **Maximum** | 12610 | 10385 | 9996 | 14538 | 9225 | 14181 | 3595 | 8395 | | | |
| **Minimum** | 462 | 611 | 1057 | 390 | 796 | 520 | 301 | 105 | | | |
| **Total** | 53352 | 41152 | 51792 | 56760 | 43429 | 57562 | 23668 | 40082 | | | |

## Table 34. Annual summary of total phosphorus loads (kg / yr) and flow as ($m^3$ / yr) to Lake Simcoe from 1990-1998

Numbers in bold italics were calculated using methods described in the text

| Year | Atmospheric (kg) | $m^3x10^8$ (a) | Urban point source Total (kg) | $m^3x10^7$ (b) | Urban non-point source (kg) | $m^3x10^7$ (c) | Vegetable Polders (kg) | $m^3x10^7$ (d) | Tributaries (kg) | $m^3x10^8$ (e) | Total (kg / yr) (f) | Total $m^3x10^9$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1990-91** | 53400 | 6.252 | ***4700*** | ***2.590*** | 14400 | 4.257 | 7300 | 1.5980 | 76800 | 9.854 | 156500 | 1.695 |
| **1991-92** | 41200 | 4.765 | 4700 | 2.590 | 15500 | 3.487 | 4500 | 0.7195 | 26700 | 4.980 | 92500 | 1.042 |
| **1992-93** | 51800 | 6.644 | 4600 | 2.711 | 16500 | 5.199 | 5800 | 0.7749 | 75300 | 8.746 | 154000 | 1.626 |
| **1993-94** | 56800 | 5.864 | 6300 | 2.688 | 17600 | 4.882 | 2200 | 0.3199 | 20000 | 5.334 | 102800 | 1.199 |
| **1994-95** | 43400 | 5.238 | 7000 | 2.764 | 18700 | 4.625 | 2000 | 0.7743 | 14400 | 4.959 | 85400 | 1.101 |
| **1995-96** | 57600 | 7.500 | 6100 | 3.279 | 19700 | 7.001 | 10200 | 2.2000 | 27700 | 9.426 | 121300 | 1.817 |
| **1996-97** | 23700 | 6.272 | 6800 | 3.216 | 20800 | 6.176 | 8000 | 1.2410 | 41800 | 10.820 | 101000 | 1.816 |
| **1997-98** | 40100 | 4.518 | 5700 | 2.931 | 21900 | 4.674 | 5600 | 0.8625 | 27600 | 6.743 | 101000 | 1.211 |

(a) Flows calculated as described in Section 5.1

(b) Flows calculated as described in Section 5.2, (neither phosphorus nor flow data were available for 1990 - 1991, 1991 - 1992 data was substituted)

(c) Flows calculated as described in Section 5.3

(d) Flows calculated as described in Section 5.4

(e) Flows calculated as described in Section 5.0, (inclusion of forest, wetland, scrubland, cultivated and barren pasture )

(f) Total (kg / yr) were rounded to the nearest 100

**Table 35. Urban area ($km^2$) 1990 - 1998 within the Lake Simcoe catchment based on 1985 and 2000 low level areal photographic interpretation.**

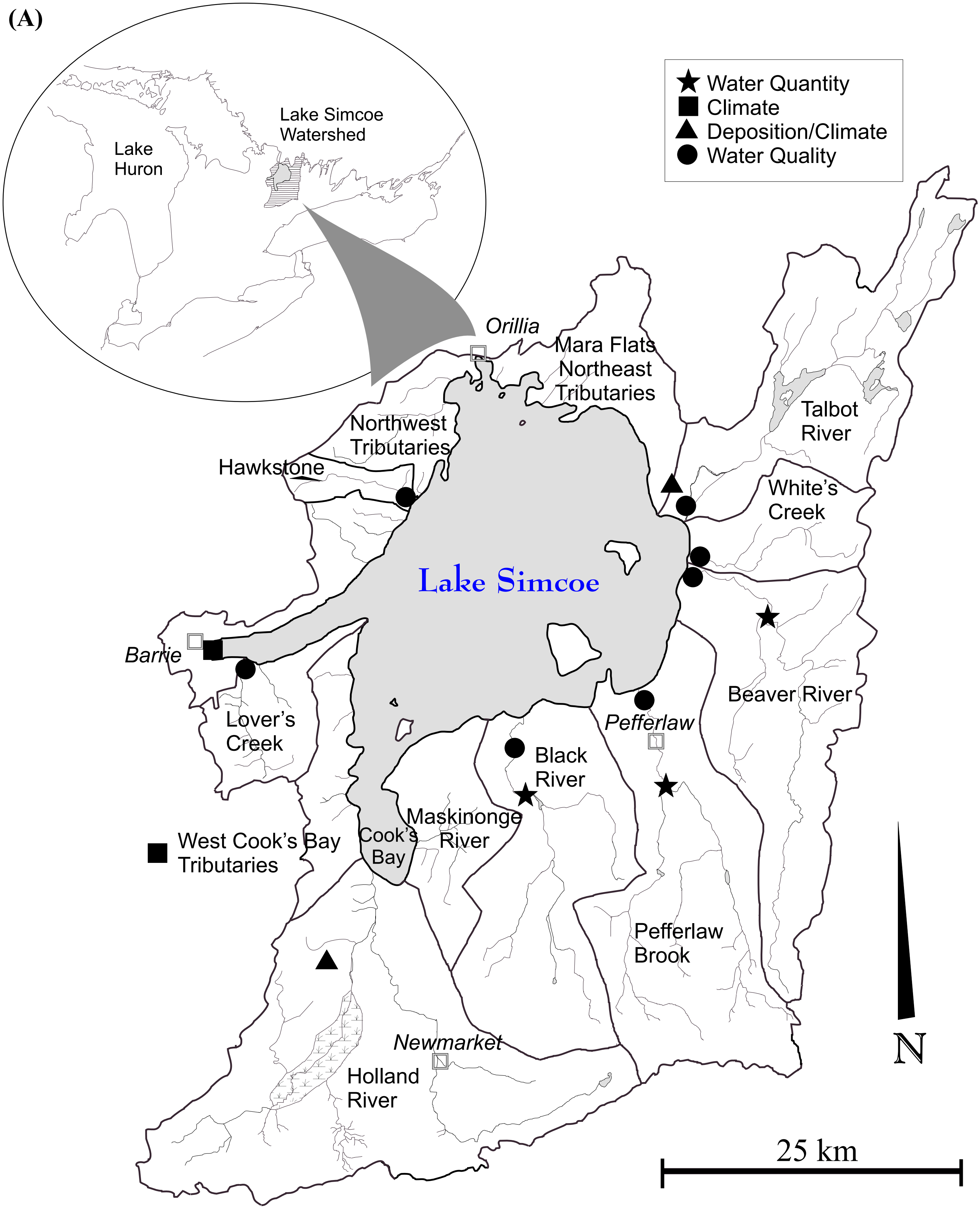
| | 1985 | 2000 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Aurora** | 9.20 | 49.46 | 22.6 | 25.3 | 28.0 | 30.7 | 33.4 | 36.0 | 38.7 | 41.4 | 44.1 | 46.8 | 49.5 |
| **Barrie** | 15.45 | 44.36 | 25.1 | 27.0 | 28.9 | 30.9 | 32.8 | 34.7 | 36.7 | 38.6 | 40.5 | 42.4 | 44.4 |
| **Beaverton** | 2.63 | 3.11 | 2.8 | 2.8 | 2.9 | 2.9 | 2.9 | 3.0 | 3.0 | 3.0 | 3.0 | 3.1 | 3.1 |
| **Bradford** | 2.83 | 5.00 | 3.6 | 3.7 | 3.8 | 4.0 | 4.1 | 4.3 | 4.4 | 4.6 | 4.7 | 4.9 | 5.0 |
| **Cannington** | 0.98 | 1.33 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.2 | 1.3 | 1.3 | 1.3 | 1.3 |
| **Holland Landing** | 2.11 | 5.15 | 3.1 | 3.3 | 3.5 | 3.7 | 3.9 | 4.1 | 4.3 | 4.5 | 4.7 | 4.9 | 5.2 |
| **Keswick** | 3.43 | 5.89 | 4.2 | 4.4 | 4.6 | 4.7 | 4.9 | 5.1 | 5.2 | 5.4 | 5.6 | 5.7 | 5.9 |
| **Mt. Albert** | 0.94 | 1.65 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 | 1.4 | 1.5 | 1.5 | 1.6 | 1.6 | 1.7 |
| **Newmarket** | 11.00 | 38.50 | 20.2 | 22.0 | 23.8 | 25.7 | 27.5 | 29.3 | 31.2 | 33.0 | 34.8 | 36.7 | 38.5 |
| **Orillia** | 12.40 | 22.48 | 15.8 | 16.4 | 17.1 | 17.8 | 18.4 | 19.1 | 19.8 | 20.5 | 21.1 | 21.8 | 22.5 |
| **Schomberg** | 0.91 | 1.28 | 1.0 | 1.1 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.2 | 1.3 | 1.3 |
| **Sharon** | 0.93 | 1.61 | 1.2 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 | 1.4 | 1.5 | 1.5 | 1.6 | 1.6 |
| **Sunderland** | 0.71 | 0.92 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| **Sutton** | 2.95 | 3.55 | 3.2 | 3.2 | 3.2 | 3.3 | 3.3 | 3.4 | 3.4 | 3.4 | 3.5 | 3.5 | 3.6 |
| **Uxbridge** | 2.01 | 5.69 | 3.2 | 3.5 | 3.7 | 4.0 | 4.2 | 4.5 | 4.7 | 5.0 | 5.2 | 5.4 | 5.7 |

