TASK GROUP C (CANADIAN SECTION)
ACTIVITY 3
INTERNATIONAL REFERENCE GROUP
ON
GREAT LAKES
POLLUTION FROM LAND USE ACTIVITIES

POLLUTION FROM URBAN LAND USE IN THE GRAND AND SAUGEEN WATERSHEDS

J. E. O'Neill
Ontario Ministry of the Environment
Toronto, Ontario

January, 1979

3.0 DISCLAIMER

The study discussed in this document was carried out as part of the efforts of the Pollution from Land Use Activities Reference Group, an organization of the International Joint Commission, established under the Canada-U.S. Water Quality Agreement in 1972. Funding was provided through the Ontario Ministry of the Environment. Findings and conclusions are those of the author and do not necessarily represent the views of the Reference Group or its recommendations to the Commission.

4.0 ACKNOWLEDGEMENTS

The assistance of the following in the preparation of the Urban Land Use Technical Report is gratefully acknowledged:

R. Avadhanula
B. Bodo
M. Cameron
R. D'Ippolito
G. Hebbert
R. Hore
W. Leipciger
D. Onn
R. Ostry

The contribution to this report by the Ministry's Laboratory Services Branch is also acknowledged.

5.0 TABLE OF CONTENTS

6.0 LIST OF TABLES

7.0 LIST OF FIGURES

8.0 SUMMARY

Under the IJC-PLUARG program, seven urban study areas in the Grand River and Saugeen River pilot watersheds were studied between 1974 and 1977, namely: Kitchener - Waterloo - Cambridge, Schneider Creek, Montgomery Creek, Guelph, New Hamburg, Durham and Allan Park. The pollutants identified in runoff from these urban areas were: total phosphorus, metals (lead, copper, chromium), chloride, organic chemicals and bacteria. The pollutant problems were greatest (in terms of unit-area loads) in the most urbanized areas at the Schneider Creek, Montgomery Creek, Kitchener - Waterloo - Cambridge and Guelph sites. No significant pollutant contributions were measured in the least urbanized areas at New Hamburg, Durham and Allan Park.

Suspended sediment, in itself, was not found to be a pollutant at any of the urban watershed studies; however, it is an important factor in the in-stream transport of pollutants from urban areas. A majority of the parameters tested in suspended sediment at Schneider Creek, Montgomery Creek and Guelph were at levels considered to be heavily polluted using the U.S. EPA criteria for dredged material. Generally, the poorest sediment quality was observed at Montgomery and Schneider creeks (with respect to metals, PCBs and pesticides). A significant proportion (50-75%) of the metals load and the majority (greater than 85%) of the phosphorus and organic chemical loads were transported in association with suspended sediment.

At Schneider and Montgomery creeks it was estimated that about 90% of the total phosphorus and 96% of the suspended-sediment annual loads occurred as a result of runoff events (melts and rainstorms). The greatest proportion (50-60%) of the total runoff loads occurred during the spring-melt period (February, March and April). Approximately 16-37% of the total runoff load occurred as a result of summer storms during August and September.

The main sources of pollution in urban areas appear to be residential and commercial land, and industrial point sources. A major pathway by which pollutants enter receiving waters in urban areas is thought to be the wash-off of accumulations of airborne-derived contaminants from impervious surfaces. Residential and industrial construction sites, at which the vegetative cover has been removed and areas where on-site protection measures have not been undertaken, appear to be sources of greatly increased sediment and sediment-associated pollutant loads.

9.0 INTRODUCTION

9.1 STUDY OBJECTIVES

As a result of the Great Lakes Water Quality Agreement of April 15, 1972, the International Joint Commission (IJC) established the Pollution from Land Use Activities Reference Group (PLUARG). The Reference Group was requested to conduct studies on the impact of land-use activities and practices on the water quality of the Great Lakes basin and to recommend remedial measures for maintaining or improving Great Lakes' water quality.

The PLUARG study program consisted of four major tasks as outlined in the Reference Group's February 1974 study plan.

> "Task A is devoted to the collection and assessment of management and research information and, in its later stages to the critical analysis of implications of potential recommendations. Task B is first the preparation of a land use inventory, largely from existing data, and, second, the analysis of trends in land use patterns and practices. Task C is the detailed survey of selected watersheds to determine the sources of pollutants, their relative significance and the assessment of the degree of transmission of pollutants to boundary waters. Task D is devoted to obtaining supplementary information on the inputs of materials to the boundary waters, their effect on water quality and their significance in these waters in the future and under alternative management schemes."

As part of the Task C program, several pilot watersheds were chosen in the United States and Canada for intensive study, to cover a wide variety of potential sources of pollution to the boundary waters of the Great Lakes. Using criteria based on climate, geology, soil characteristics and land uses, and information available from completed or ongoing studies, the Grand and Saugeen rivers were chosen as pilot watersheds for intensive study under Task C in Canada (Figure 1). The magnitude and significance of material inputs from the following land uses and practices were identified for study and measurement under the PLUARG activities in Canada:

> agriculture, urban, transportation, sanitary landfills, processed organic-waste disposal, spray irrigation, extractive industries and private-waste disposal.

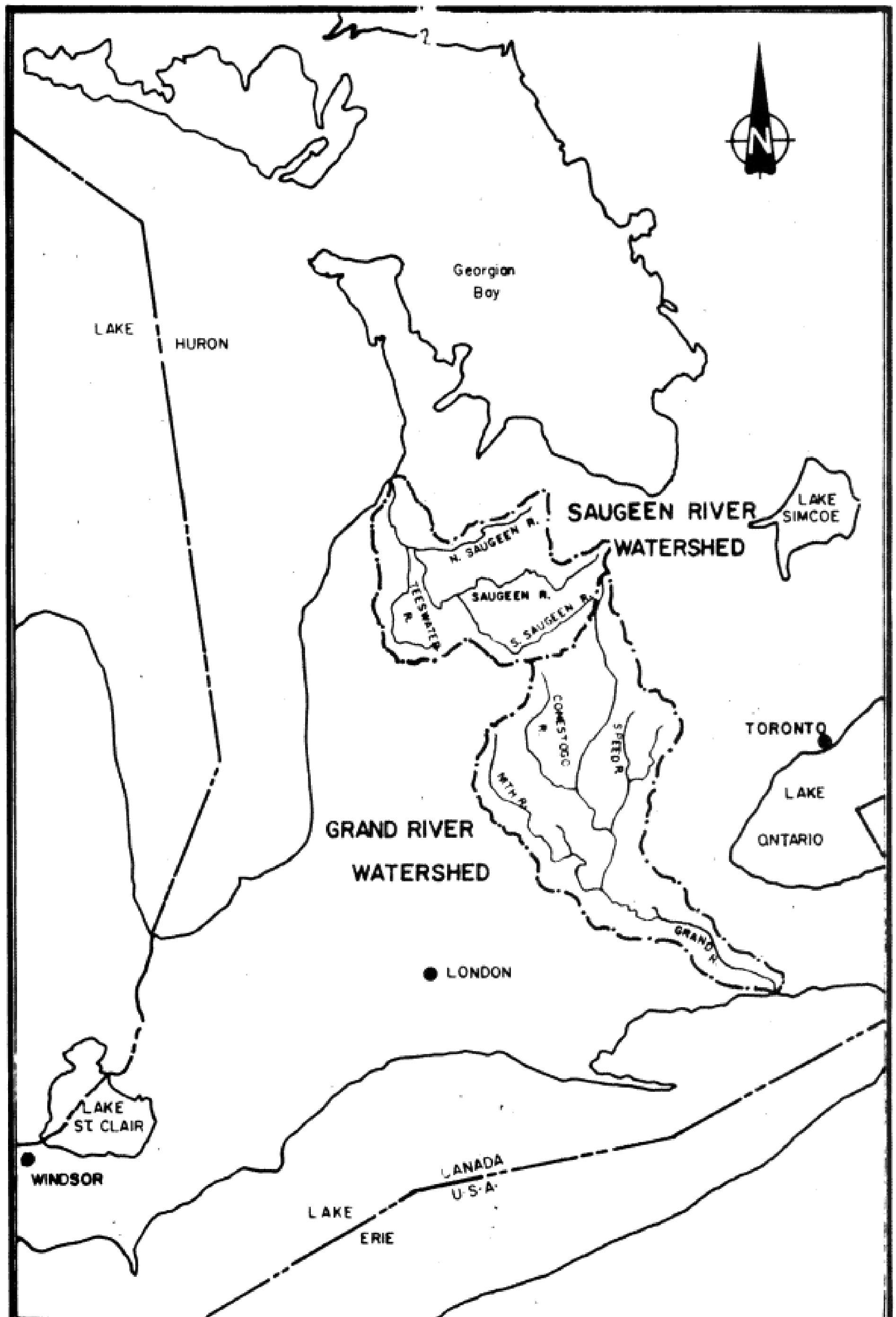

Figure I : LOCATION OF CANADIAN TASK C PILOT WATERSHEDS

Scale : 0 50 100 Kilometres

The Ontario Ministry of the Environment (MOE) was responsible for conducting studies under Activities 1, 3 and 4 of Task C, as described in the MOE "Work Plan" (1976). Activities 1 and 3 concerned the study of specific land uses (e.g. agriculture, urban, etc.), while Activity 4 involved the operation of main-stem monitoring networks in the Grand and Saugeen watersheds, downstream of the land-use studies. The results of the MOE studies are presented in the Summary Pilot Watershed reports for the Grand River (1978) and the Saugeen River (1978). In addition, four technical reports have been prepared: "Urban Land Use", "Rural, Transportation, Extractive and Undisturbed Land Uses", "Waste Disposal", and "Methodology".

