Lake
Simcoe
Environmental
Management
Strategy

Implementation
Program

Estimated Monthly Flows and Exports of Total Nitrogen and Phosphorus from Lake Simcoe at Atherley

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ESTIMATED MONTHLY FLOWS AND EXPORTS OF TOTAL NITROGEN AND PHOSPHORUS FROM LAKE SIMCOE AT ATHERLEY

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for

The Lake Simcoe Environmental
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LAKE SIMCOE ENVIRONMENTAL MANAGEMENT STRATEGY IMPLEMENTATION PROGRAM

FOREWORD

This report is one of a series of technical reports prepared in the course of the Lake Simcoe Environmental Management Strategy (LSEMS) Implementation Program. This program is under the direction of the LSEMS Steering Committee, comprised of representatives of the following agencies:

- Ministry of Agriculture, Food and Rural Affairs;
- Ministry of the Environment and Energy;
- Ministry of Natural Resources; and
- Lake Simcoe Region Conservation Authority.

The Lake Simcoe Environmental Management Strategy (LSEMS) studies were initiated in 1981 in response to concern over the loss of a coldwater fishery in Lake Simcoe. The studies concluded that increased urban growth and poor agricultural practices within the drainage basin were filling the lake with excess nutrients. These nutrients promote increased weed growth in the lake with the end result being a decrease in the water's oxygen supply. The "Final Report and Recommendations of the Steering Committee" was released in 1985. The report recommended that a phosphorus control strategy be designed to reduce phosphorus inputs from rural and urban sources. In 1990 the Lake Simcoe Region Conservation Authority was named lead agency to coordinate the LSEMS Implementation Program, a five year plan to improve the water quality of Lake Simcoe. The Conservation Authority will have overall coordination responsibilities as outlined in the LSEMS Cabinet Submission and subsequent agreement (Recommendation E.1). At the completion of the five year plan (1994) a report will be submitted to the Cabinet. This report will outline the activities and progress of the LSEMS Implementation Program during its five years. After reviewing the progress of the program the Cabinet may continue the implementation program.

The goal of the LSEMS Implementation Program is to improve the water quality and natural coldwater fishery of Lake Simcoe by reducing the phosphorus loading to the lake. The LSEMS Implementation Program will initiate remedial measures and control options designed to reduce phosphorus inputs entering Lake Simcoe, monitor the effectiveness of these remedial measures and controls and evaluate the overall response of the lake to this program. Through cost sharing programs, environmental awareness of the public and further studies, the goal of restoring a naturally reproducing coldwater fishery in Lake Simcoe by improving water quality can be reached.

Questions with respect to the contents of this report should be directed to:

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DISCLAIMER

The material presented in these reports is analytical support information and does not necessarily constitute policy or approved management priorities of the Province or the Conservation Authority and/or the evaluation of the data and findings, should not be based solely on this specific report. Instead they should be analyzed in light of other reports produced within the comprehensive framework of this environmental management strategy and the implementation of the recommendations.

Reference to equipment, brand names or suppliers in this publication is not to be interpreted as an endorsement of that product or supplier by the authors, the Ministries of Agriculture, Food and Rural Affairs, Environment and Energy or Natural Resources or the Lake Simcoe Region Conservation Authority.

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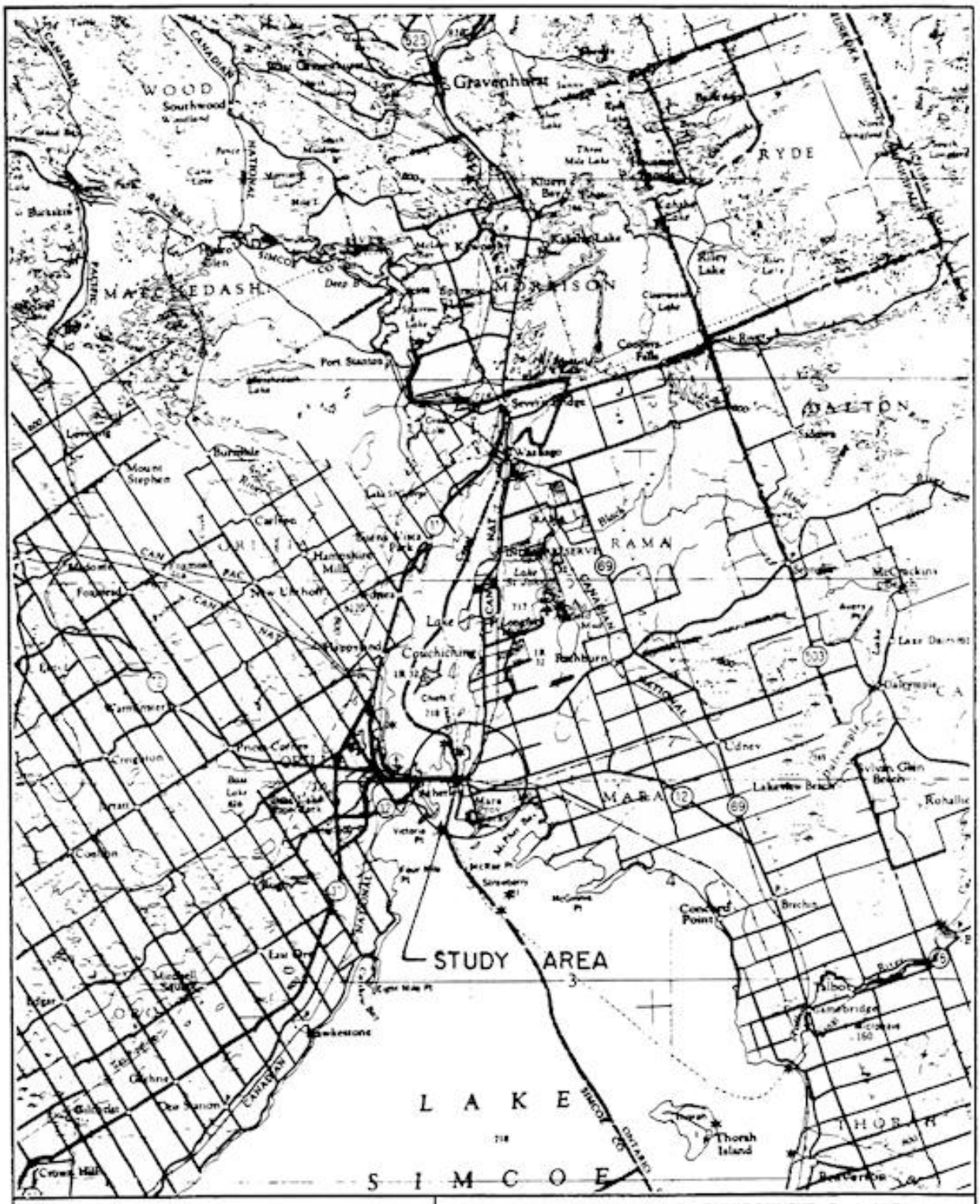
1.0 INTRODUCTION