**Table 36 . Mean annual total phosphorus (TP) export ($kg / km^2 /yr$) from 1990 -1998 for monitored Lake Simcoe sub-watersheds and their land use categories.**

| % | Beaver River BV | Black River[4] BL | Pefferlaw River PFR | Talbot River[4] LSTAU | Hawkstone River HS | Whites Creek LSWT | Lovers Creek LV | East Holland River HL | Kettleby Creek KB | Pottageville Creek PT | North Schomberg River NS | Upper Schomberg River US | Vegetable polder Bradford pump house PP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Forest[1]** | *22* | *33* | *32* | *24* | *37* | *23* | *26* | *22* | *21* | *23* | *23* | *21* | 0 |
| **Wetland[1]** | *12* | *10* | *10* | *19* | *10* | *11* | *6* | *9* | *5* | *6* | *6* | *5* | 0 |
| **Scrubland[1]** | *13* | *11* | *12* | *31* | *10* | *17* | *12* | *11* | *13* | *9* | *9* | *13* | 0 |
| **Cultivated[1]** | 21 | 16 | 16 | 9 | 16 | 27 | 15 | 8 | 29 | 25 | 8 | 29 | 0 |
| **Polder[1]** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 15 | 0 | 100 |
| **Barren/Pasture[1]** | 31 | 23 | 27 | 12 | 25 | 21 | 34 | 13 | 31 | 36 | 29 | 31 | 0 |
| **Urban[2]** | 2 | 2 | 1 | 0 | 0 | 0 | 7 | 32 | 0 | 0 | 8 | 0 | 0 |
| **TP export[3] ($kg/km^2/yr$)** | **12** | **12** | **12** | **7** | **6** | **11** | **9** | **65** | **54** | **15** | **27** | **19** | **109** |
| **S.D.** | **6** | **4** | **4** | **2** | **1** | **6** | **4** | **47** | **46** | **5** | **27** | **12** | **64** |
| **Range** | **5 to 22** | **7 to 20** | **7 to 18** | **5 to 11** | **4 to 7** | **4 to 20** | **7 to 17** | **20 to 153** | **19 to 154** | **8 to 23** | **8 to 87** | **6 to 44** | **40 to 149** |

1. Land use categories other than urban areas as a *percent* (%) were determined from a 1993 satellite image. 2. Urban area as a *percent* (%) was determined by interpolation from 1985 and 2000 air photos (see Sect. 5.3). 3. TP export is a mean annual value for 1990 - 1998 water years
4. Land categories do not include water reservoirs

(A)



Lake Huron
Lake Simcoe Watershed
Water Quantity
Climate
Deposition/Climate
Water Quality
Orillia
Mara Flats
Northeast Tributaries
Northwest Tributaries
Hawkstone
Talbot River
White's Creek
Lake Simcoe
Barrie
Beaver River
Lover's Creek
Pefferlaw
Black River
Maskinonge River
Cook's Bay
West Cook's Bay Tributaries
Pefferlaw Brook
Newmarket
Holland River
N
25 km

Figure 2: The Holland River Drainage Basin

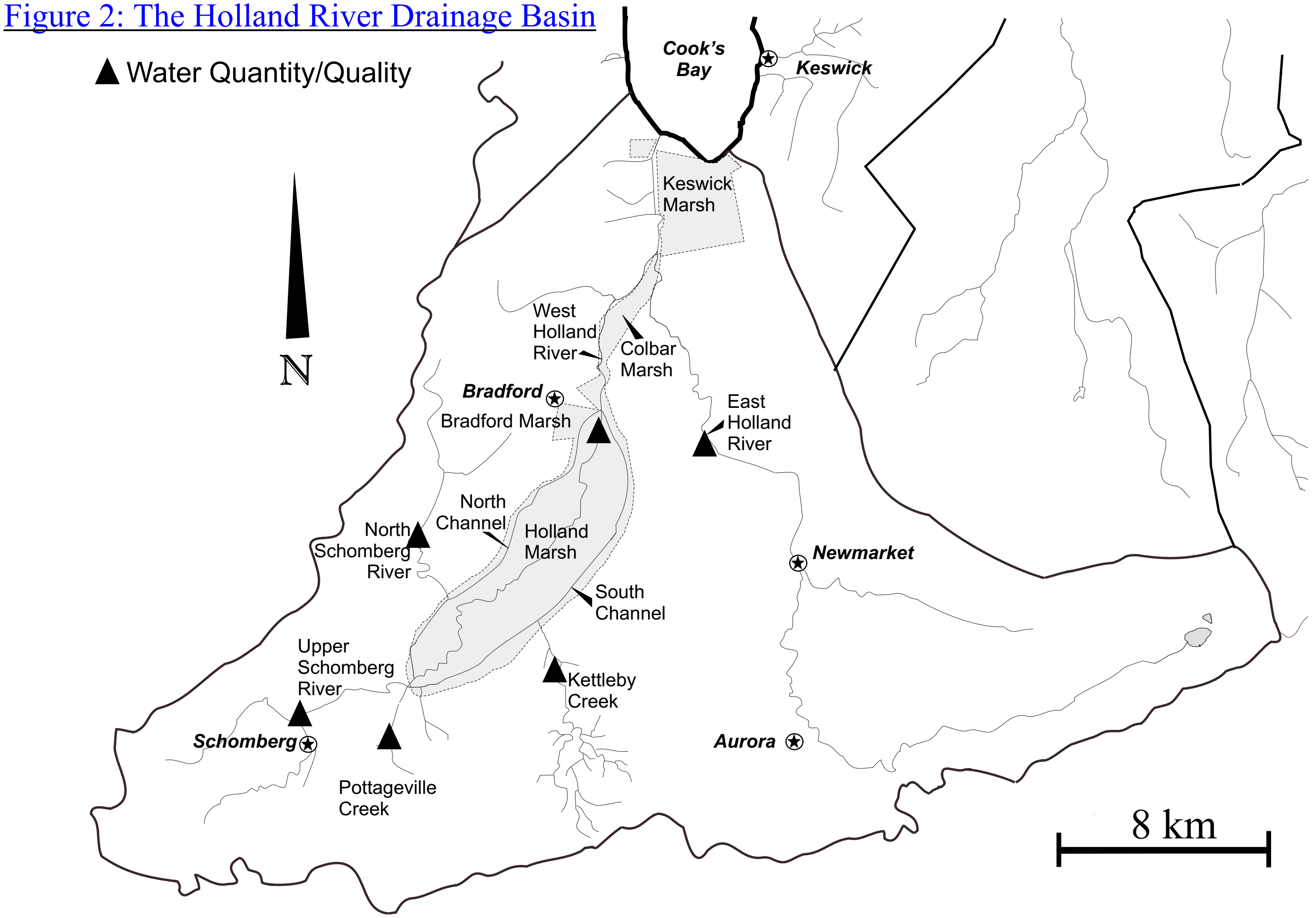


Figure 3. Monthly areal runoff (mm mo$^{-1}$) for the eastern aspect 1990 - 1998

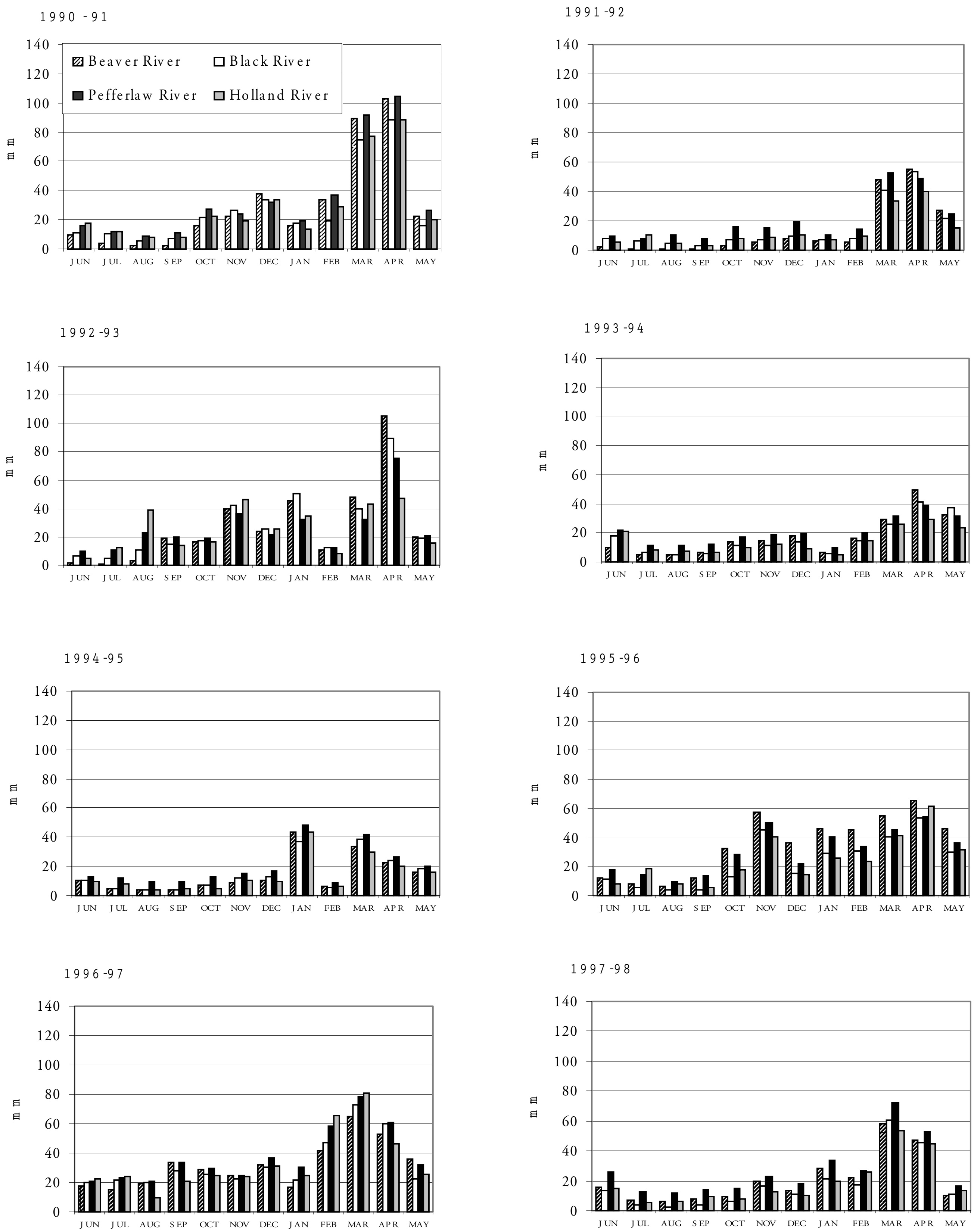


Figure 4. Monthly areal runoff (mm mo$^{-1}$) for the southern aspect 1990 - 1998