This technical report is concerned with the following purposes:

1) the determination of the pollutants derived from urban areas,
2) the estimation of the magnitude of the pollutant contributions from urban areas in terms of unit-area loadings,
3) the determination of the sources of pollutants within urban areas and the evaluation of their relative significance,
4) the investigation of the nature of pollutant transport from urban areas.

The studies referred to in this report were conducted in the Grand and Saugeen pilot watersheds between 1974 and 1977. Except where otherwise noted, 1976 mean annual values are used (concentration, loads, flow, etc.). The reason for this is that the 1976 data record has the best sample collection frequency. Furthermore, the 1974 and 1975 data records were incomplete at some stations due to delays in equipment installation and equipment malfunctions, whereas the 1977 data record ended in June.

9.2 STUDY APPROACH

Six municipalities were selected for initial study in 1974 and 1975, ranging from cities with sanitary and storm sewer systems, through smaller towns with varying types of sewage systems, to small communities with septic tank systems. The urban areas selected in 1974 and 1975 were: Kitchener-Waterloo-Cambridge, Guelph, Simcoe, New Hamburg, Chesley and Priceville. In 1975, the studies at Simcoe, Chesley and Priceville were judged to be unsatisfactory, due to hydrologic measurement problems, and were discontinued. In their place, studies were initiated at Durham, Allan Park, Schneider Creek in Kitchener, and Montgomery Creek in Kitchener.

Monitoring stations were selected upstream and downstream of the urban areas for the purpose of collecting water quality and quantity information required for pollutant loading estimates. The difference between the pollutant load measured at the outlet (downstream) station, and the inflow (upstream) stations was considered to be the net pollutant load from the study area. The load from diffuse urban sources in the study area was then estimated by subtracting measured point sources and other non-urban diffuse sources from the net pollutant load. The unit-area value was then determined by dividing the load from diffuse urban land by the area of urban land in the study area.

The upstream-downstream study approach was not used in the Schneider Creek and Montgomery Creek watersheds in Kitchener, since these watersheds were predominately urban (>60%). A single station was established at the outlet of each study area to measure loads. Except for the lack of an upstream station, the unit-area load values at Schneider Creek and Montgomery Creek were estimated in the same way as for the other study areas. Unit-area load values for the urban subcategories (residential, commercial, industrial and others) were estimated using the "STORM" model (Singer, 1977).

Intensive studies were undertaken at several urban sites to obtain information on sediment quality and transport, and to quantify pollutant loads during runoff events. Point-source studies in the Grand River and Saugeen River watersheds were undertaken to supplement existing Ontario Ministry of the Environment data on effluent quality from municipal and industrial sources.

Land-use inventories were assembled to facilitate the extrapolation of data from the urban study areas to the pilot watersheds using the Canada Land Inventory (CLI) system. This system is based on census data from 1968-1974. Land-use information for the Schneider Creek and Montgomery Creek urban watersheds were updated using black and white aerial photography taken in April 1975.

The land-use data, point-source load estimates, and unit-area loads developed for other land uses (Avadhanula, in press) were used to estimate diffuse loads in the Grand River and the Saugeen River basins. The extrapolation of the urban results, developed in this report, to the pilot watersheds is discussed in the Summary Pilot Watershed reports of the Grand and Saugeen watersheds (Ontario Ministry of the Environment, 1978).

9.3 METHODS

9.3.1 DATA COLLECTION

The data collection program for the urban studies consisted primarily of water quality and quantity measurement for the purposes of pollutant load calculations and unit-area load estimations. Continuous flow data were obtained from streamflow gauging stations constructed for the PLUARG program. Flow data were also obtained from existing Water Survey of Canada gauging stations. Stream water samples were collected by manual and automatic techniques and submitted for chemical analyses. Careful attention was given to sample collection techniques, equipment, sample preservation, and analyses in order to ensure representative data. Details of flow measurement, sample collection, handling and analytical procedures are discussed at greater length in the methodology report (Onn, in press).

Sediment-quality data were collected at the urban monitoring stations in order to provide estimates of sediment-associated loads. Studies involving the chemical and physical characterization of fluvial suspended sediment were carried out at stations with high suspended loads (e.g. Guelph and Montgomery and Schneider creeks in Kitchener). Bed-material samples were collected at all urban study areas. The details of sample collection are contained in the methodology report (Onn, in press).

9.3.2 POINT SOURCE ESTIMATES

Studies were undertaken to supplement the existing effluent-quality information on file with the Ontario Ministry of the Environment for municipal sewage treatment plants and industries in the Grand River and Saugeen River basins ("Evaluation of the Effect of Some Waste Disposal Practices on Great Lakes Water Quality", in press). Estimates of point-source loads derived from these studies were used in the calculation of unit-area loads in urban areas and to assist in the evaluation of the relative significance of sources within urban areas.

9.3.3 IJC LOAD ESTIMATION METHOD

As suggested in the IJC-PLUARG, "Quality Control Handbook For Pilot Watershed Studies,"(March 1977 revision), a stratified, random sampling model employing a ratio estimator was adopted as a suitable method of load calculation. The method provides estimates of both mean and variance and was recommended in order to make broad comparisons of tributary loadings across the entire Great Lakes basin.

9.3.4 SEDCON METHOD OF LOAD ESTIMATION

To provide estimates of monthly loads and to separate total load into 'base' and 'runoff' components, a method of load calculation known as SEDCON was used. This semi-graphical procedure was originally devised by the Water Survey of Canada. Concentrations were plotted directly on the water-level trace of the streamflow record and then subjectively interpolated to approximate a continuous record of concentration. An interpolation procedure was then used to generate mean daily concentrations or loads, as required. This method was applied at the Montgomery Creek and Schneider Creek studies in Kitchener for suspended sediment and total phosphorus.

9.3.5 UNIT-AREA LOAD ESTIMATES

Monitoring data from the urban study areas were used to estimate unit-area loads. The total load was estimated for each monitoring station according to the IJC recommended method. Where there were no inflow monitoring stations (e.g. Schneider Creek and Montgomery Creek studies in Kitchener), then the unit-area load was determined by dividing the total annual load (minus any point-source loads) by the drainage area. Where there were inflow monitoring stations (e.g. Guelph, New Hamburg, Kitchener-Waterloo-Cambridge, Durham and Allan Park), then the sum of the inflow loads and point-source loads were subtracted from the outflow load to give the net load for the study area. The unit-area load was then determined by dividing the net load by the study drainage area.

The unit-area loads for residential, commercial, industrial and other urban land-use subcategories (e.g. open space, parks, cemeteries, etc.) were developed for the Grand River watershed from urban-runoff modelling conducted by the Ontario Ministry of the Environment and the Environmental Protection Service under the Canada/Ontario Agreement, in conjunction with the American Public Works Association and the University of Florida (Singer, 1977). The original values (Sullivan, et al, 1976) were modified by combining sewered and unsewered unit-area loads according to the sewer distribution for the urban study areas in the Grand River basin (87% sewered and 13% unsewered).

9.3.6 ESTIMATES BASED ON SUSPENDED-SEDIMENT CHEMISTRY

It was not possible to obtain load estimates for several parameters using the IJC recommended method or SEDCON procedures because of very poor sampling frequency (e.g. PCBs and pesticides). In these cases loads were estimated on the basis of suspended sediment chemical data. This procedure involved the calculation of the mean-annual pollutant concentration in suspended sediment and the determination of the sediment-associated percentage of the total load. The procedure has the advantage of providing estimates of total, dissolved and sediment-associated loads. The mean-annual pollutant concentration in suspended sediment is derived from suspended-sediment chemical data. The sediment-associated percentage of the total load (S%) is calculated by the equation:

$$S\,\% = \frac{SSCw \bullet PCss}{(SSCw \bullet PCss) + PCw}$$

where SSC_w is the suspended-sediment concentration in water, PCss is the pollutant concentration in suspended sediment, PCw is the pollutant concentration in water.

The sediment-associated load is the product of the mean pollutant concentration measured in the suspended-sediment fraction (PCss) and the annual sediment load as calculated by the IJC method. Knowing the sediment-associated percentage of the total load (5%) and the sediment-associated load it is then possible to calculate the total and dissolved loads.

It appears that the load estimates are fairly reliable when the pollutant concentration in suspended sediment (PCss) does not vary greatly with time. For example, the total phosphorus annual load estimates at Schneider Creek are 7.88 tonnes (sediment chemistry method) versus 7.32 tonnes (IJC method), and at Montgomery Creek the estimates are 0.71 tonnes (sediment chemistry method) versus 0.72 tonnes (IJC method).

9.3.7 IDENTIFICATION OF POLLUTANTS

The determination of what constitutes a stream-water pollutant may not always be a simple task. If a particular substance which does not occur naturally in the environment (e.g. PCBs) is detected in stream water or sediment samples then the stream may be considered to be polluted. On the other hand, if a substance occurs naturally, (e.g. phosphorus) then its presence in the stream environment is, by itself, not proof of pollution. In such cases pollution is usually deemed to have occurred if the concentration of the substance in stream water or sediment exceeds some prescribed level.

