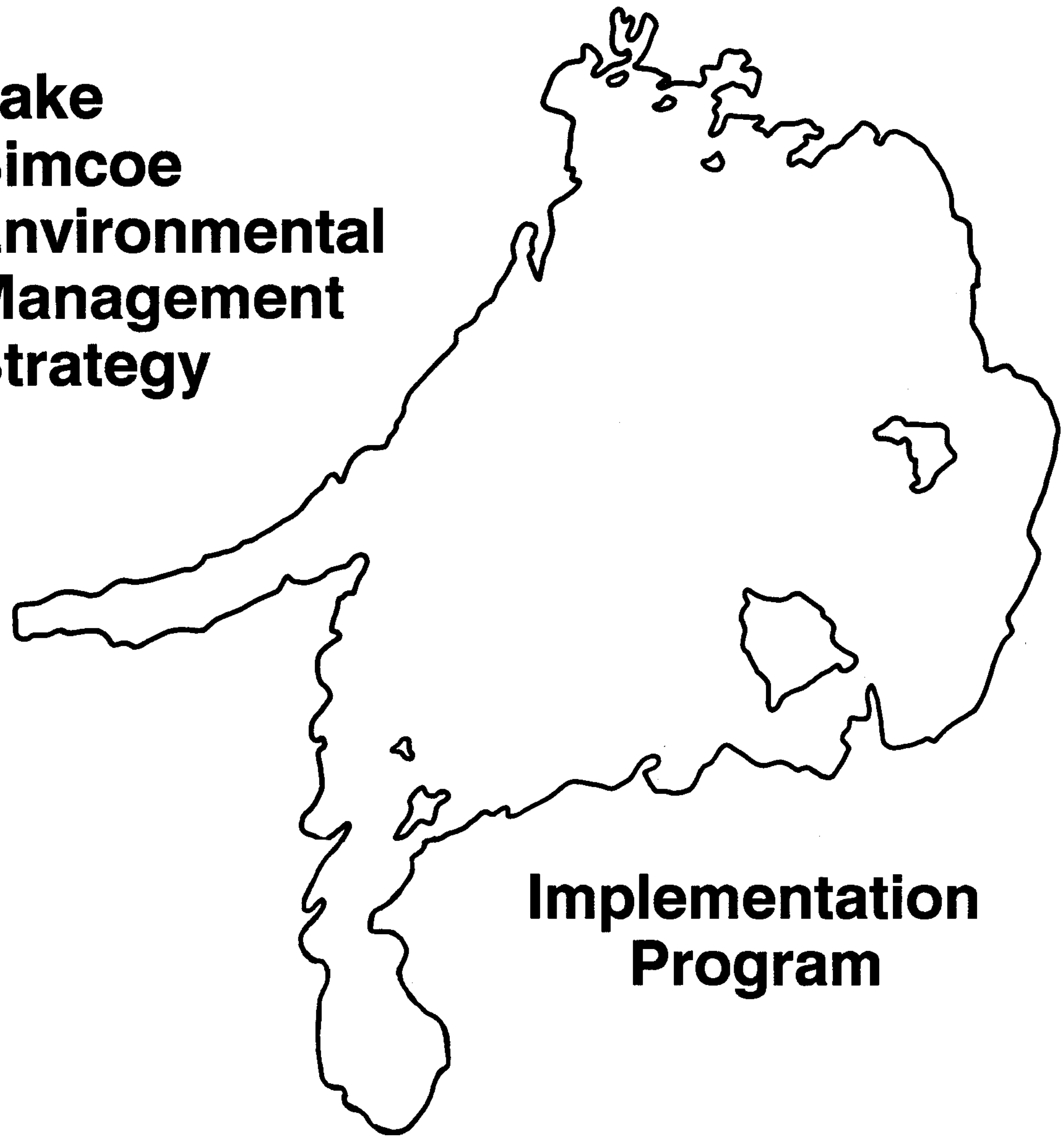
Lake Simcoe Environmental Management Strategy



Implementation Program

Estimated Outflow from Lake Simcoe at Atherly, 1982 - 1986

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LAKE SIMCOE ENVIRONMENTAL MANAGEMENT STRATEGY

LSEMS

ESTIMATED OUTFLOW FROM LAKE SIMCOE AT ATHERLEY 1982 - 1986

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for

The Lake Simcoe Environmental Management Strategy Technical Committee, July, 1987

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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 and Food;
- Ministry of the Environment;
- 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 and Food, Environment 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 1982 to 1986 inclusive.