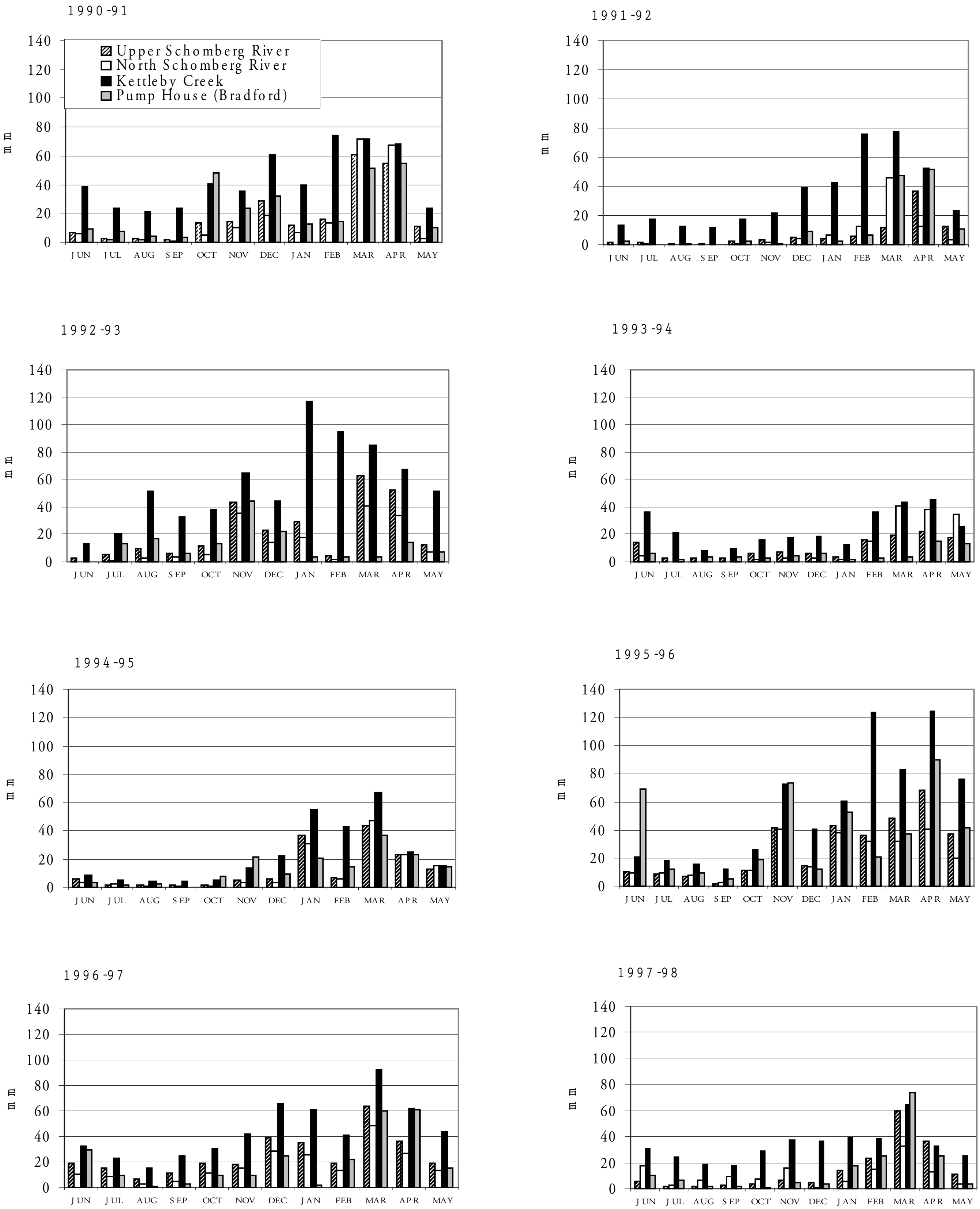


Figure 5. Lake Simcoe precipitation ($m^3\ mo^{-1}$) 1990 – 1998.

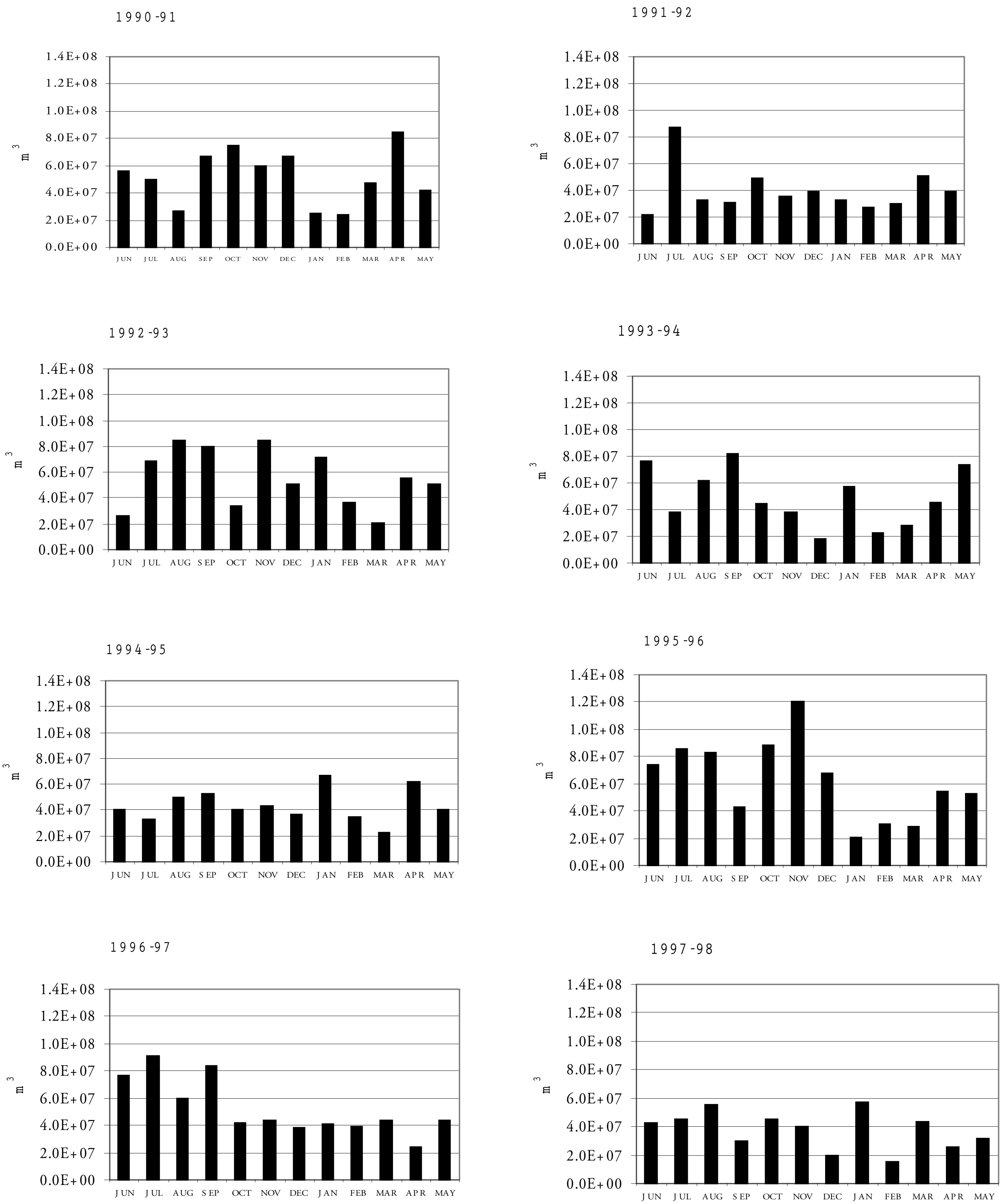


Figure 6. Lake Simcoe inflow tributaries eastern aspect ($m^3\ mo^{-1}$) 1990 -1998