The Ministry of the Environment's "Guidelines and Criteria for Water Quality Management in Ontario"* (hereafter referred to as MOE guideline criteria) provides one set of comparison values that may be conveniently used to identify pollutants. The MOE guideline criteria are expressed as permissible or desirable stream-water concentrations for several water uses (e.g. public water supplies, fish and wildlife, etc.) .

The water and sediment quality parameters listed in the "Quality Control Handbook for Pilot Watershed Studies" (1976) were analyzed routinely at all urban studies. Emphasis was placed on those parameters which are thought to contribute to eutrophication and toxicity problems in the Great Lakes. The priority parameters discussed in this report are as follows:

---

* Revised version, "Water Management", in preparation.

WATER	SEDIMENT
Total Phosphorus	Total Phosphorus
Filtered Reactive Phosphorus	Total Nitrogen
Filtered (Nitrate & Nitrite)- Nitrogen	Copper
	Chromium
Total Kjeldahl Nitrogen	Cobalt
Suspended Sediment	Lead
Lead	Zinc
Copper	Mercury
Zinc	Arsenic
Chloride	Nickel
	Organochlorine pesticides
Bacteria	PCBs

9.5 URBAN STUDY AREAS

9.5.1 KITCHENER-WATERLOO-CAMBRIDGE

The Kitchener-Waterloo-Cambridge urban study area is located in the central portion of the Grand River basin (Figure 2). The drainage sector is 64,310 hectares in extent consisting of 68% agricultural, 20% wooded and 12% urban land.

The largest urban centres in the Grand River basin are located in this drainage sector, namely: Kitchener, (population 132,000), Waterloo (50,000) and Cambridge (71,500). During recent years these urban areas have experienced a rapid growth in industry, commerce and housing. The population of the region has increased from 220,000 in 1966 to approximately 291,000 in 1976, a growth rate of approximately 3% per year.

The cities in the study area are serviced by separated storm and sanitary sewer systems. Municipal sewage treatment plants are located on the Grand River at Doon, Laurel Creek at Waterloo, the Speed River at Hespeler and on the Grand River at Galt and at Preston (Figure 2). In addition to these point sources of pollution, there are approximately 40 industries in the area which discharge cooling water (including some process water) directly to the storm sewer system.

The main stem of the Grand River and two major tributaries (the Conestogo River and the Speed River) are influent to the study area. Water quality and quantity monitoring stations were operated (1975 and 1976) at all the inflow stations to the study area, namely: on the Grand River at Winterbourne (UL-21), on the Conestogo River at St. Jacobs (GR-14), on the Speed River at Glenchristie (EX-4), and at the outlet of the study area on the Grand River below Cambridge (UL-22, Figure 2).

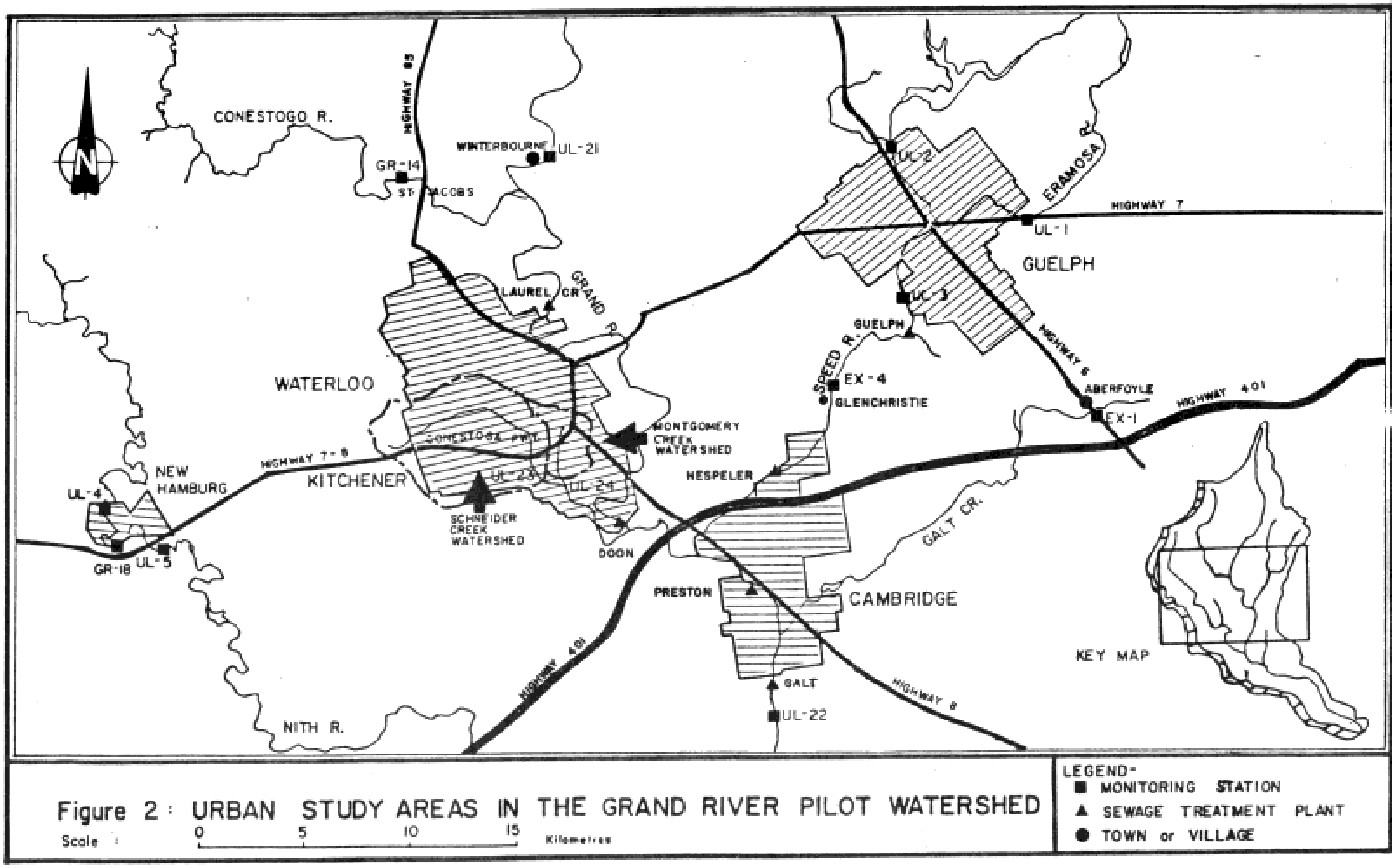

Figure 2 : URBAN STUDY AREAS IN THE GRAND RIVER PILOT WATERSHED

9.5.2 SCHNEIDER CREEK, KITCHENER

The Schneider Creek watershed drains the southwestern portion of the City of Kitchener (Figure 2). The drainage area is 3,577 hectares in extent, consisting of 60% urban, 35% agriculture and 5% wooded land. The main urban land uses in the basin are: residential (primarily single family dwelling) 42%, commercial 5%, industrial 4%, recreational 8%, and transportation 1%. The urban land is situated entirely in the middle and lower portions of the watershed while agriculture and wooded land uses are confined to the headwaters of the basin.

The population of the basin is estimated to be 74,000. Residential and industrial expansion took place during the study period (1976-77) on agricultural land in the basin. During this period approximately 75 hectares of agricultural land (2% of the total basin area) were turned over to urban uses.

The Schneider Creek watershed is serviced by completely separate storm and sanitary sewer systems. There are seven major industries located in the watershed which discharge cooling water (some process water may be included) directly to the storm sewers.

A major storm sewer system outfall is located approximately 50 metres upstream of the outlet monitoring station (UL-23). Sewage is transported through the sanitary sewer system to the Kitchener sewage treatment plant. This plant is located on the Grand River near the Village of Doon about 7 kilometres downstream of the Schneider Creek monitoring station UL-23 (Figure 2).

9.5.3 MONTGOMERY CREEK, KITCHENER

Montgomery Creek, a tributary of Schneider Creek, drains the eastern portion of the City of Kitchener, (Figure 2). This watershed, 958 hectares in extent, is 96% urban and 4% wooded. The main urban uses in the basin are: residential 64%, recreational 13%, commercial 12%, transportation 6% and industrial 1%. The population of the catchment is estimated to be 58,000. Storm and sanitary sewer systems are completely separate in the watershed. There is one major industry which discharges cooling water to the storm sewer system. Several small storm sewers (less than 40 cm diameter) discharge into Montgomery Creek. During the course of the study (1976-77), a large storm sewer was constructed in the basin with the outfall being located about 300 metres upstream of the outlet monitoring station (UL-24). Sanitary sewage is treated at the Kitchener sewage treatment plant located on the Grand River near the Village of Doon about 5 kilometres downstream of UL-24.

9.5.4 GUELPH

The Guelph study area, situated in the east-central part of the Grand River basin, is 4,123 hectares in extent (Figure 2). Land use in the Guelph study area is distributed as follows: urban 67%, agriculture 25% and wooded 8%. The total land use which is in urban land is subdivided as follows: residential 39%, commercial 4%, industrial 11%, recreational 12% and transportation 1%.