Atherley is a small community which lies between Lake Simcoe to the south and Lake Couchiching to the north (location plan, Figure 1). Water flows from Lake Simcoe to Lake Couchiching through a narrows adjacent to the Community of Atherley.

Cumming Cockburn Limited was commissioned by the Ministry of the Environment to undertake an hydrologic analysis to estimate the outflows from Lake Simcoe at Atherley. The flow estimates were to be derived utilizing monthly time steps in the analyses, and were to be summarized as monthly averages for the period 1986 to 1990 inclusive. The monthly export of nitrogen and phosphorus were also estimated for the period from 1983 to 1990.


Gravenhurst
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STUDY AREA 3
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Figure .1 STUDY AREA LOCATION

2.0 METHODOLOGY

2.1 General

In order to determine the average monthly outflows from Lake Simcoe at Atherley, two methods of analysis were developed and compared. Each analysis required adjustments for evaporative losses, for changes in lake storage, for precipitation, and for pro-ration of the recorded flows at Washago, the outlet of Lake Couchiching.

Both methodologies are discussed in Section 2.3.

The monthly export of nitrogen and phosphorus were then calculated by using the estimated flows by both these methods and the results are presented in Section 2.4.

2.2 Data

In order to estimate the monthly flows and export of N and P at Atherley, numerous sources of data and information were collected and reviewed. This data included:

1) Mean monthly flow records from the Water Survey of Canada for station 02EC017, Lake Couchiching outflow at Washago

2) Total monthly precipitation recorded at station 6115820, Orillia T.S. from the Atmospheric Environment Service

3) Monthly Evaporation Data calculated by the Atmospheric Environment Service from data collected at station 6166418, the Peterborough Airport. Evaporation data for 1990 was not available from archives and the average data from 1980 - 1989 was used for the year 1990.

4) Monthly water levels recorded for each month for three stations, Lake Simcoe at Jackson's Point, Lake Simcoe at Atherley, and Lake Couchiching at Washago. These levels were obtained from the Trent Severn Waterway, Environment Canada, Parks in Peterborough.

5) Mapping of Lake Simcoe and Lake Couchiching.

6) Water quality data supplied by the Ministry of Environment.

Precipitation

The total monthly precipitation recorded at Orillia was considered to be the most representative of the precipitation falling on Lakes Couchiching and Simcoe. This station is located between the two lakes at the north and south ends of Lake Simcoe and Lake Couchiching respectively.

Lake Evaporation

The estimated daily lake evaporation based on Peterborough data was used, as it is the closest and most representative station, with respect to topography, elevation and other hydrologic characteristics. Monthly evaporation was estimated by the AES water budget procedures from 1980 - 1989 for the Peterborough Airport station.

Monthly Water Levels

The monthly water level records for Lake Simcoe at Jackson's Point, Lake Simcoe at Atherley and Lake Couchiching at Washago were obtained and used to derive the monthly change in live storage in both Lake Couchiching and Lake Simcoe.

Water levels have not been recorded for Lake Couchiching at Washago since 1988. The water level data for Lake Couchiching for three years from 1988 to 1990 was estimated from the monthly average (Jackson's Point and Atherley) water levels recorded for Lake Simcoe and historically observed differences over a period of 7 years (i.e. 1982 - 1987). Couchiching lake levels were lower than Lake Simcoe levels as shown below:

January	0.028 m
February	0.051 m
March	0.051 m
April	0.035 m

May	0.029 m
June	0.028 m
July	0.032 m
August	0.025 m
September	0.023 m
October	0.036 m
November	0.043 m
December	0.036 m

This information was used to estimate Lake Couchiching levels, where the data was not available.

Mapping

Mapping from the Ministry of Natural Resources was obtained for the watersheds of Lake Couchiching and Lake Simcoe; this mapping was to a scale of 1:50,000. These maps were used to determine drainage areas and lake surface areas, etc. The land area which drains into Lake Couchiching was determined to be 64.44 km^2, while the surface area of Lake Couchiching was determined to be 44.75 km^2. In addition, the surface area of Lake Simcoe was found to be 728.2 km^2 and contributing land area was found to be approximately 2873 km^2.