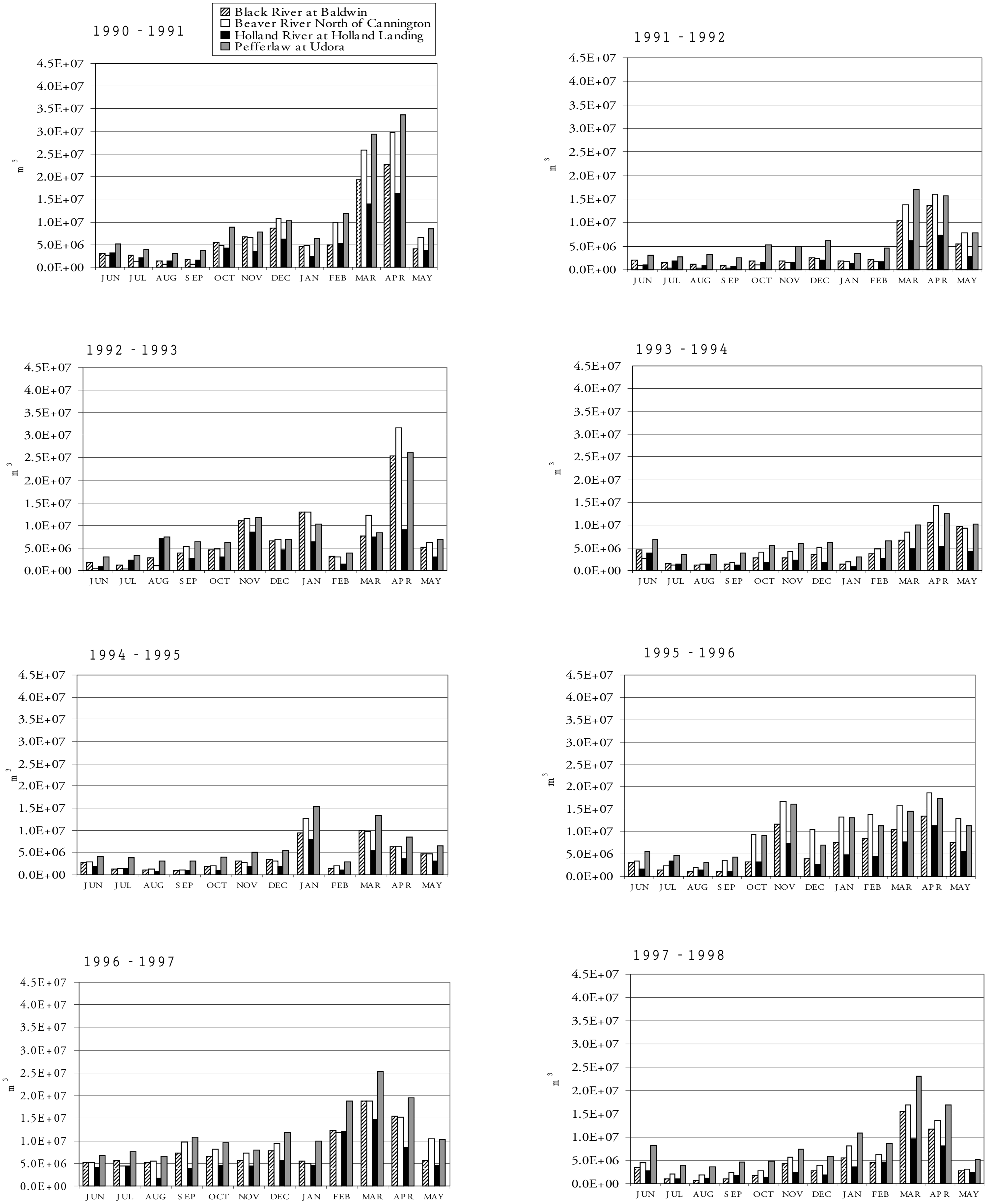


Figure 7. Lake Simcoe inflow tributaries southern aspect ($m^3 mo^{-1}$) 1990 - 1998

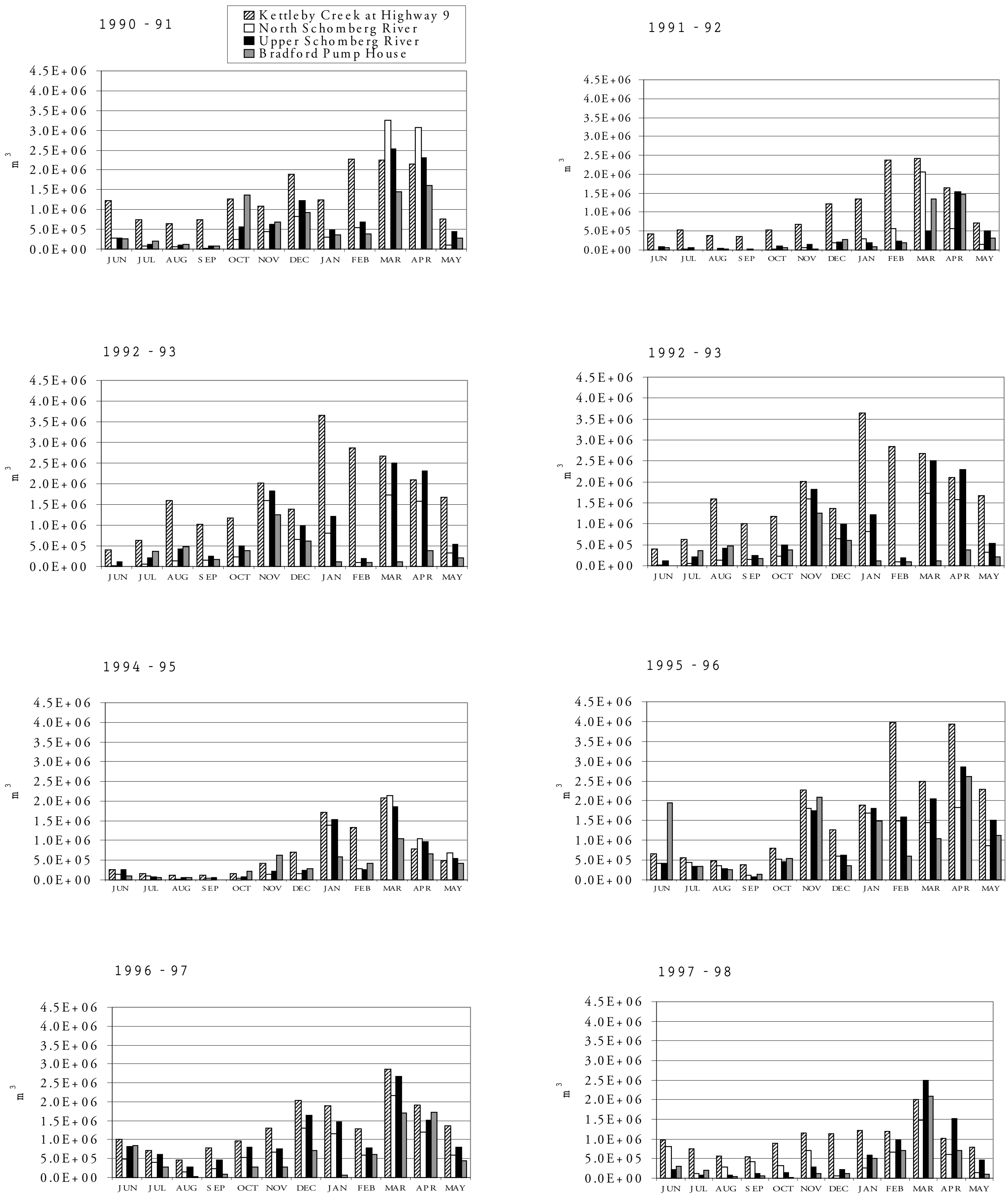
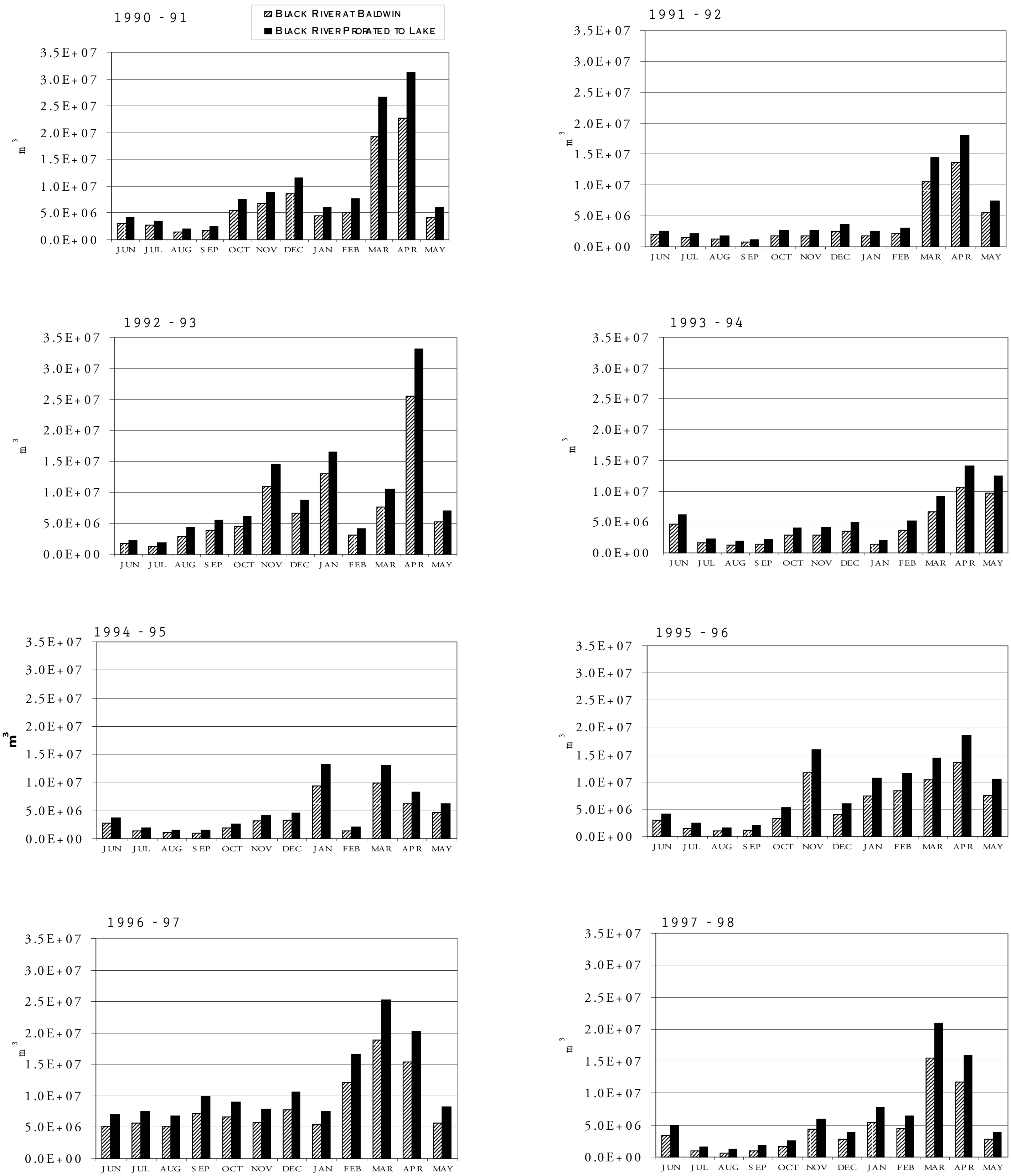