With a population of 70,122, Guelph is the third largest city in the Grand River watershed. Residential, commercial and industrial expansion has taken place in recent years along the City's fringes. The average population growth rate for Guelph over the past ten years is 2.5% per year. The City of Guelph has completely separate storm and sanitary sewer systems. Storm sewers outfall at several locations along the Speed and Eramosa rivers in the study area. Possible sources of storm-sewer pollution to the river are approximately 30 major industrial point sources which discharge cooling water (some process water may be included) to the system . The Guelph sewage treatment plant is located approximately 500 metres below the outlet monitoring station (UL-3) on the Speed River.

The Speed River and Eramosa River are influent to the study area (Figure 2). Water quality and quantity monitoring stations were operated at the inflow points on the Speed River (UL-2) and on the Eramosa River (UL-1) as shown in Figure 2.

9.5.5 NEW HAMBURG

The New Hamburg study area is located on the Nith River about 30 kilometres east of Kitchener (Figure 2). The study drainage area is 1,100 hectares in extent. Land use is distributed as follows: agriculture 81 %, urban 14 % and wooded 5 %. The population of the Town of New Hamburg is approximately 3,500.

The Town is serviced by a completely separate storm and sanitary sewer system. There is one major industry in the study area which discharges cooling water directly to the storm sewer system. Sewage from the Town is collected and treated in two sewage lagoons which discharge to the river about 2.5 kilometres downstream of the outlet monitoring station.

Water quality and quantity data were collected on the Nith River at station UL-4, upstream of the Town; at GR-18, at the dam near the centre of the Town and at UL-5, downstream of the Town at the Highway #8 bridge (Figure 2).

9.5.6 DURHAM

The Town of Durham is located in the east-central part of the Saugeen River basin (Figure 3). The study area is 192 hectares in extent consisting of 76% urban and 24% extractive land. The population of the Town is slightly less than 2,500.

Most of the Town is serviced by completely separate storm and sanitary sewer systems. It is estimated that approximately 1% of the sewer systems are combined. There are no major industries in the study area which discharge to the storm sewer system. The Durham sewage treatment plant discharges to the Saugeen River about 1 kilometre downstream of the outlet monitoring station (UL-15).

A water quality and quantity monitoring station (UL-14) was located on the Saugeen River at the Highway #6 bridge at the inflow point of the study area. Water-quality data were collected at the railway bridge downstream of the Town (UL-15, Figure 3).

9.5.7 ALLAN PARK

The community of Allan Park is located on a small tributary of the Saugeen River known as Camp Creek (Figure 3). The study area is only 96 hectares in extent and composed primarily of agricultural (67%) and wooded land (33%). The population of this small community is estimated to be about 50, concentrated in about 15 houses located on the road adjacent to Camp Creek.

Waste disposal in the community of Allan Park is accomplished by means of septic-tank systems. The systems are located from 50 to 150 metres away from the stream. An examination of the stream through the study area revealed no direct connections of septic-tank systems to the watercourse.

Flow records and water-quality data were collected on Camp Creek at the inflow part of the study area (UL-12, Figure 3). Water-quality information was collected on Camp Creek at the outlet monitoring station, UL-13.

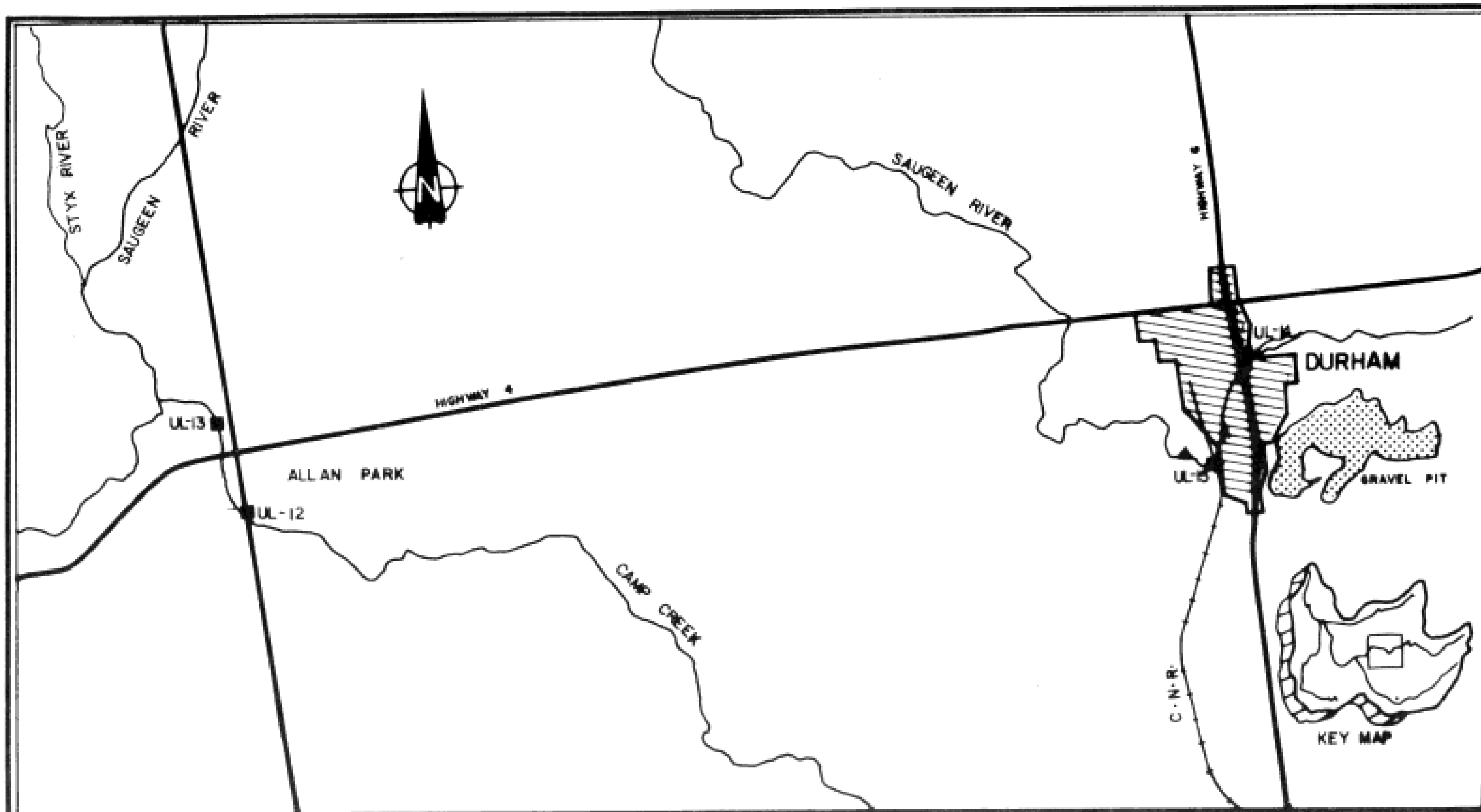

Figure 3: URBAN STUDY AREAS IN THE SAUGEEN RIVER PILOT WATERSHED

Scale: 0 1 2 3 Kilometres

LEGEND-
■ MONITORING STATION
▲ SEWAGE TREATMENT PLANT

10.0 EXPERIMENTAL RESULTS

Tabulated results of the data collection program are summarized in the following tables:

Table 1. 1976 Mean Annual Pollutant Concentrations In Surface Water At Urban Sites

Table 2. 1976 Mean Annual Pollutant Concentrations In Suspended Sediment At Urban Sites

Table 3. 1976 Mean Annual Pollutant Concentrations In Bed Material At Urban Sites

Table 4. A Comparison Of The 1976 Water Quality At Urban And Undisturbed Sites

Table 5. Unit Area Loads For Urban Study Areas

Table 6. Relative Significance Of Sources In The Schneider Creek Watershed

Table 7. Relative Significance Of Sources In The Montgomery Creek Watershed

Table 8. Total, Dissolved, Suspended And Bed Loads At Schneider Creek

Table 9. Total, Dissolved, Suspended And Bed Loads At Montgomery Creek

Table 10. Total, Base, And Runoff Loads At Schneider Creek - Suspended Sediment

Table 11. Total, Base And Runoff Loads At Schneider Creek - Total Phosphorus

Table 12. Total, Base, And Runoff Loads At Montgomery Creek - Suspended Sediment

Table 13. Total, Base And Runoff Loads At Montgomery Creek - Total Phosphorus

TABLE 1: 1976 MEAN ANNUAL POLLUTANT CONCENTRATIONS IN SURFACE WATER*** AT URBAN SITES

PARAMETER	MOE GUIDELINE CRITERIA** Concent-ration mg/L	USE	Kitchener-Waterloo-Cambridge	Schneider Creek	Montgomery Creek	Guelph	New Hamburg	Durham	Allan Park	Aberfoyle
			1976 MEAN ANNUAL CONCENTRATION (mg/L)							
Phosphorus	<0.03	F&W(R)	0.252*	0.278*	0.080*	0.032	0.074*	0.018	0.019	0.010
$F(NO_3+NO_2)$-N	<10.0	PWS	1.914	1.430	2.183	1.044	1.944	0.443	0.906	0.222
Chloride	<250	PWS	35	115	175	26	15	7	8	6
Arsenic	< 0.01	F&W (R)	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001
Chromium	< 0.10	F&W (R)	0.018	0.019	0.009	0.003	0.005	0.002	0.002	0.002
Nickel	<0.025	F&W (R)	0.010	0.006	0.004	0.002	0.004	0.001	0.001	0.002
Cadmium	< 0.002	F&W (R)	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Mercury	< 0.0002	F&W (R)	0.00004	0.00009	0.00014	0.00005	-	0.00007	0.00007	0.00006
Copper	< 0.005	F&W(R)	0.009*	0.025*	0.012*	0.004	0.011*	0.004	0.004	0.004
Lead	< 0.005	F&W(R)	0.011*	0.050*	0.052*	0.006*	0.003	0.003	0.003	0.003
Zinc	< 0.03	F&W(R)	0.044*	0.075*	0.052*	0.028	0.025	0.010	0.005	0.027