Water Quality

The water quality data have been recorded by the Ministry of Environment since 1983. The data for nitrogen included NH_3, NO_2 + NO_3, NO_2 and Total Kjeldahl Nitrogen. Total unfiltered phosphorus was also recorded. The data was recorded at irregular intervals, i.e., approximately about 8 times a month on an average basis. The monthly average for nitrogen and phosphorus was calculated and used to estimate the monthly export of different components of nitrogen and their total and phosphorus export.

2.3 Discharge Estimates

2.3.1 General

The two methods used to estimate the monthly flows at Atherley are similar. Each method makes adjustments for evaporative losses, precipitation and changes in lake storage. In addition, each method also utilizes flows recorded at the outlet of Lake Couchiching at Washago, and prorates these flows by the difference in drainage areas back to the inlet of Lake Couchiching. Generally, the equation is as follows:

$$Q_A = Q_W \text{ (PRO) } \pm S - PRE + EVP.* \quad (1)$$

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

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

PRO = Pro-ration factor based on difference in drainage areas between Washago and Atherley

S = Change in lake storage

PRE = Precipitation

EVP = Lake evaporation

* This assumes that all parameters have compatible units of m^3/s.

During the months of December, January and February, there were no adjustments made for evaporation and/or precipitation due to ice cover on the lakes. Therefore, adjustments were made utilizing storage only in these months.

2.3.2 Method 1

The expanded equation for Method 1 is given in Appendix I and includes adjustments to the flow accounting for the net effects of precipitation, evaporation and change in storage from Lake Couchiching and Lake Simcoe to the recorded flows at the outlet of Lake Couchiching at Washago. First the watershed inflows to the lake were estimated. Then these flows were prorated back to Atherley on the basis of the difference of the land drainage areas between the two sites.

TABLE 1: METHOD 1 - Estimated Monthly Flows at Atherley.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987	32.9	25.5	32.5	17.1	15.5	16.2	30.1	30.3	16.3	16.2	34.6	45.9
1988	41.4	47.7	24.5	9.1	9.3	15.1	13.3	13.5	17.4	19.7	23.1	25.4
1989	22.5	25.6	13.6	13.6	41.0	43.7	30.2	17.1	19.1	15.2	24.5	46.1
1990	29.9	43.2	41.1	60.1	33.9	25.2	27.3	34.6	17.2	16.0	20.5	29.6

Flows are given in cubic metres per second (m^3/s)

These drainage areas are approximately 2937 km^2 and 2873 km^2 for Washago and Atherley respectively, giving a pro-ration factor of 0.978.

These prorated flows represented the flows at Atherley based on contributing land area only. In order to obtain the actual flows at Atherley, the net effects of precipitation, evaporation and change in storage for Lake Simcoe alone were representatively incorporated in the flow estimates. The resulting average monthly flows at Atherley are summarized in Table 1.

These are the primary flow estimates at Atherley, and a secondary check was then undertaken using slightly different assumptions as discussed in the following section.

2.3.3 Method 2

Method 2 also utilized general equation 1 (section 2.3.1) but did not adjust the recorded flows at Washago prior to transfer to Atherley. Appendix II gives a detailed description of the expanded equation used for Method 2. The existing flows at Washago were prorated by a factor of 0.983 derived by accounting for the contributing land draining into Lake Couchiching from the drainage area published for Washago. These prorated flows were then subsequently adjusted by the net effects of precipitation, evaporation, and change in storage on Lake Couchiching to estimate the average monthly flows at Atherley (see Table 2).

This method was used as a secondary check due to the large differences in overland contributing areas.

2.4 Estimation of Nitrogen and Phosphorus Export

Estimated monthly flows have been used to calculate monthly export of nitrogen and phosphorus. The results are presented from 1983 to 1990 on a monthly basis. The monthly and yearly average of 8 years record along with the standard deviation and total export over this period is also presented.

2.4.1 Nitrogen Export

Total nitrogen export by using the flows calculated by Methods 1 and 2 are presented in Tables 3 and 4, respectively. The summary of nitrogen export is presented in Tables described below:

Nitrite, NO_2	Table 5 (Method 1)
	Table 6 (Method 2)
Nitrate, NO_3	Table 7 (Method 1)
	Table 8 (Method 2)
Nitrite + Nitrate (NO_2 + NO_3)	Table 9 (Method 1)
	Table 10 (Method 2)
Total Kjeldahl Nitrogen (TK N)	Table 11 (Method 1)
	Table 12 (Method 2)

The average difference in the total nitrogen export calculated by these two methods is less than 1% which indicates that estimation of nitrogen export by either method is appropriate.

2.4.2 Phosphorus Export

Total phosphorus export as calculated by using the estimated flows by Method 1 and Method 2 is presented in Tables 13 and 14, respectively. Because of the lower concentration of Phosphorus, the estimates of phosphorus export by either of these methods is practically the same and hence, the flows estimated by either method could be used to calculate the phosphorus export.