METHODOLOGY

General

In order to determine the average monthly outflows from Lake Simcoe at Atherley, two methods of analyses were compared. Each analyses 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

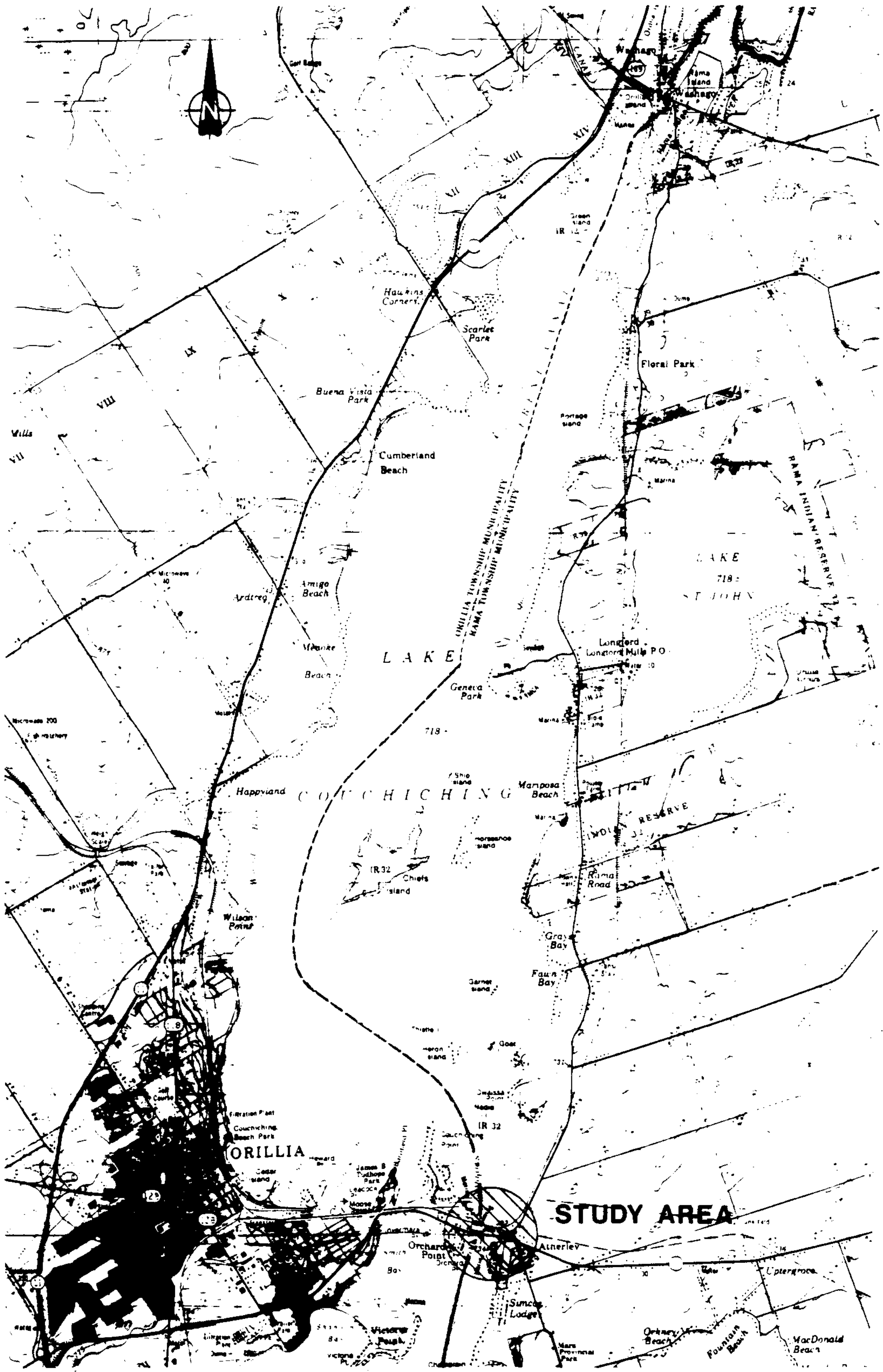
Data

In order to estimate the monthly flows 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. Daily Lake Evaporation Data calculated by the Atmospheric Environment Service from data collected at station 6166418, the Peterborough Airport
4. Monthly water levels recorded on the first of 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 at Lake Simcoe and Lake Couchiching.

Precipitation

The total monthly precipitation recorded at Orillia was considered to be the most representative of the precipitation falling on



Ontario Ministry of the Environment & Lake Simcoe Region Conservation Authority

Location Plan

Monthly Flows at Atherley

Figure 1

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 geological characteristics at which pan evaporation data is monitored. A numerical equation was used (Appendix I) to calculate daily lake evaporation based on measured pan evaporation, total wind mileage, dry bulb temperature, temperature of the water in the pan and the fraction of advected energy used for evaporation. These daily values were summed and divided by the number of days in each month to obtain estimates of mean monthly lake evaporation.