Figure 8: Black River proration flows ($m^3\ mo^{-1}$) to the chemistry sampling location



# Figure 9 : Beaver River prorated flows ($m^3$ $mo^{-1}$) to the chemistry sampling location.

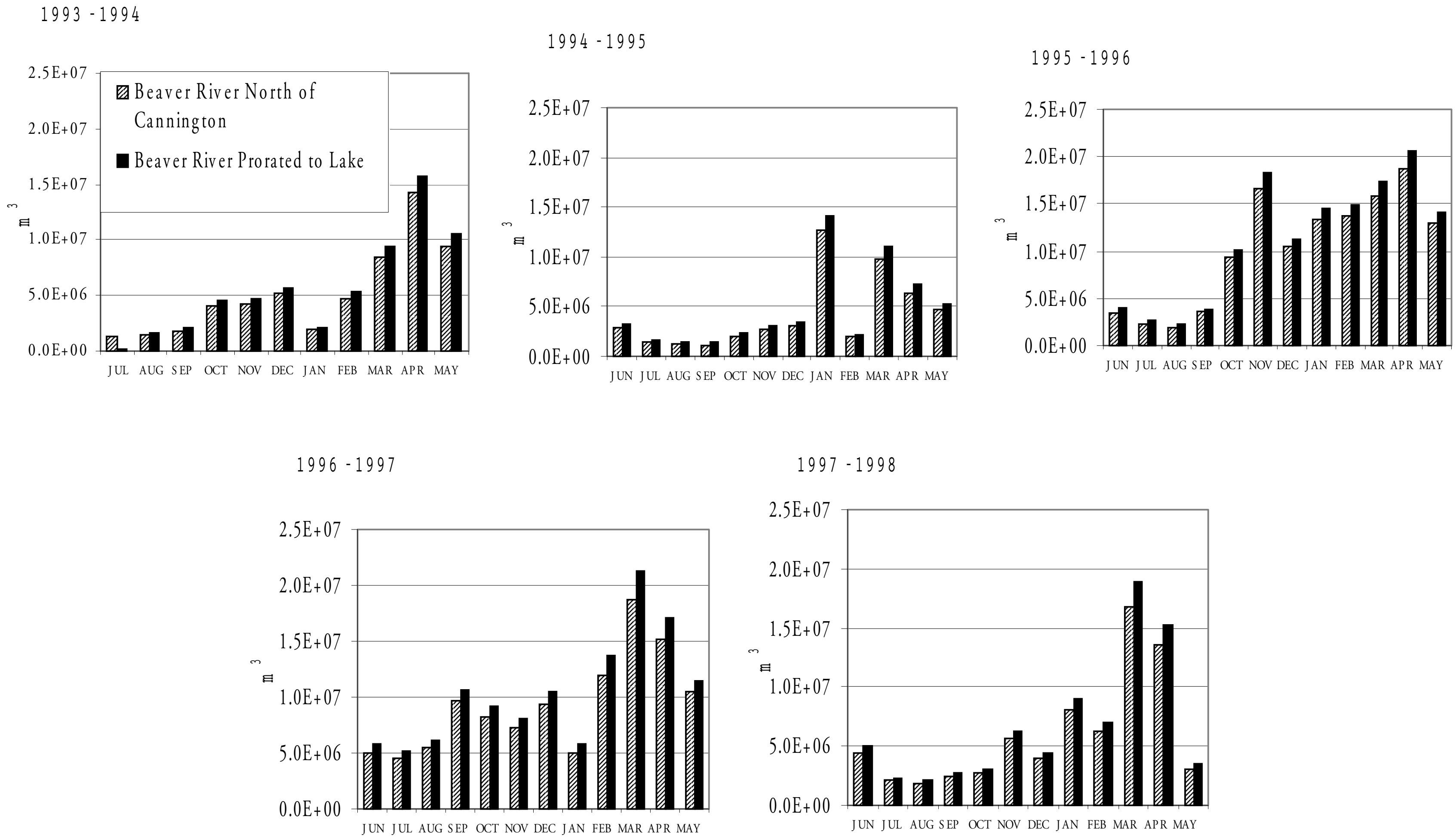


Figure 10: Pefferlaw River prorated flows ($m^3$ $mo^{-1}$) to the chemistry sampling location.

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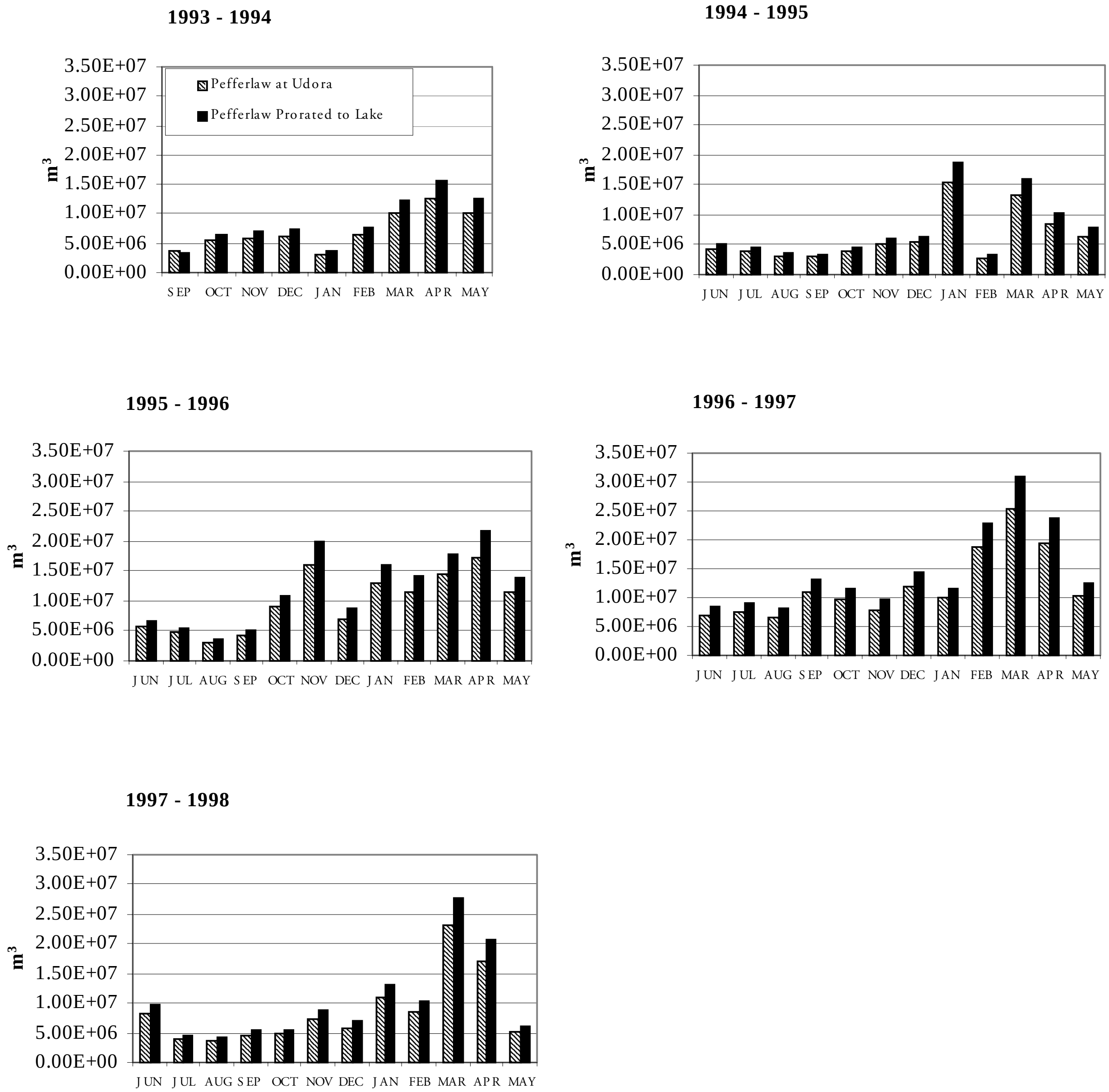


Figure 11. Lake Simcoe outflow utilizing a two stage proration on (1) Swift Rapids to Lake Couchiching outlet and (2) Lake Couchiching To Atherley Narrows ($m^3$) 1990 – 1998.