TABLE 2 : METHOD 2. Estimated Monthly Flows at Atherley.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987	32.7	26.1	34.0	17.5	15.9	16.8	29.8	29.9	15.9	16.0	34.1	46.0
1988	41.5	47.8	25.8	9.5	9.6	15.1	13.7	13.3	16.8	19.1	22.5	25.7
1989	22.7	26.0	14.4	14.3	41.0	43.3	30.5	16.6	18.6	15.0	23.5	46.2
1990	29.8	44.5	42.2	59.8	33.9	25.1	26.9	34.2	17.0	15.7	19.9	29.4

Flows are given in cubic metres per second (m^3/s)

TABLE 3: METHOD 1 - Estimated Monthly Nitrogen Export from Lake Simcoe.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum	Avg
Year	Total Nitrogen in Metric Tons of N													
1983	112.9	80.1	18.2	50.4	87.2	27.6	17.2	17.7	21.0	20.9	16.9	14.5	484.7	40.4
1984	30.6	51.8	67.2	31.0	30.2	41.1	35.2	25.4	40.9	24.1	12.7	12.4	402.5	33.5
1985	30.8	45.4	73.1	63.4	33.0	23.5	22.0	27.2	37.4	42.6	54.5	49.4	502.4	41.9
1986	45.9	31.3	38.8	17.6	23.7	45.0	36.7	46.9	54.8	92.6	40.2	53.2	526.7	43.9
1987	30.8	22.8	26.2	16.4	14.9	13.4	25.8	30.0	16.1	18.2	34.1	54.1	303.0	25.2
1988	71.0	188.8	29.5	9.9	10.2	16.0	13.5	15.5	15.3	23.7	22.8	27.9	444.2	37.0
1989	27.1	25.4	15.0	14.5	46.1	45.3	30.7	18.3	18.8	15.1	31.8	45.7	333.8	27.8
1990	28.0	37.6	41.8	54.5	35.4	24.8	28.5	32.4	21.4	18.0	23.9	32.5	379.0	31.6
Sum	377.1	483.2	309.9	257.7	280.9	236.8	209.7	213.5	225.8	255.2	236.8	289.6	3376.2	
Avg	47.1	60.4	38.7	32.2	35.1	29.6	26.2	26.7	28.2	31.9	29.6	36.2	422.0	
Std	28.4	51.5	20.1	19.6	22.4	11.8	7.7	9.6	13.5	24.3	12.7	15.8	75.9	

TABLE 4: METHOD 2 - Estimated Monthly Nitrogen Export from Lake Simcoe.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum	Avg
Year	Total Nitrogen in Metric Tons of N (sum of NO_3 -N + NO_2 -N + TKN)													
1983	112.8	81.6	19.8	50.8	87.8	27.2	16.3	17.4	20.5	22.1	18.6	13.5	488.5	40.7
1984	31.5	53.5	67.8	31.2	29.6	40.2	34.8	24.8	42.2	25.6	11.2	11.8	404.2	33.7
1985	32.3	45.8	73.5	63.1	32.3	23.2	21.5	28.4	38.7	41.8	54.3	50.7	505.5	42.1
1986	46.3	31.5	38.5	16.8	23.4	44.6	37.9	48.3	54.0	92.6	40.9	53.9	528.8	44.1
1987	30.7	23.4	27.3	16.8	15.3	13.9	25.5	29.6	15.7	18.0	33.6	54.2	304.0	25.3
1988	71.1	189.2	31.1	10.3	10.5	16.0	13.9	15.3	14.8	23.0	22.2	28.2	445.9	37.2
1989	27.4	25.8	15.8	15.2	46.1	44.9	31.0	17.8	18.3	14.9	30.5	45.8	333.4	27.8
1990	27.9	38.8	43.0	54.3	35.4	24.7	28.1	32.1	21.2	17.7	23.2	32.3	378.5	31.5
Sum	380.0	489.5	316.9	258.5	280.5	234.7	209.1	213.7	225.3	255.7	234.5	290.4	3388.9	
Avg	47.5	61.2	39.6	32.3	35.1	29.3	26.1	26.7	28.2	32.0	29.3	36.3	423.6	
Std	28.2	51.4	19.8	19.5	22.6	11.6	8.0	10.1	13.8	24.2	12.8	16.3	76.9	

TABLE 5: METHOD 1 - Estimated Monthly Nitrite Export from Lake Simcoe.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum	Avg
Year	Total Nitrite in Metric Tons of N													
1983	0.422	0.470	0.693	2.216	3.635	0.264	0.298	0.085	0.103	0.099	0.033	0.330	8.6	0.7
1984	0.128	0.264	0.379	0.145	0.206	0.154	0.091	0.110	0.130	0.096	0.067	0.088	1.9	0.2
1985	0.072	0.225	0.584	1.038	0.269	0.117	0.112	0.092	0.153	0.612	1.103	0.546	4.9	0.4
1986	0.353	0.206	0.649	0.254	0.278	0.346	0.367	0.099	0.334	1.072	0.658	0.167	4.8	0.4
1987	0.176	0.247	0.470	0.332	0.303	0.239	0.306	0.243	0.118	0.100	0.135	0.762	3.4	0.3
1988	0.322	1.470	0.217	0.073	0.077	0.051	0.053	0.101	0.113	0.306	0.299	0.190	3.3	0.3
1989	0.181	0.124	0.109	0.106	0.439	0.453	0.243	0.137	0.099	0.081	0.191	0.123	2.3	0.2
1990	0.160	0.209	0.330	0.312	0.272	0.457	0.219	0.463	0.223	0.086	0.159	0.079	3.0	0.2
Sum	1.8	3.2	3.4	4.5	5.5	2.1	1.7	1.3	1.3	2.5	2.6	2.3	32.2	
Avg	0.2	0.4	0.4	0.6	0.7	0.3	0.2	0.2	0.2	0.3	0.3	0.3	4.0	
Std	0.1	0.4	0.2	0.7	1.1	0.1	0.1	0.1	0.1	0.3	0.3	0.2	2.0	