A&R aesthetics and recreation
PWS public water supplies
F&W fish and wildlife protection
- no data
* exceeds MOE guideline criteria
** desirable criteria, (R) revised values (See Section 9.3.7)
*** Surface water includes dissolved and suspended sediment components
F $(NO_3 + NO_2)$ -N filtered (Nitrate + Nitrite) -Nitrogen

TABLE 1: Continued

PARAMETER	MOE Guideline Criteria**	USE	1976 MEAN ANNUAL CONCENTRATION (µg/L)							
			Kitchener-Waterloo-Cambridge	Schneider Creek	Montgomery Creek	Guelph	New Hamburg	Durham	Allan Park	Aberfoyle
PCBs	absent	F&W	ND	0.040*	0.024*	0.003*	ND	ND	ND	ND
ΣDDT	absent	F&W	0.0003*	0.0002*	0.0002*	ND	ND	ND	ND	ND
ΣChlordane	absent	F&W	ND	ND	0.0004*	ND	ND	ND	ND	ND
Lindane	absent	F&W	ND	ND	ND	ND	ND	ND	ND	ND
Dieldrin	absent	F&W	0.0004*	0.0002*	0.0010*	0.0003*	ND	ND	ND	ND
Endrin	absent	F&W	ND	0.0005*	0.0003*	ND	ND	ND	ND	ND
ΣBHC	absent	F&W	ND	ND	ND	ND	ND	ND	ND	ND
Heptachlor-Epoxide	absent	F&W	ND	0.0003*	0.0004*	ND	ND	ND	ND	ND
HCB	absent	F&W	ND	ND	ND	ND	ND	ND	ND	ND
Heptachlor	absent	F&W	ND	ND	ND	ND	ND	ND	ND	ND
Aldrin	absent	F&W	ND	ND	ND	ND	ND	ND	ND	ND
Endosulfan	absent	F&W	ND	ND	ND	ND	ND	ND	ND	ND
Mirex	absent	F&W	ND	ND	ND	ND	ND	ND	ND	ND
Atrazine	absent	F&W	0.100*	0.019*	ND	ND	0.06*	ND	ND	ND
Prometryne	absent	F&W	0.030*	ND	ND	ND	ND	ND	ND	ND
Simazine	absent	F&W	0.020*	0.01*	ND	ND	ND	ND	ND	ND
Sencor	absent	F&W	ND	ND	ND	ND	ND	ND	ND	Trace
Bladex	absent	F&W	ND	ND	ND	ND	ND	ND	ND	ND

F&W fish and wildlife protection
* exceeds guideline criteria
** desirable criteria (see Section 9.3.7)

TABLE 2: 1976 MEAN ANNUAL POLLUTANT CONCENTRATIONS IN SUSPENDED SEDIMENT AT URBAN SITES

PARAMETER	1976 MEAN ANNUAL CONCENTRATIONS (µg/g)				
	EPA-heavily polluted criteria	Schneider Creek	Montgomery Creek	Guelph	Aberfoyle
Phosphorus	650	1600*	1310*	1497*	-
Nitrogen	2000	3375*	4360*	5560*	-
Arsenic	8	10.1*	10.4*	7.7	4.2
Chromium	75	91.8*	122*	54	44
Nickel	50	30.5	31.8	24.0	25
Cadmium	6	2.9	15.1*	3.6	2.7
Mercury	1	0.18	0.18	0.24	0.16
Copper	50	165*	121*	83*	52*
Lead	60	495*	937*	401*	-
Zinc	200	697*	849*	1004*	470*
Cobalt	-	10.2	8.4	10.0	5

* exceeds EPA guideline criteria - no data

ND not detected

TABLE 2: Continued

	1976 MEAN ANNUAL CONCENTRATIONS (ng/g)			
PARAMETER **	Schneider Creek	Montgomery Creek	Guelph	Aberfoyle
PCBs	197	596	85	ND
ΣDDT	9.4	35.9	2.0	ND
ΣChlordane	4.4	36.1	5.0	ND
Lindane	2.2	4.3	0.7	ND
Dieldrin	3.9	5.4	1.2	ND
Endrin	0.4	0.6	ND	ND
ΣBHC	3.9	2.5	0.8	ND
Heptachlor Epoxide	1.6	5.4	1.3	ND
HCB	3.0	3.3	ND	ND
Heptachlor	ND	1.4	ND	ND
Aldrin	ND	ND	ND	ND
Endosulfan	ND	ND	ND	ND
Mirex	ND	ND	ND	ND

** No criteria available

TABLE 3: 1976 MEAN ANNUAL POLLUTANT CONCENTRATIONS IN BED MATERIAL AT URBAN SITES

PARAMETER	1976 MEAN ANNUAL CONCENTRATIONS (µg/g)							
	Kitchener-Waterloo-Cambridge	Schneider Creek	Montgomery Creek	Guelph	New Hamburg	Durham	Allan Park	Aberfoyle
Phosphorus	360	290	240	268	240	-	-	290
Nitrogen	500	270	300	440	500	-	-	470
Arsenic	-	2	2	2	4	2	2	2
Chromium	21	9	7	11	10	14	11	5
Nickel	5.8	7	3	7	7	4	3	4
Cadmium	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3
Mercury	0.09	0.03	0.01	0.08	0.02	-	-	0.02
Copper	12	9	8	9	33	45	31	9
Lead	61	24	31	22	140	15	5	15
Zinc	76	44	51	130	69	46	26	136
Cobalt	2	3	3	2	2	3	3	3

- no data
ND not detected

TABLE 3: Continued

PARAMETER	1976 MEAN ANNUAL CONCENTRATIONS (ng/g)							
	Kitchener-Waterloo-Cambridge	Schneider Creek	Montgomery Creek	Guelph	New Hamburg	Durham	Allan Park	Aberfoyle
PCBs	ND	55	ND	35	ND	ND	ND	4
ΣDDT	ND	0.06	ND	0.06	ND	ND	ND	0.2
ΣChlordane	ND	ND	ND	0.5	ND	ND	ND	0.2
Lindane	ND	ND	0.33	0.5	ND	ND	ND	0.2
Dieldrin	ND	ND	ND	1.0	ND	ND	ND	ND
Endrin	ND	ND	ND	ND	ND	ND	ND	ND
ΣBHC	ND	ND	ND	0.33	ND	ND	ND	0.33
Heptathlon Epoxide	ND	ND	ND	ND	ND	ND	ND	ND
HCB	ND	ND	ND	-	ND	ND	ND	ND
Heptachlor	ND	ND	ND	ND	ND	ND	ND	ND
Aldrin	ND	ND	ND	ND	ND	ND	ND	ND
Endosulfan	ND	ND	ND	ND	ND	ND	ND	ND
Mirex	ND	ND	ND	ND	ND	ND	ND	ND

- no data
ND not detected

TABLE 4: A COMPARISON OF THE 1976 WATER QUALITY AT URBAN AND UNDISTURBED SITES

PARAMETER	MEAN ANNUAL CONCENTRATION / CONCENTRATION AT ABERFOYLE*							
	Kitchener-Waterloo-Cambridge	Schneider Creek	Montgomery Creek	Guelph	New Hamburg	Durham	Allan Park	Aberfoyle
Phosphorus	25	28	8	3	7	2	2	1
$F(NO_3+NO_2)$-N	9	6	10	5	9	2	4	1
Chloride	6	21	31	5	3	1	1	1
Arsenic	3	2	2	1	1	1	1	1
Chromium	9	10	5	2	3	1	1	1
Nickel	5	3	2	1	2	1	1	1
Cadmium	3	1	1	1	1	1	1	1
Mercury	1	2	3	1	-	1	1	1
Copper	2	6	3	1	3	1	1	1
Lead	4	17	17	2	1	1	1	1
Zinc	2	3	2	1	1	<1	<1	1

- no data

$F(NO_3+ NO_2)$-N, filtered (Nitrate + Nitrite)-Nitrogen

* The mean annual concentration of each parameter at the urban sites was divided by the corresponding value at the Aberfoyle (undisturbed or background) site.