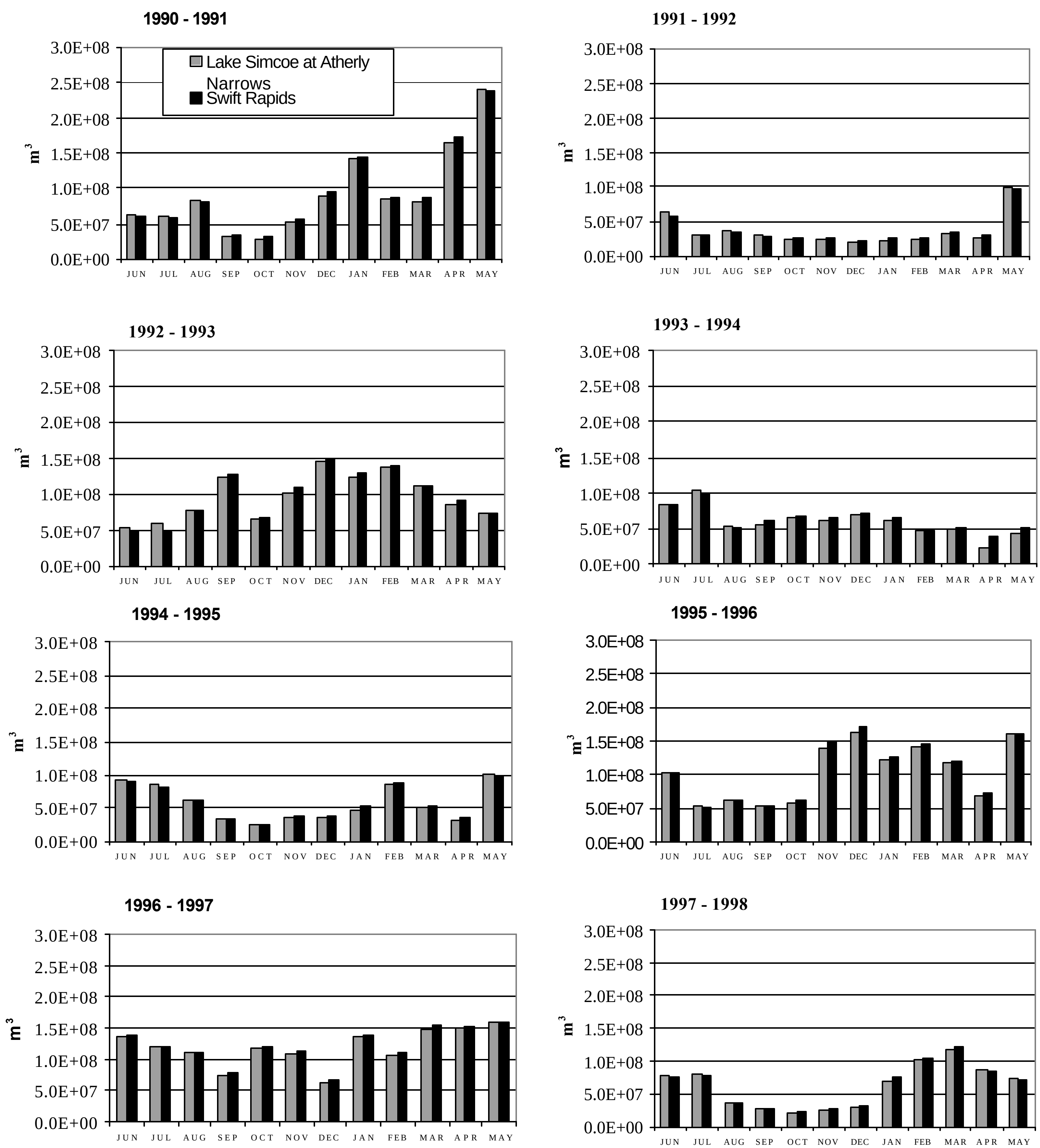
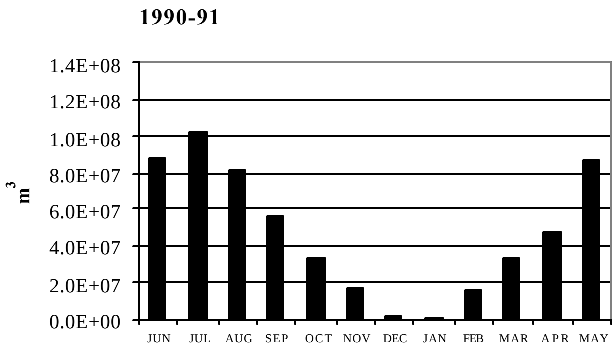
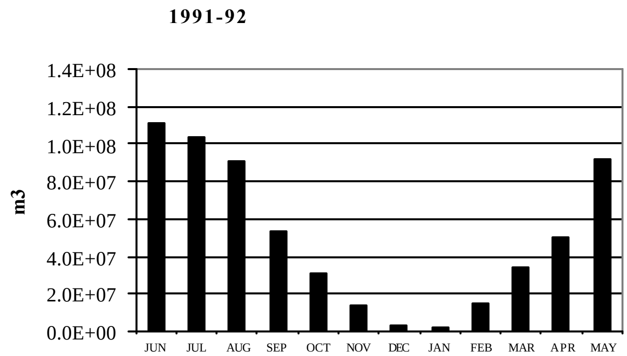
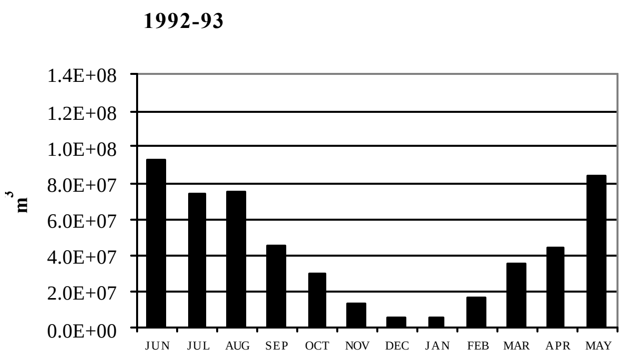
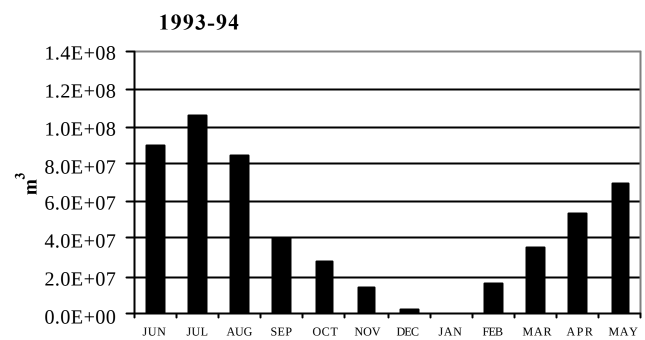


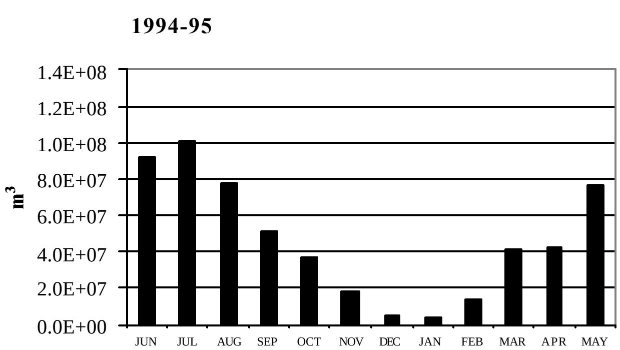
Figure 12. Lake Simcoe evaporation ($m^3\ mo^{-1}$) 1990 - 1998

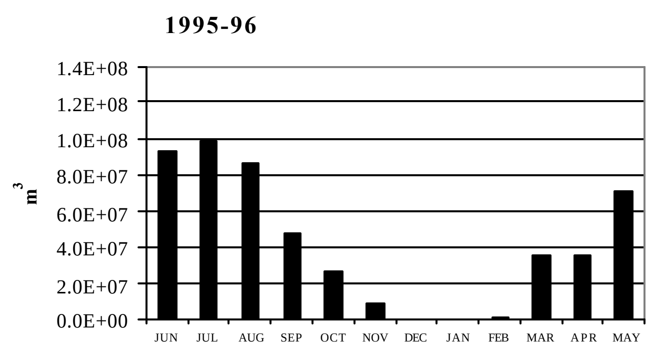


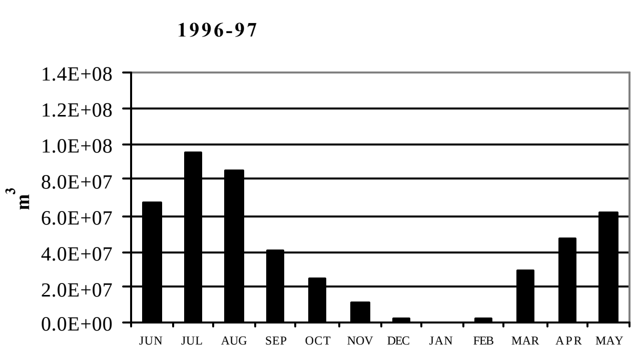



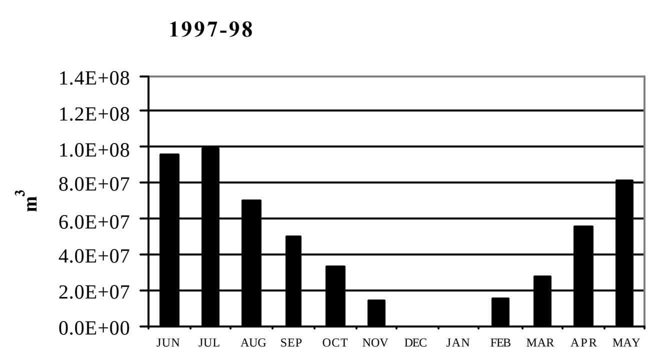



Figure 13. Annual total phosphorus loading (kg $yr^{-1}$) for the gauged watersheds 1990 – 1998.