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.

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 found 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.

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:

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

where Q_A = Flow at Atherley (Inlet to Lake Couchiching)
Q_W = Recorded flow at Washago (Outlet of Lake Couchiching)
PRO = Pro-ration factor based on difference in drainage areas between Washago and Atherley
ΔS = 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 II 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. 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 III 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.

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%. In our opinion, the estimated monthly flows at Atherley should be within this accuracy tolerance.

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.

TABLE 1 : METHOD 1

Monthly Flows at Atherley

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						Months						
1982	36.3	43.5	44.4	46.9	17.7	41.2	31.8	25.3	30.0	24.2	15.6	39.3
1983	78.8	64.7	19.9	45.0	75.4	25.5	15.9	15.8	19.9	18.5	12.8	13.7
1984	31.9	55.4	67.3	27.9	23.3	33.0	24.4	24.1	35.9	22.3	8.4	8.0
1985	33.4	58.1	80.7	61.6	33.5	19.7	19.0	26.4	42.1	44.8	53.2	43.4
1986	43.9	34.0	37.3	16.6	21.6	44.5	35.1	46.1	51.6	91.0	70.5	56.7

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

TABLE 2 : METHOD 2

Monthly Flows at Atherley

	Months											
Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1982	36.5	43.2	45.4	48.7	18.0	41.5	31.4	24.5	29.7	23.7	16.7	40.8
1983	78.7	65.9	21.6	45.4	75.9	25.1	15.1	15.5	19.4	19.6	14.1	12.8
1984	32.9	57.2	67.9	28.1	22.8	32.3	24.1	23.6	37.1	23.7	7.4	7.6
1985	35.1	58.6	81.2	61.3	32.8	19.4	18.5	27.5	43.5	44.0	53.0	44.5
1986	44.3	34.3	36.9	15.8	21.3	44.1	36.3	47.5	50.8	91.0	71.8	57.5

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

APPENDIX I

Daily Lake Evaporation in SI Units

E_L = 0.7 (E_p + 0.00642 * P * β_p * (0.37 + 0.00255 * U_p) T)

E_L = computed daily lake evaporation (mm)

E_p = net daily pan loss in mm (i.e. E_p = water added - water removal + rainfall

rainfall for past 24 hrs (mm)

P = station pressure (kilopascal)

P = 101.325 (1-0.00002257 * Z)$^{5.25}$

Z = station elevation in metres

β_p = fraction of advected energy (Class A pan) used for evaporation

β_p = 0.35 + 0.01044 * T_w + 0.000559 * Up for 0<Up<161

T_w = mean water temperature in pan (°C)

Up = daily wind run in km

for 161 $\leq$Up<322

β_p = 0.35 + 0.01044 * T_w + 0.08 + (0.000249 (Up - 161))

for 322 $\leq$Up <483

β_p = 0.35 + 0.01044 * T_w + 0.12 + (0.000124 (Up - 322))

for Up $\geq$483

β_p = 0.35 + 0.01044 * T_w + 0.14 + (0.000062 (Up - 483))

T = mean water temperature (T_w) and mean air temperature (T_a) difference

for $T_w > T_a$: $T = (T_w - T_a)^{0.88}$

for $T_w < T_a$: $T = -((T_a - T_w)^{0.88})$

for $T_h = T_a$: T = 0

$T_w = T_a$

Reference: Kohler, M.A., T.J. Nordenson, and W.E. Fox, "Evaporation from Pans and Lakes", Research Paper No. 38, U.S. Weather Bureau, 1955

APPENDIX II

Equation Used for Method 1

If January, February, or December

$FLOW = Q_W \pm S_C \pm S_S$

$Q_A = Flow\ (0.978) + (\pm S_S)$

Rest of Year

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

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

$FLOW = Q_W + C + S$

$Q_A = FLOW\ (0.978) - S$

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

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

this gives units of (m^3/s)

APPENDIX III

Equation Used for Method 2

If January, February, or December

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

Rest of Year

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

where 0.983 = Drainage area proration factor (Section 2.3.2)

See Appendix II for explanation of terms.

APPENDIX

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

A. Morton, Lake Simcoe Region Conservation Authority (Chairman)

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

J. Kinkead, Watershed Management Branch, Ministry of the Environment

J. Merritt, Director - Central Region, 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

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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