TABLE 6: METHOD 2 - Estimated Monthly Nitrite Export from Lake Simcoe.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum	Avg
Year	Total Nitrite in Metric Tons of N													
1983	0.422	0.478	0.752	2.236	3.659	0.260	0.283	0.083	0.101	0.105	0.037	0.309	8.7	0.7
1984	0.132	0.272	0.382	0.146	0.202	0.151	0.090	0.107	0.135	0.102	0.059	0.083	1.9	0.2
1985	0.075	0.227	0.587	1.033	0.264	0.116	0.109	0.096	0.158	0.601	1.099	0.560	4.9	0.4
1986	0.356	0.207	0.642	0.242	0.274	0.343	0.379	0.102	0.329	1.072	0.670	0.169	4.8	0.4
1987	0.175	0.253	0.492	0.340	0.311	0.248	0.303	0.240	0.115	0.099	0.133	0.764	3.5	0.3
1988	0.322	1.473	0.228	0.076	0.080	0.051	0.055	0.100	0.109	0.297	0.292	0.193	3.3	0.3
1989	0.182	0.126	0.116	0.111	0.439	0.449	0.245	0.133	0.096	0.080	0.183	0.124	2.3	0.2
1990	0.160	0.215	0.339	0.310	0.272	0.455	0.216	0.458	0.220	0.084	0.155	0.079	3.0	0.2
Sum	1.8	3.3	3.5	4.5	5.5	2.1	1.7	1.3	1.3	2.4	2.6	2.3	32.3	
Avg	0.2	0.4	0.4	0.6	0.7	0.3	0.2	0.2	0.2	0.3	0.3	0.3	4.0	
Std	0.1	0.4	0.2	0.7	1.1	0.1	0.1	0.1	0.1	0.3	0.3	0.2	2.0	

TABLE 7: METHOD 1 - Estimated Monthly Nitrate Export from Lake Simcoe.

	Jan	Feb	Mar.	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum	Avg
Year	Total Nitrate in Metric Tons of N													
1983	1.055	25.044	1.333	3.732	4.443	1.718	0.511	0.296	0.361	0.396	0.034	0.477	39.4	3.3
1984	2.563	2.915	2.163	1.302	0.187	1.138	1.464	1.614	0.921	0.681	0.070	0.930	15.9	1.3
1985	1.387	0.829	3.502	6.866	2.961	0.970	2.382	0.799	1.211	2.388	1.140	3.917	28.4	2.4
1986	3.175	2.575	3.766	1.403	1.047	1.384	1.514	0.988	4.855	2.705	0.680	3.432	27.5	2.3
1987	1.586	0.987	2.002	1.241	0.872	0.588	1.612	2.029	0.887	0.824	0.139	3.196	16.0	1.3
1988	2.994	109.72	2.690	1.014	0.548	0.744	0.677	0.723	0.812	0.739	0.309	1.293	122.3	10.2
1989	1.507	0.743	1.676	1.41	1.537	0.566	0.324	0.137	0.149	0.285	0.197	0.494	9.0	0.8
1990	1.121	0.627	1.981	3.116	0.726	0.131	0.219	1.112	0.357	0.214	0.165	0.396	10.2	0.8
Sum	15.4	143.4	19.1	20.1	12.3	7.2	8.7	7.7	9.6	8.2	2.7	14.1	268.6	
Avg	1.9	17.9	2.4	2.5	1.5	0.9	1.1	1.0	1.2	1.0	0.3	1.8	33.6	
Std	0.8	35.6	0.8	1.9	1.4	0.5	0.7	0.6	1.4	0.9	0.4	1.4	34.9	

TABLE 8: METHOD 2 - Estimated Monthly Nitrate Export from Lake Simcoe.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov.	Dec	Sum	Avg
Year	Total Nitrate in Metric Tons of N													
1983	1.054	25.508	1.446	3.766	4.472	1.692	0.485	0.291	0.352	0.420	0.402	0.446	40.3	3.4
1984	2.644	3.010	2.182	1.311	0.183	1.113	1.446	1.580	0.952	0.724	0.203	0.883	16.2	1.4
1985	1.457	0.836	3.523	6.832	2.899	0.955	2.319	0.832	1.252	2.345	5.083	4.017	32.4	2.7
1986	3.204	2.597	3.726	1.335	1.033	1.372	1.565	1.018	4.780	2.705	3.052	3.481	29.9	2.5
1987	1.577	1.010	2.095	1.270	0.894	0.610	1.596	2.002	0.865	0.814	2.121	3.203	18.1	1.5
1988	3.001	109.95	2.833	1.059	0.566	0.744	0.697	0.712	0.784	0.716	0.991	1.308	123.4	10.3
1989	1.520	0.755	1.774	1.483	1.537	0.561	0.327	0.133	0.145	0.281	0.914	0.495	9.9	0.8
1990	1.117	0.646	2.035	3.100	0.726	0.130	0.216	1.099	0.353	0.210	0.309	0.394	10.3	0.9
Sum	15.6	144.3	19.6	20.2	12.3	7.2	8.7	7.7	9.5	8.2	13.1	14.2	280.5	
Avg	1.9	18.0	2.5	2.5	1.5	0.9	1.1	1.0	1.2	1.0	1.6	1.8	35.1	
Std	0.8	35.6	0.8	1.9	1.3	0.5	0.7	0.6	1.4	0.9	1.6	1.4	34.9	