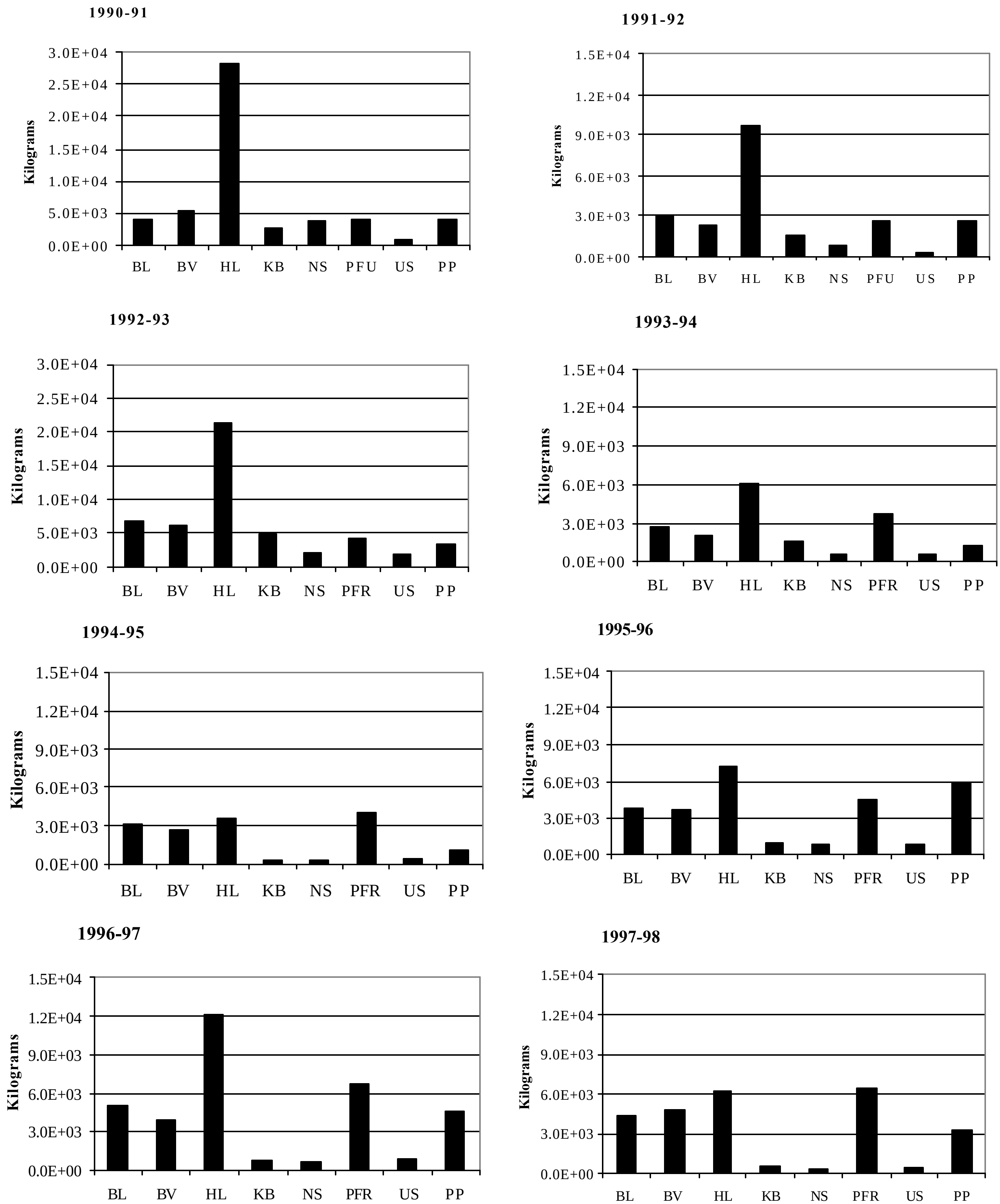


Figure 14. Monthly total phosphorus loading (kg $mo^{-1}$) for the gauged watersheds 1990 – 1998.
Note: Holland River total phosphorus loading kg scale in 1990-91 & 1992-93

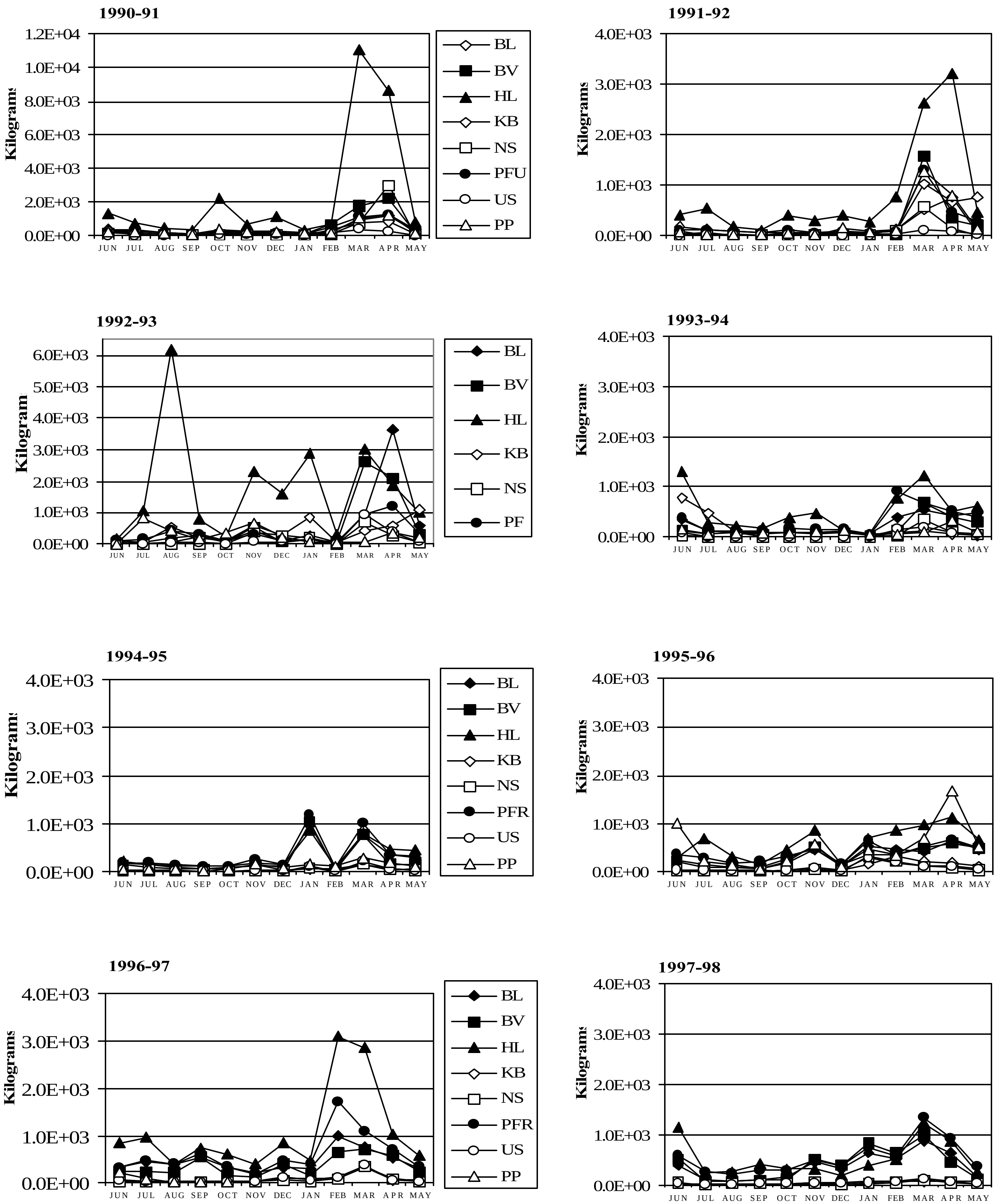


Figure 15. Total phosphorus loads from precipitation (kg $mo^{-1}$) to Lake Simcoe 1990 - 1998