TABLE 5: UNIT AREA LOADS FOR URBAN STUDY AREAS

PARAMETER	1976 MEAN ANNUAL UNIT-AREA LOAD (kg/ha/yr)**							
	Kitchener-Waterloo-Cambridge	Schneider Creek	Montgomery Creek	Guelph	New Hamburg	Durham	Allan Park	Aberfoyle
Phosphorus	4.756	2.047	0.757	0.299	*	*	*	0.036
$F(NO_2+NO_3)$-N	12.452	6.446	2.995	12.300	*	*	*	0.923
Chloride	282	402	128	751	-	-	*	34
Arsenic	-	0.157	0.021	0.007	-	-	-	-
Chromium	-	0.483	0.083	*	-	-	-	-
Nickel	-	0.225	0.030	0.007	-	-	-	-
Cadmium	0.008	0.101	0.067	*	-	-	-	0.004
Mercury	-	0.001	ND	ND	-	-	-	-
Copper	0.206	0.191	0.053	0.023	0.001	*	*	0.016
Lead	0.250	0.776	0.347	0.459	*	*	*	0.010
Zinc	0.250	0.962	0.336	0.591	0.001	*	*	0.108
Cobalt	-	0.032	0.003	0.004	*	*	*	-
Suspended Sediment	4,576	1,745	415	199	15	*	*	9

$F(NO_2+ NO_3)$-N, filtered (Nitrite + Nitrate)-Nitrogen

* negative unit-area load

ND not detected

\- no data

** Methodology used is outlined in Section 9.3.5.

TABLE 5: Continued

PARAMETER	1976 MEAN ANNUAL UNIT-AREA LOAD (mg/ha/yr)**							
	Kitchener-Waterloo-Cambridge	Schneider Creek	Montgomery Creek	Guelph	New Hamburg	Durham	Allan Park	Aberfoyle
PCBs	-	259	238	3	ND	ND	ND	ND
ΣDDT	-	12.4	14.3	0.1	ND	ND	ND	ND
ΣChlordane	-	5.8	14.4	3.1	ND	ND	ND	ND
Lindane	-	2.9	1.7	0.1	ND	ND	ND	ND
Dieldrin	-	5.1	2.2	0.5	ND	ND	ND	ND
Endrin	-	0.6	0.2	ND	ND	ND	ND	ND
ΣB.C.	-	5.1	1.0	0.1	ND	ND	ND	ND
Heptathlon Epoxide	-	2.0	2.2	0.5	ND	ND	ND	ND
HCB	-	4.0	0.5	ND	ND	ND	ND	ND
Heptathlon	-	ND	0.5	ND	ND	ND	ND	ND
Aldrin	-	ND	ND	ND	ND	ND	ND	ND
Endosulfan	-	ND	ND	ND	ND	ND	ND	ND
Mirex	-	ND	ND	ND	ND	ND	ND	ND

ND not detected
- no data
** Methodology used is outlined in Section 9.3.5

TABLE 6: RELATIVE SIGNIFICANCE OF SOURCES IN THE SCHNEIDER CREEK WATERSHED

	Commercial*	Industrial*	Residential*	Other*	Wooded/idle	Agriculture	Point Sources
AREA (ha)	179	143	1,502	322	179	1,252	-
LAND USE(%)	5	4	42	9**	5	35	
Suspended Sediment							
UAL (kg/ha/yr)	825	1,082	619	14	41	569	-
Estimated load (tonnes)	148	155	930	5	7	712	59
% of total estimated load	7	8	46	<1	<1	35	3
Total Phosphorus							
UAL (kg/ha/yr)	0.917	0.855	0.416	0.180	0.083	0.899	-
Estimated load (tonnes)	0.164	0.122	0.625	0.060	0.015	1.126	1.470
% of total estimated load	5	3	17	2	<1	31	41
Total Nitrogen							
UAL (kg/ha/yr)	11.00	14.00	4.97	0.33	5.15	11.70	-
Estimated load (tonnes)	1.97	2.00	7.46	0.11	0.92	14 .65	27.00
% of total estimated load	4	4	14	<1	2	27	50

* Singer (1977)

** The land-use percentage of 'other' is determined by adding recreational and transportation land-use percentages (Section 9.5.2)

\- no data

UAL Unit-area load.

TABLE 7: RELATIVE SIGNIFICANCE OF SOURCES IN THE MONTGOMERY CREEK WATERSHED

	Commercial*	Industrial*	Residential*	Other*	Wooded/idle	Agriculture	Point Sources
AREA (ha)	115	10	613	182	38	0	
LAND USE (%)	12	1	64	19**	4	0	
Suspended Sediment							
UAL (kg/ha/yr)	825	1,082	619	14	41	569	-
Estimated load (tonnes)	95	11	379	3	2	0	1
% of total estimated load	19	2	77	<1	<1	0	<1
Total Phosphorus							
UAL (kg/ha/yr)	0.917	0.855	0.416	0.180	0.083	0.899	-
Estimated load (tonnes)	0.105	0.009	0.255	0.033	0.003	0	0
% of total estimated load	26	2	63	8	1	0	0
Total Nitrogen							
UAL (kg/ha/yr)	11.00	14.00	4.97	0.33	5.15	11.70	-
Estimated load (tonnes)	1.27	0.14	3.05	0.06	0.20	0	0.40
% of total estimated load	25	3	60	1	4	0	8

* Singer (1977)

** The land-use percentage of 'other' is determined by adding recreational and transportation land-use percentages (Section 9.5.3),

\- no data

UAL Unit-area load.

TABLE 8: TOTAL, DISSOLVED, SUSPENDED AND BED LOADS AT SCHNEIDER CREEK

Parameter	Dissolved Load ***		Suspended Load***		Bed Load		Total Load**
	Tonnes	% of Total Load	Tonnes	% of Total Load	Tonnes	% of Total Load	Tonnes
Sediment	-		6242	90	694	10*	6935
Phosphorus	0.397	5	7.282	92	0.201	3	7.880
Nitrogen	15.576	42	21.067	57	0.187	1	36.829
Chloride	916.0	100	-	-	-	-	-
Arsenic	0.014	80	0.004	20	0.001	<1	0.019
Cadmium	0.186	91	0.018	9	< 0.001	< 1	0.204
Chromium	0.398	41	0.573	59	0.006	<1	0.977
Copper	0.232	50	0.223	49	0.006	1	0.461
Nickel	0.263	57	0.190	41	0.005	2	0.458
Lead	0.773	46	0.907	53	0.017	1	1.697
Zinc	0.586	27	1.585	72	0.031	2	2.202
PCBs	ND	0	0.001230	97	0.000038	3	0.001268
DDT	ND	0	0.000059	100	< 0.000001	0	0.000059
Chlordane	ND	0	0.000027	100	ND	0	0.000027
Lindane	ND	0	0.000014	100	ND	0	0.000014
Dieldrin	ND	0	0.000024	100	ND	0	0.000024
Endrin	ND	0	0.000002	100	ND	0	0.000002
BHC	ND	0	0.000024	100	ND	0	0.000024
Hept. Epoxide	ND	0	0.000010	100	ND	0	0.000010
HCB	ND	0	0.000019	100	ND	0	0.000019
Heptachlor	ND	-	ND	-	ND	-	ND
Aldrin	ND	-	ND	-	ND	-	ND
Endosulfan	ND	-	ND	-	ND	-	ND
Mirex	ND	-	ND	-	ND	-	ND

- no data
ND not detected
* Bed load assumed to be 10% of Total Sediment Load (for other parameters; Bed Load = Bed material Concentration X 694 tonnes)
** Total Load = Dissolved Load + Suspended Load + Bed Load
*** Suspended-Sediment Chemistry (See Section 9.3.6)

TABLE 9: TOTAL, DISSOLVED, SUSPENDED AND BED LOADS AT MONTGOMERY CREEK

Parameter	Dissolved Load ***		Suspended Load***		Bed Load		Total Load**
	Tonnes	% of Total Load	Tonnes	% of Total Load	Tonnes	% of Total Load	Tonnes
Sediment			383	90	43	10*	426
Phosphorus	0.078	11	0.628	88	0.010	1	0.711
Nitrogen	4.620	73	1.670	26	0.013	1	6.303
Chloride	124	100	-	-		-	-
Arsenic	0.016	80	0.004	20	< .001	0	0.020
Cadmium	0.007	88	0.001	12	< .001	0	0.008
Chromium	0.033	41	0.047	59	< .001	0	0.080
Copper	0.025	51	0.024	49	< .001	0	0.049
Nickel	0.017	58	0.012	42	< .001	0	0.029
Lead	0.147	46	0.172	54	0.001	< 1	0.320
Zinc	0.084	27	0.227	73	0.002	< 1	0.313
PCBs	ND	0	0.000228	100	ND	0	0.000228
DDT	ND	0	0.000014	100	ND	0	0.000014
Chlordane	ND	0	0.000014	100	ND	0	0.000014
Lindane	ND	0	0.000002	100	0.000001	0	0.000002
Dieldrin	ND	0	0.000002	100	ND	0	0.000002
Endrin	ND	0	<0.000001	100	ND	0	<0.000001
BHC	ND	0	0.000001	100	ND	0	0.000001
Hept. Epoxide	ND	0	0.000002	100	ND	0	0.000002
HCB	ND	0	0.000001	100	ND	0	0.000001
Aldrin	ND	-	ND	-	ND	-	ND
Endosulfan	ND	-	ND	-	ND	-	ND
Mirex	ND	-	ND	-	ND	-	ND

- no data

ND not detected

* Bed load assumed to be 10% of Total Sediment Load, (for other parameters; Bed Load = Bed material Concentration x 43 tonnes)

** Total Load = Dissolved Load + Suspended Load + Bed Load

*** Suspended-Sediment Chemistry (See Section 9.3.6)

TABLE 10: TOTAL, BASE AND RUNOFF LOADS AT SCHNEIDER CREEK (SEDIMENT)