TABLE 9: METHOD 1 - Estimated Monthly Nitrite and Nitrate Export from Lake Simcoe.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Sum	Avg
Year	Total Nitrite and Nitrate in Metric Tons of N													
1983	1.055	25.357	1.972	5.832	7.876	1.983	0.767	0.339	0.413	0.446	0.398	0.807	47.2	3.9
1984	1.025	3.193	2.524	1.085	0.624	1.283	1.568	1.743	1.024	0.776	0.305	1.029	16.2	1.3
1985	1.431	1.124	4.107	7.983	3.230	1.072	2.494	0.919	1.419	3.000	6.205	4.417	37.4	3.1
1986	3.527	2.797	4.396	1.678	1.331	1.730	1.880	1.111	5.216	3.900	3.655	3.645	34.9	2.9
1987	1.762	1.234	2.524	1.596	1.162	0.840	1.935	2.272	0.972	0.911	2.242	3.934	21.4	1.8
1988	3.327	111.15	2.887	1.085	0.623	0.783	0.712	0.832	0.902	1.055	1.317	1.429	126.1	10.5
1989	1.687	0.867	1.785	1.516	1.977	1.019	0.485	0.275	0.248	0.366	1.143	0.617	12.0	1.0
1990	1.281	0.836	2.312	3.427	0.999	0.327	0.439	1.483	0.580	0.300	0.478	0.476	12.9	1.1
Sum	15.1	146.6	22.5	24.2	17.8	9.0	10.3	9.0	10.8	10.8	15.7	16.4	308.1	
Avg	1.9	18.3	2.8	3.0	2.2	1.1	1.3	1.1	1.3	1.3	2.0	2.0	38.5	
Std	0.9	35.9	0.9	2.4	2.3	0.5	0.7	0.6	1.5	1.3	1.9	1.5	35.2	

TABLE 10: METHOD 2 - Estimated Monthly Nitrite and Nitrate Export from Lake Simcoe.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum	Avg
Year	Total Nitrite and Nitrate in Metric Tons of N													
1983	1.054	25.827	2.141	5.884	7.928	1.952	0.728	0.332	0.402	0.472	0.439	0.754	47.9	4.0
1984	1.057	3.296	2.546	1.093	0.611	1.256	1.549	1.707	1.058	0.825	0.269	0.977	16.2	1.4
1985	1.504	1.134	4.132	7.944	3.163	1.056	2.428	0.958	1.466	2.946	6.182	4.529	37.4	3.1
1986	3.560	2.821	4.349	1.597	1.312	1.715	1.945	1.145	5.135	3.900	3.722	3.696	34.9	2.9
1987	1.752	1.263	2.641	1.633	1.192	0.871	1.916	2.242	0.948	0.900	2.210	3.943	21.5	1.8
1988	3.335	111.38	3.041	1.133	0.643	0.783	0.734	0.819	0.871	1.023	1.283	1.446	126.5	10.5
1989	1.702	0.881	1.890	1.594	1.977	1.010	0.490	0.267	0.241	0.362	1.096	0.619	12.1	1.0
1990	1.277	0.861	2.374	3.410	0.999	0.325	0.432	1.466	0.573	0.294	0.464	0.472	12.9	1.1
Sum	15.2	147.5	23.1	24.3	17.8	9.0	10.2	8.9	10.7	10.7	15.7	16.4	309.6	
Avg	1.9	18.4	2.9	3.0	2.2	1.1	1.3	1.1	1.3	1.3	2.0	2.1	38.7	
Std	0.9	36.0	0.8	2.4	2.3	0.5	0.7	0.6	1.5	1.2	1.9	1.6	35.3	

TABLE 11: METHOD 1 - Estimated Monthly Total Kjeldahl Nitrogen (TKN), Export from Lake Simcoe.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum	Avg
Year	Total Kjeldahl Nitrogen (TKN) in metric tons													
1983	111.86	54.78	16.36	44.56	80.98	25.65	16.40	17.35	20.63	20.46	16.52	13.69	439.2	36.6
1984	29.90	48.58	64.89	29.65	29.33	40.20	33.98	23.88	40.01	23.29	12.41	11.36	387.5	32.3
1985	29.52	44.98	69.17	55.88	29.61	22.47	19.34	26.16	36.01	39.60	48.26	45.33	466.3	38.9
1986	42.33	28.79	34.97	15.92	22.56	42.68	34.78	45.69	49.49	90.18	49.34	50.12	506.8	42.2
1987	29.08	21.59	24.37	15.07	13.70	12.60	24.19	27.59	14.79	17.36	31.39	50.40	282.1	23.5
1988	67.64	77.69	26.25	8.96	9.47	15.26	12.82	14.82	14.43	22.69	21.56	26.53	318.1	26.5
1989	25.31	24.15	13.48	13.04	43.93	44.18	30.74	18.32	18.81	14.66	30.48	45.69	322.8	26.9
1990	27.23	37.62	38.53	51.41	34.50	24.17	27.79	31.51	20.51	17.57	23.38	31.71	365.9	30.5
Sum	362.9	338.2	288.0	234.5	264.1	227.2	200.0	205.3	214.7	245.8	233.3	274.8	3088.9	
Avg	45.4	42.3	36.0	29.3	33.0	28.4	25.0	25.7	26.8	30.7	29.2	34.4	386.1	
Std	28.3	17.4	19.6	17.6	20.9	11.6	7.7	9.2	12.3	23.6	12.8	14.9	73.9	