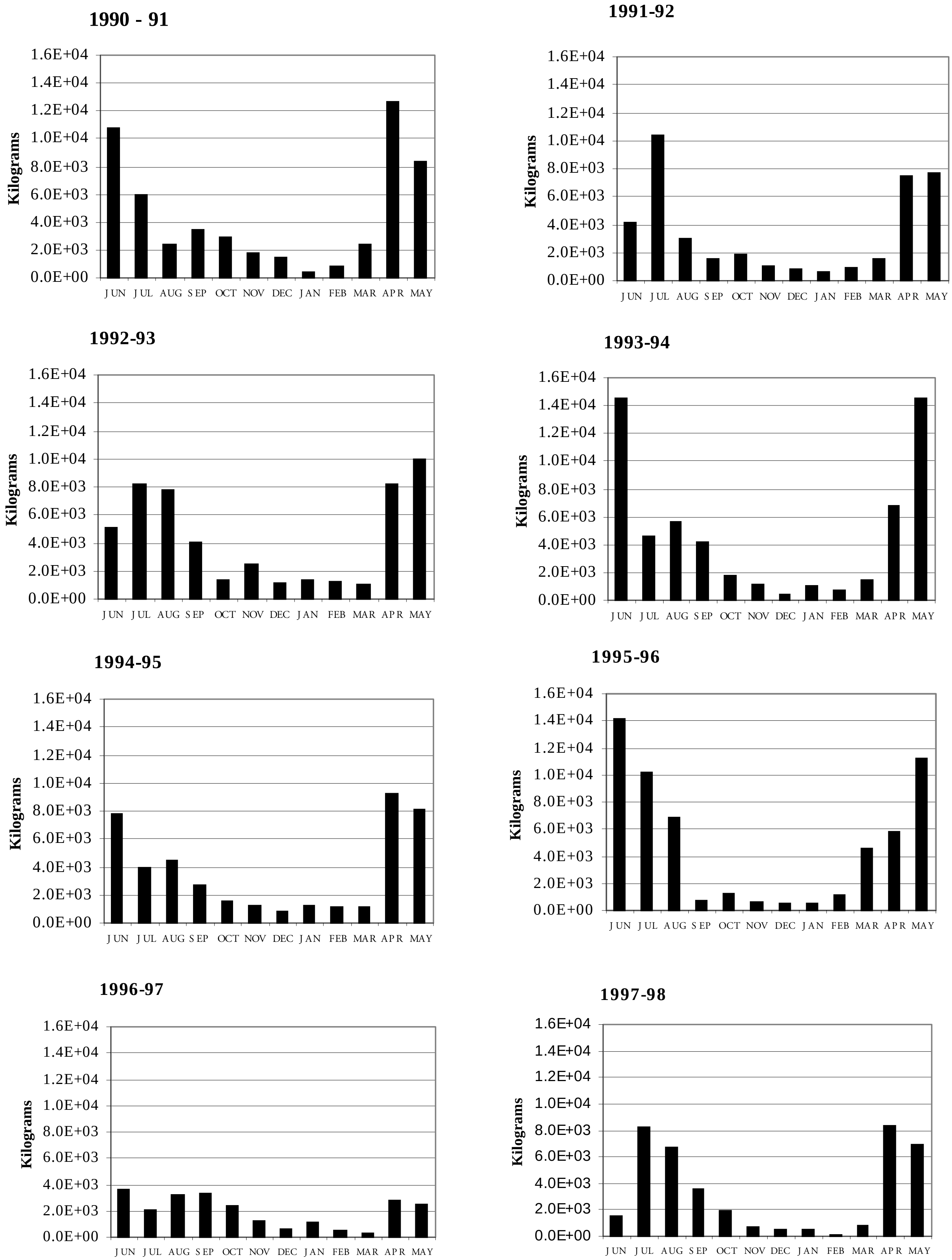
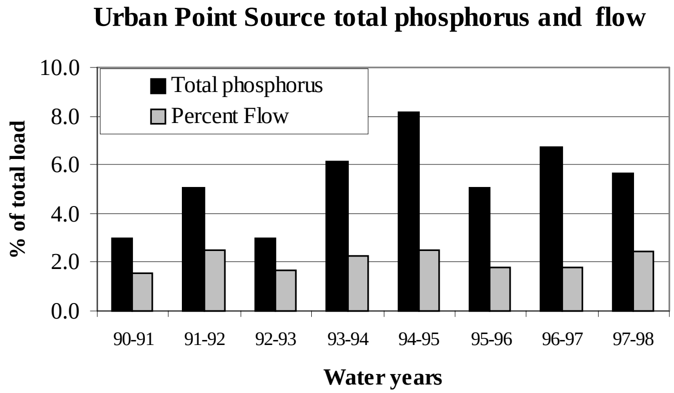
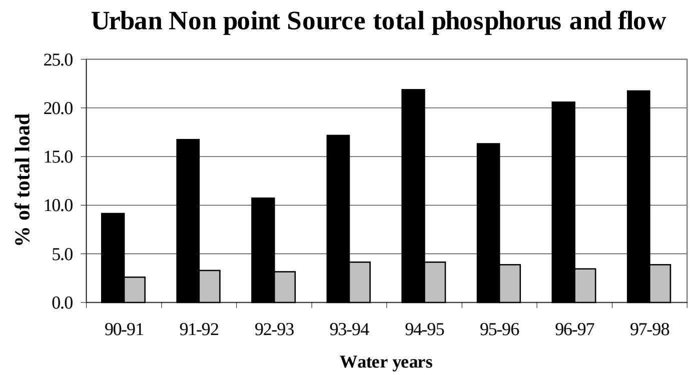
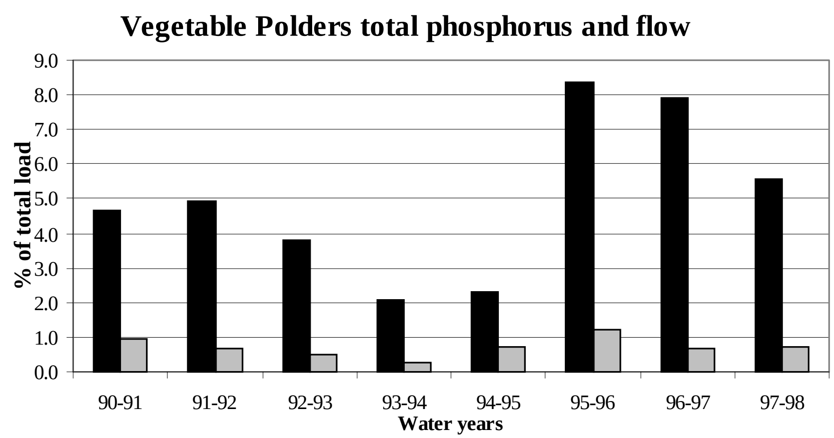
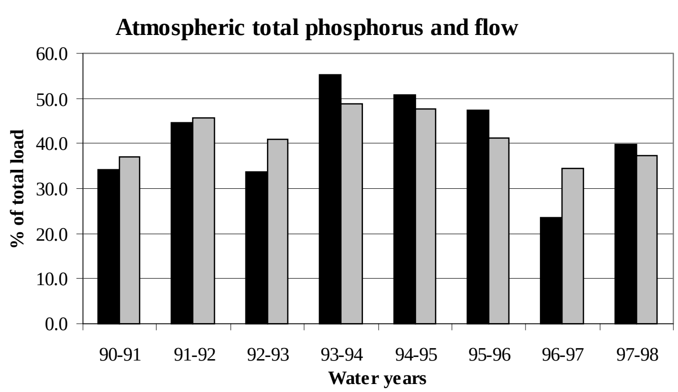


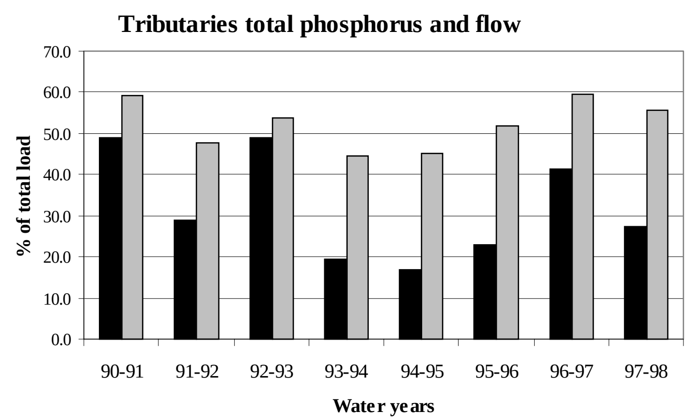
Figure 16. Annual summary of total phosphorus loads (kg $yr^{-1}$) and flow as ($m^3$ $yr^{-1}$) to Lake Simcoe 1990 – 1998. Expressed as a percent of total load and flow.



## ACKNOWLEDGEMENTS

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1. Environment Canada, Water Survey Brch. (Susan Saunders)
2. Environment Canada, Parks Brch. (Bruce Kitchen)
3. Environment Canada, Ontario Weather Centre (Jim Cook)
4. M.O.E. Environmental Monitoring and Reporting Brch. (Brian Whitehead)
5. M.O.E. Dorset Environmental Science Centre (Dr.P.J. Dillon / Wolfgang Scheider)
6. South Lake Simcoe Conservation Authority (Mike Walters, Geoff Peat)
7. Bradford West Gwillimbury (Municipality) (Art Janse)
8. M.O.E. Central Region (Steve Maude, Ellen Schmarje)

Data Modelers (Hydrology[1], Chemistry[2]):

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2. M.O.E. Dorset Environmental Science Centre Dr. J.G. Winter [2]
2. M.O.E. Dorset Environmental Science Centre M.N. Futter[2]

The list of provided data and interval of participants throughout this study 1990-98 include:

Laboratory Analysis (Rexdale [1], Dorset [2]):

1. MOE Laboratory Services Rexdale 1990 - 1993
2. MOE Dorset Environmental Science Centre 1993 - 1998 (Stewart Barnes, Peter Sutey, Don Evans)

Technical Support , Monitoring (LSEMS [1], MOE [2])

1. South Lake Simcoe Conservation Authority (Geoff Peat)
2. MOE Dorset Environmental Science Centre 1993 - 1998 (L.D. Scott, R.E. Girard, J.G. Findeis, J.E. Jones)
3. Douglas Snell (Snell Data Consultants Inc.)

Stream flow from Water Survey of Canada 1990-98 for Pefferlaw Brook, Upper Schomberg and the Holland River at Holland Landing, and WSC 1990-93 for the Beaver and Black River stream gauges and the latter from OMOE 1993-98 .

The South Lake Simcoe Conservation Authority provided stream flow data for Kettleby and the North Schomberg 1990-93 and OMOE 1993-98. Similarly SLSCA provided stream chemistry 1990-93 and OMOE 1993-98.

Meteorological parameters were initially provided by the Ontario Weather Centre 1990-95 (Jim Cook) utilizing Environment Canada and Ontario Weather Centre data, and later by OMOE 1995-98.

Lake Staff Gauge data was provided by Parks Canada 1990-98 (Bruce Kitchen) for Lake Couchiching and Lake Simcoe and facilitated the Atherley Narrows outflow proration from Swift Rapids by Lem Scott.

Stream flow data for Swift Rapids and Lake Couchiching outflow were provided by Water Survey of Canada 1990-98 (Sue Saunders)

Sub-watershed areas and GIS areas were provided by the South Lake Simcoe Conservation Authority (Geoff Peat) and the total Watershed areas for Lake Simcoe were provided by Water Survey of Canada (Sue Saunders).
Compiling of the chemical data was done by OMOE (Martyn Futter and Joe Findeis) with editing of the chemistry database by Dr. P.J. Dillon and L.D. Scott.

Point source data (flow and chemistry) from 14 Sewage Treatment Plants 1991-98 were provided from Central Region OMOE (Steve Maude and Ellen Schmarje)

Primary Bradford Marsh Pump discharge records 1990-98 were obtained from the Municipality of Bradford-West Gwillimbury (Art Janse) . These provided for the discharge estimates from the inner Holland Marsh.

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