SURVEY TIME PERIOD		SUSPENDED SEDIMENT			
		RUNOFF			
		LOAD (t)	PERCENTAGE OF MONTHLY TOTAL	BASE LOAD (t)	MONTHLY TOTAL LOAD (t)
1976	July	21.5	94.6	1.2	22.7
	August	392.4	98.6	5.5	397.9
	September	502.7	99.3	3.5	506.2
	October	37.1	89.0	4.6	41.7
	November	7.3	49.9	7.3	14.6
	December	7.0	56.1	5.4	12.4
1977	January	1.3	39.9	1.9	3.2
	February	30.8	90.9	3.1	33.9
	March	1107.1	97.1	32.7	1139.8
	April	243.3	93.6	16.7	260.0
	May	2.4	29.4	5.8	8.2
	June	0.5	57.6	0.4	0.9
Total Annual		2353.4	NA	88.1	2441.5
Monthly Mean		196.1	NA	7.3	203.5

NA - not applicable
t - tonnes

TABLE 11: TOTAL, BASE AND RUNOFF LOADS AT SCHNEIDER CREEK (PHOSPHORUS)

SURVEY TIME PERIOD		TOTAL PHOSPHORUS			
		RUNOFF		BASE LOAD (t)	MONTHLY TOTAL LOAD (t)
		LOAD (t)	PERCENTAGE OF MONTHLY TOTAL		
1976	July	58.4	91.7	5.3	63.7
	August	240.9	96.6	8.5	249.4
	September	457.0	97.2	13.4	470.4
	October	61.7	79.6	15.8	77.5
	November	14.5	39.4	22.3	36.8
	December	18.1	51.4	17.1	35.2
1977	January	0.8	4.6	16.7	17.5
	February	49.2	74.2	17.1	66.3
	March	1349.6	94.5	78.4	1428.0
	April	267.8	89.4	31.8	299.6
	May	6.0	15.9	31.8	37.8
	June	4.4	25.9	12.6	17.0
Total Annual		2528.4	NA	270.8	2799.2
Monthly Mean		210.7	NA	22.6	233.3

NA - not applicable
t - tonnes

TABLE 12: TOTAL, BASE AND RUNOFF LOADS AT MONTGOMERY CREEK (SEDIMENT)

SURVEY TIME PERIOD		SUSPENDED SEDIMENT			
		RUNOFF		BASE LOAD (t)	MONTHLY TOTAL LOAD (t)
		LOAD (t)	PERCENTAGE OF MONTHLY TOTAL		
1976	July	4.6	93.9	0.3	4.9
	August	5.5	94.8	0.3	5.8
	September	14.7	97.4	0.4	15.1
	October	3.9	90.7	0.4	4.3
	November	0.9	56.3	0.7	1.6
	December	1.3	81.3	0.3	1.6
1977	January	0.0	0.0	0.2	0.2
	February	9.6	97.0	0.3	9.9
	March	26.8	97.8	0.6	27.4
	April	27.9	98.2	0.5	28.4
	May	3.8	92.7	0.3	4.1
	June	4.6	93.9	0.3	4.9
Total Annual		103.6	NA	4.6	108.2
Monthly Mean		8.6	NA	0.4	9.0

NA - not applicable
t - tonnes

TABLE 13: TOTAL, BASE AND RUNOFF LOADS AT MONTGOMERY CREEK (PHOSPHORUS)

SURVEY TIME PERIOD		TOTAL PHOSPHORUS			
		RUNOFF		BASE LOAD (t)	MONTHLY TOTAL LOAD (t)
		LOAD (t)	PERCENTAGE OF MONTHLY TOTAL		
1976	July	8.2	86.3	1.3	9.5
	August	10.6	90.6	1.1	11.7
	September	17.9	94.2	1.1	19.0
	October	8.9	86.4	1.14	10.3
	November	3.2	57.1	2.4	5.6
	December	2.8	80.0	0.7	3.5
1977	January	0.0	0.0	0.5	0.5
	February	9.8	91.6	0.9	10.7
	March	58.5	94.4	3.5	62.0
	April	35.7	94.2	2.2	37.9
	May	5.9	79.9	1.5	7.4
	June	8.2	86.3	1.3	9.5
Total Annual		169.7	NA	17.9	187.6
Monthly Mean		14.1	NA	1.5	15.6

NA - not applicable
t - tonnes

11.0 INTERPRETATIONS AND CONCLUSIONS

11.1 CAUSES AND SOURCES OF POLLUTANT CONTRIBUTIONS FROM URBAN AREAS

The major pollutants produced in the urban areas that were studied in the Grand and Saugeen watersheds have been identified using the method described in Section 9.3.7. For example, a parameter was identified as a pollutant at a site if one or more of the following conditions existed:

1) the mean annual concentration at the site exceeded MOE guideline criteria,
2) the mean annual concentration at the site was at least an order of magnitude greater than background levels,
3) a parameter which does not occur naturally was detected at the site.

For the purposes of pollutant identification at the urban areas, the mean annual concentrations of parameters at station EX-1 near Aberfoyle (Figure 2) were assumed to be at background levels and representative of relatively undisturbed land. The watershed above station EX-1 consists of 49% agriculture (primarily low intensity agricultural uses such as pasture) and 51% woodland. In addition, almost the entire length of Galt Creek above EX-1 (i.e. >95%) is bordered by woods.

The mean annual concentrations of pollutants in surface water at Aberfoyle were lower than the larger urban areas. Concentrations at Durham and Allan Park (Table 1) were similar to Aberfoyle, probably as a result of limited urban land use at these sites contributing only small amounts of pollutants. The zinc and nickel levels which are higher at Aberfoyle than at Durham and Allan Park are below MOE guideline criteria. The differences in levels are probably due to variations in soil chemistry in these watersheds.

Although station EX-1 at Aberfoyle represents background conditions for water and suspended-sediment parameters (Tables 1 and 2), it does not appear to represent background conditions for bed-material parameters (Table 3). The reason for this is unclear, but may be due to the complex relationships which exist among pollutant concentrations in sediment and factors such as particle size, organic-matter content and soil chemistry.

The pollutants identified at the urban watersheds are: total phosphorus, chloride, metals, organic chemicals and bacteria. The possible sources of these pollutants are listed below:

1) Streambank erosion and sheet erosion may be greatly accelerated as a result of construction activities and produce suspended sediment and sediment-associated pollutants such as phosphorus and metals.
2) Point sources which discharge directly to a stream or storm sewer system contribute metals, nutrients and bacteria. These sources may be industrial, commercial or residential.
3) Runoff from diffuse sources other than urban (e.g. agriculture) is a source of a variety of pollutants.
4) Runoff from impervious surface areas such as roofs, parking lots, streets and industrial sites directly to a stream or storm sewer system is a source of chloride, bacteria, suspended sediment and associated contaminants such as phosphorus, metals and pesticides. The main sources of contaminants which accumulate on surfaces in the urban environment are:

    a) atmospheric deposition of material from vehicle exhausts, industrial smoke stacks, building heating emissions, dust and open-air incineration of wastes (e.g. lead, PCBs),
    b) improper or careless waste-disposal practices from street litter, animal wastes and careless storage of chemicals on industrial or construction sites (e.g. phosphorus, metals, bacteria),
    c) accidental spillage, ranging from massive spills of contaminants to the slow leakage of automobile fluids onto the streets (e.g. metals, PCBs),
    d) proper application of pesticides and/or disposal of empty pesticide containers,
    e) the application of deicing compounds to road surfaces (e.g. chloride).

11.1.1 PHOSPHORUS

Phosphorus was identified as a pollutant in surface waters (see Table 1) at four urban areas that were studied, namely: Kitchener-Waterloo-Cambridge, Schneider Creek, Montgomery Creek and New Hamburg. The mean annual phosphorus concentrations at these sites exceeded the MOE guideline criterion (Table 1) and ranged from 7 to 28 times greater than the level at the EX-1, Aberfoyle site (Table 2). In addition, phosphorus levels in suspended sediment exceeded the EPA guideline criterion at the three stations for which data were available, namely: Schneider Creek, Montgomery Creek and Guelph (Table 2). Phosphorus levels in bed material were less than the EPA guideline criterion at all stations for which data were available (Table 3).

The possible sources of phosphorus pollution at the urban study areas are: natural streambank and sheet erosion, agriculture, point sources and urban runoff from impervious surfaces.

11.1.2 CHLORIDE

The mean annual concentrations of chloride in surface waters at all the urban study areas were less than the MOE guideline criterion of 250 mg/L; however, the Schneider Creek and Montgomery Creek watersheds were observed to be 21 times and 31 times greater, respectively, than the background levels (Table 2) recorded at Aberfoyle (EX-1). No data were available for chloride levels in sediments.

The source of the elevated chloride levels in the two Kitchener watersheds (Schneider and Montgomery creeks) is believed to be deicing operations (sodium chloride) on a four-lane divided highway (the Conestoga Parkway, Figure 2) which crosses both streams, and the extensive road and highway network in the City of Kitchener.

11.1.3 METALS

The elements arsenic, cadmium, chromium, nickel and mercury were not considered to be pollutants in surface waters or bed materials (as defined in Section 11.1) at any of the urban study areas examined in this report. In all cases the mean annual concentrations of the above-mentioned parameters were less than the MOE or EPA guideline criteria (Tables 1 and 3). In suspended-sediment samples, arsenic, cadmium and chromium exceeded the EPA guideline criteria (Table 2) at the Schneider Creek and Montgomery Creek watersheds.