TABLE 12: METHOD 2 - Estimated Monthly Total Kjeldahl Nitrogen (TKN), Export from Lake Simcoe.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum	Avg
Year	Total Kjeldahl Nitrogen (TKN) in metric tons													
1983	111.72	55.80	17.76	44.95	81.52	25.24	15.57	17.02	20.11	21.68	18.20	12.79	442.4	36.9
1984	30.84	50.16	65.47	29.86	28.70	39.35	33.57	23.39	41.35	24.76	10.93	10.79	389.2	32.4
1985	31.02	45.36	69.60	55.61	28.99	22.13	18.83	27.25	37.21	38.89	48.08	46.48	469.5	39.1
1986	42.72	29.04	34.59	15.15	22.25	42.29	35.97	47.07	48.72	90.18	50.25	50.82	509.1	42.4
1987	28.90	22.10	25.50	15.42	14.05	13.06	23.94	27.23	14.42	17.14	30.94	50.51	283.2	23.6
1988	67.80	77.85	27.64	9.36	9.77	15.26	13.21	14.61	13.93	22.00	21.00	26.85	319.3	26.6
1989	25.54	24.53	14.27	13.71	43.93	43.77	31.04	17.78	18.32	14.46	29.24	45.78	322.4	26.9
1990	27.14	38.76	39.56	51.15	34.50	24.07	27.38	31.14	20.27	17.24	22.70	31.50	365.4	30.5
Sum	365.7	343.6	294.4	235.2	263.7	225.2	199.5	205.5	214.3	246.4	231.3	275.5	3100.4	
Avg	45.7	43.0	36.8	29.4	33.0	28.1	24.9	25.7	26.8	30.8	28.9	34.4	387.5	
Std	28.1	17.4	19.3	17.5	21.0	11.3	7.9	9.7	12.6	23.5	13.1	15.4	74.8	

TABLE 13: METHOD 1 - Estimated Monthly Phosphorous Export from Lake Simcoe.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum	Avg
Year	Total Phosphorous in metric tons													
1983	2.1	1.6	0.7	2.0	4.0	1.1	0.6	0.5	1.0	1.0	0.8	0.6	16.0	1.3
1984	1.0	1.7	1.4	0.8	1.0	1.2	0.6	0.5	1.3	0.7	0.3	0.5	11.1	0.9
1985	1.0	1.1	2.4	2.2	0.8	0.8	0.4	0.7	1.4	1.7	1.7	1.9	16.1	1.3
1986	1.2	1.1	1.1	0.6	0.8	1.6	0.9	1.1	1.1	2.7	2.6	2.0	16.7	1.4
1987	0.7	0.4	0.7	0.6	0.5	0.4	0.8	0.5	0.5	0.6	1.0	1.8	8.3	0.7
1988	2.4	5.7	0.6	0.2	0.3	0.5	0.3	0.3	0.4	0.7	0.7	0.7	12.8	1.1
1989	0.5	0.6	0.4	0.4	1.4	1.7	0.7	0.5	0.6	0.4	1.7	0.9	9.8	0.8
1990	0.6	0.9	0.9	1.2	1.1	0.7	0.7	0.7	0.4	0.6	0.7	1.0	9.7	0.8
Sum	9.5	13.1	8.1	8.0	9.8	8.1	5.0	4.8	6.6	8.4	9.6	9.4	100.5	
Avg	1.2	1.6	1.0	1.0	1.2	1.0	0.6	0.6	0.8	1.0	1.2	1.2	12.6	
Std	0.6	1.6	0.6	0.7	1.1	0.5	0.2	0.2	0.4	0.7	0.7	0.6	3.1	

TABLE 14: METHOD 2 - Estimated Monthly Phosphorous Export from Lake Simcoe.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum	Avg
Year	Total Phosphorous in metric tons													
1983	2.1	1.6	0.8	2.0	4.1	1.1	0.6	0.5	1.0	1.0	0.9	0.5	16.2	1.3
1984	1.1	1.7	1.5	0.8	1.0	1.2	0.6	0.5	1.3	0.8	0.3	0.5	11.2	0.9
1985	1.0	1.1	2.4	2.2	0.8	0.8	0.4	0.7	1.5	1.6	1.6	1.9	16.2	1.3
1986	1.2	1.1	1.1	0.6	0.7	1.6	1.0	1.1	1.1	2.7	2.6	2.0	16.8	1.4
1987	0.7	0.4	0.7	0.6	0.5	0.5	0.8	0.5	0.4	0.6	1.0	1.8	8.4	0.7
1988	2.4	5.7	0.6	0.2	0.3	0.5	0.3	0.3	0.4	0.7	0.6	0.7	12.8	1.1
1989	0.5	0.6	0.4	0.4	1.4	1.7	0.7	0.4	0.6	0.4	1.6	0.9	9.8	0.8
1990	0.6	1.0	0.9	1.2	1.1	0.7	0.7	0.7	0.4	0.6	0.7	1.0	9.7	0.8
Sum	9.7	13.1	8.4	7.9	9.8	8.1	5.1	4.8	6.7	8.4	9.4	9.2	101.1	
Avg	1.2	1.6	1.1	1.0	1.2	1.0	0.6	0.6	0.8	1.1	1.2	1.2	12.6	
Std	0.6	1.6	0.6	0.7	1.1	0.4	0.2	0.2	0.4	0.7	0.7	0.6	3.2	

3.0 SUMMARY OF RESULTS

The estimated monthly average flows from Lake Simcoe to Lake Couchiching at Atherley are summarized in Table 1. The secondary estimates obtained by Method 2 verified the primary flow estimates at Atherley. A comparison of the results between Methods 1 and 2 indicated a maximum difference in estimates up to about 10%.

The primary estimate is considered to be more representative of the actual situation since it accounts for the differences in lake to land area ratios.

It is of interest to note that for some months over the period of record examined, the flows at Atherley were found to be slightly higher than the flows at Washago. This has been attributed to storage changes on Lake Couchiching.

The results of nitrogen and phosphorus export have been presented for both methods. The accuracies of calculating the nitrogen and phosphorus export by using the flows estimated by either of the two methods is not affected to the same extent as those of the flows alone. Hence, for estimation of nitrogen and phosphorus export, the flows estimated by either of these two methods could be used without affecting the prediction accuracy of nitrogen and phosphorus export. The average total nitrogen and phosphorus export over the record period is estimated to be approximately 422 and 12 metric tonnes per year, respectively by Method 1 which is more representative of the actual situation for estimation of flows. Average nitrite, nitrate and TK N export is estimated to be 4, 34 and 386 metric tonnes per year, respectively.

The noted discrepancy in the total nitrogen export and the summation of different nitrogen components is less than 0.5% which is attributed to the round off errors.

APPENDIX I

Equation Used for Method 1

If January, February, or December

$FLOW = Qw \pm \Delta S_C \pm \Delta S_S$

Q_A = Flow (0.978) + $(\pm \Delta S)_S$

Rest of Year

C = EVP * (44750000/10000)/(24*3600)
$\pm \Delta S_C$ - PRE * (44750000/1000)/(MDAY * 24 * 3600)

S = EVP * (718205782/10000)/(24*3600)
$\pm \Delta S_S$ - PRE * (718205782/1000)/(MDAY * 24 * 3600)

$FLOW = Q_w + C + S$

Q_A = FLOW (0.978) - S

Q_w = Recorded flow at Washago (m^3/s)

Q_A = Estimated flow at Atherley (m^3/s)

0.978 = Drainage Area Pro-ration factor (Section 2.3.2)

ΔS_c = Change in storage Lake Couchiching (m^3/s)

ΔS_S = Change in storage Lake Simcoe (m^3/s)

EVP = Mean monthly lake evaporation (10^{-1} mm)

PRE = Total monthly precipitation (mm)

44750000 = Surface area Lake Couchiching (m^2)

718205782 = Surface area Lake Simcoe (m^2)

MDAY = number of days in month

24 * 3600 = number seconds in day

10000 = factor to change (10^{-1} mm) to (m)

1000 = factor to change (mm) to (m)

ΔS = were previously derived from changes in lake levels recorded in metres

$$\text{i.e } \Delta S = \frac{\text{(lake level change (m))} * \text{Area of lake}}{3600 * 24 * \text{MDAY}}$$

this gives units of (m^3/s)

APPENDIX II

Equation Used for Method 2

If January, February, or December

$$Q_A = (Q_W \pm) (0.983) \pm \Delta S_C$$

Rest of Year

$$Q_A = Q_W \pm (0.983) + EVP * (44750000/10000)/(24 * 3600) \pm \Delta S_C - PRE * (44750000/1000)/(MDAY * 24 * 3600)$$

where 0.983 = Drainage area proration factor (Section 2.3.1.2)

See Appendix I for explanation of rest of terms.

APPENDIX

MEMBERSHIP ON THE STEERING COMMITTEE FOR THE LAKE SIMCOE ENVIRONMENTAL MANAGEMENT STRATEGY IMPLEMENTATION PROGRAM

D. Marquis, Lake Simcoe Region Conservation Authority (Chairman)
A. Morton, Lake Simcoe Region Conservation Authority (past member)
J. Barker, Maple District, Ministry of Natural Resources
E. Cavanagh, York County, Ministry of Agriculture and Food
R. DesJardine, Central Region, Ministry of Natural Resources (past member)
J. Kinkead, Watershed Management Branch, Ministry of the Environment (past member)
J. Merritt, Director - Central Region, Ministry of the Environment
P. Miller, Watershed Management Branch, Ministry of the Environment
B. Noels, Lake Simcoe Region Conservation Authority (Secretary)

APPENDIX

MEMBERSHIP ON THE TECHNICAL COMMITTEE FOR THE LAKE SIMCOE ENVIRONMENTAL MANAGEMENT STRATEGY IMPLEMENTATION PROGRAM

B. Noels, Lake Simcoe Region Conservation Authority (Chairman)
J. Beaver, Central Region, Ministry of the Environment
R. DesJardine, Central Region, Ministry of Natural Resources (past member)
J. Dobell, Huronia District, Ministry of Natural Resources
D. Green, Resources Management Branch, Ministry of Agriculture and Food (past member)
B. Kemp, Lake Simcoe Region Conservation Authority
J. Kinkead, Watershed Management Section, Ministry of the Environment (past member)
R. MacGregor, Central Region, Ministry of Natural Resources (past member)
N. Moore, Victoria-Haliburton County, Ministry of Agriculture and Food
K. Nicholls, Water Resources Branch, Ministry of the Environment
B. Peterkin, Central Region, Ministry of Natural Resources
T. Rance, Maple District, Ministry of Natural Resources
B. Stone, Northumberland County, Ministry of Agriculture and Food
M. Walters, Lake Simcoe Region Conservation Authority
C. Willox, Lake Simcoe Fisheries Assessment Unit, Ministry of Natural Resources
K. Willson, Watershed Management Section, Ministry of the Environment

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