The metals lead, copper and zinc were identified as pollutants in surface waters and suspended-sediment at several sites (Tables 1 and 2). Of the metals studied, lead appeared to pose the most serious problem. The MOE guideline criterion of 0.005 mg/L for lead in surface waters was exceeded at Kitchener-Waterloo-Cambridge, Schneider Creek, Montgomery Creek and Guelph. The highest lead levels occurred at Schneider and Montgomery creeks which both had levels 17 times greater (Table 4) than those levels measured at Aberfoyle (EX-1). Lead levels exceeded the EPA guideline criterion of 60 ug/g in suspended-sediment at Schneider Creek, Montgomery Creek and Guelph, and in bed material at Kitchener-Waterloo-Cambridge and New Hamburg.

The most probable source of this lead pollution is the atmospheric deposition of particulate lead from automobile exhausts and its subsequent washoff from surfaces (e.g. the Conestoga Parkway) into receiving streams.

Copper exceeded the MOE guideline criterion of 0.005 mg/L in surface waters at four urban areas: Kitchener-Waterloo-Cambridge, Schneider Creek, Montgomery Creek and New Hamburg (Table 1). The copper concentrations at these sites are not thought to pose very serious problems since the levels are similar to the background level recorded at Aberfoyle (Table 4). The mean annual copper concentration at Schneider Creek (the highest measured in this study) was only 6 times that of the background level at station EX-1. The EPA criterion for copper (50 ug/g) was exceeded in suspended sediment at Schneider Creek, Montgomery Creek, Guelph and Aberfoyle (Table 2). The copper levels in bed material were less than 50 µg/g at all stations. It is possible that the copper levels in the Grand and Saugeen watersheds are naturally high and that urban sources do not contribute significant amounts to receiving streams.

Zinc levels exceeded the MOE guideline criterion of 0.030 mg/L in surface waters at Kitchener-Waterloo-Cambridge, Schneider Creek and Montgomery Creek; however, these levels were only two to three times greater than the background level at station EX-1 at Aberfoyle (Table 4). Zinc levels in suspended sediment exceeded the EPA guideline criterion of 200 µg/g at Schneider Creek, Montgomery Creek, Guelph and Aberfoyle; however, zinc concentrations in bed material were less than 200 µg/g at all stations. The sources of zinc in the urban watersheds are probably a combination of natural processes and industrial discharges.

11.1.4 POLYCHLORINATED BIPHENYLS (PCBs)

Industrial chemicals known as PCBs were detected in surface water and suspended-sediment samples at Schneider Creek, Montgomery Creek and Guelph (Tables 1 and 2). The highest levels were found in suspended-sediment samples (Table 2) at Montgomery Creek (596 ppb), followed by Schneider Creek (197 ppb) and Guelph (85 ppb). PCBs were also detected in bed-material samples (Table 3) at Schneider Creek (55 ppb) and Guelph (35 ppb) but not at Montgomery Creek. No reason for this discrepancy has been found thus far. The background station at Aberfoyle contained 4 ppb PCBs in the bed material which supports earlier findings that the occurrence of PCBs in the environment is relatively wide spread (Ontario Ministry of the Environment, 1976).

The source of PCBs is most likely industrial. PCBs have many uses such as in hydraulic fluids, transformer oils, capacitors, plastics and carbonless reproducing paper. The use of PCBs in Ontario has been restricted to closed systems since 1974. The main pathways for PCBs entering the environment are unclear, but are generally thought to be leakage from disposal sites and atmospheric fallout.

11.1.5 ORGANOCHLORINE PESTICIDES

The persistent organochlorine pesticides, DDT, chlordane, dieldrin, endrin and heptachlor expoxide were detected in surface water at some urban sites (Table 1) primarily the Kitchener-Waterloo-Cambridge area, and Schneider and Montgomery creeks. The Guelph, New Hamburg, Durham, Allan Park urban studies and the Aberfoyle undisturbed study area had virtually no pesticides detected (Table 1). Lindane, BHC, HCB, heptachlor, aldrin, endosulfan and mirex were not detected at any of the urban study sites (Table 1).

The pesticides, DDT, chlordane, lindane, dieldrin, BHC and heptachlor epoxide were detected in suspended-sediment samples at Schneider Creek, Montgomery Creek and Guelph (Table 2). Data on suspended-sediment quality were not available for the other urban study areas. Endrin and HCB were detected at Schneider Creek and Montgomery Creek and heptachlor was detected only at Montgomery Creek. The pesticides, aldrin, endosulfan and mirex were not detected at any station. In addition, no organochlorine pesticides were detected in suspended sediment at Aberfoyle.

Fewer organochlorine pesticides were detected in bed material than in suspended sediment (Table 3). DDT, chlordane, lindane, dieldrin and BHC were the only pesticides detected in bed-material samples at the urban stations. These pesticides were detected primarily at Guelph and occasionally at Schneider Creek, Montgomery Creek and Aberfoyle. The pesticides, endrin, heptachlor epoxide, HCB, heptachlor, aldrin, endosulfan and mirex were not detected at any of the sites studied. Furthermore, no organochlorine pesticides were detected in bed-material samples at Kitchener-Waterloo-Cambridge, New Hamburg, Durham and Allan Parks. The occurrence of organochlorine pesticides in urban waters is presumed to be the result of residential, recreational, industrial, utility corridor and agricultural usage to control insects. At the present time the sources of these chemicals cannot be identified more accurately.

11.1.6 TRIAZINES

Atrazine, prometryne and simazine were detected occasionally (30%) in surface waters at the Kitchener-Waterloo-Cambridge, Schneider Creek and Guelph study areas (Table 1). No data were available on the presence of triazines in suspended sediment or bed material samples. The main sources of the triazines are presumed to be agricultural activities in the watersheds. The herbicides, sencor and bladex were not detected in any surface-water samples collected at the urban studies.

11.1.7 BACTERIA

Intensive studies conducted in Schneider Creek during July and August, 1976 by the Ontario Ministry of the Environment (Qureshi, 1978) demonstrated that the bacteriological water quality in this watershed was extremely poor. The population of total coliform, fecal coliform and fecal streptococci were significantly higher than the MOE guideline criteria of 5000/100 mL, 500/100 mL and 50/100 mL, respectively.

The major cause of bacterial contamination in Schneider Creek is thought to be urban runoff which contains contamination from birds, rodents, pets, litter, etc.

11.1.8 SUSPENDED SEDIMENT

Suspended sediment, in itself, was not found to be a pollutant at any of the urban watershed studies; however, it is an important factor in the in-stream transport of pollutants from urban areas. Intensive studies of suspended-sediment chemistry carried out at Schneider Creek, Montgomery Creek, and Guelph showed high levels of sediment-associated pollutants at these urban sites (Table 2).

The United States Environmental Protection Agency's heavily-polluted criteria for the disposal of dredged material (Table 2) was used as a method of pollutant identification in sediment. The presence of substances in sediment which do not occur naturally (e.g. PCBs and pesticides) was also considered to be evidence of pollution. Twenty-four parameters were tested in suspended sediment at the four sites and only six parameters were not found to be pollutants (nickel, mercury, cobalt, aldrin, endosulfan and mirex). The parameters which are considered to be pollutants in suspended sediment at Schneider Creek, Montgomery Creek, Guelph and Aberfoyle are identified in Table 2 (phosphorus, nitrogen, arsenic, chromium, cadmium, copper, lead and zinc).

The suspended-sediment quality at Montgomery Creek was the poorest of the four areas studied, in terms of the number of pollutants identified (18) and the number of maximum concentrations detected (15). The suspended-sediment quality at Schneider Creek and Guelph was also poor. Sixteen pollutants and four maximum concentrations were measured at Schneider Creek compared to 12 pollutants and three maximum concentrations at Guelph. The sediment quality at the undisturbed site (EX-1, at Aberfoyle) was very good. Only two parameters, (i.e. copper and zinc) were identified as pollutants (Table 2).

The main sources of the high suspended-sediment load at Schneider Creek are thought to be channel-bed scour and erosion from construction sites. Stream-bank erosion and erosion from relatively undisturbed land (lawns, parks, golf courses, etc.) do not appear to be significant sources of sediment in the watershed. Field reconnaissance and analysis of air photographs of the Schneider Creek watershed did not show any areas of active streambank erosion; however, most of the streambanks in the basin have been stabilized by concrete or gabion baskets. Evidence of channel-bed scouring in Schneider Creek was observed at monitoring station UL-23 during the course of the study. A stage-discharge relationship was difficult to develop at this site as a result of the changing stream-bed profile. After extreme runoff events, the intake pipes of the stage recorder and the automatic sampler were often buried by new bed deposits. Much of the sediment load (and associated pollutants) measured at this site may be transported during high-flow events.

Erosion from construction sites was probably a significant source of sediment within the watershed although its relative significance is unknown at this time. Residential and industrial construction occurred on approximately 75 hectares of former agricultural land in the headwater area of the basin and also in the southwestern part of the watershed. Construction sites which did not employ sediment retention measures (e.g. sediment basins, mulches) when the surface vegetative cover was removed were observed to produce high sediment loads in streams during rainfall events. Additional studies will be required to quantify the pollutant loads from construction sites.

Erosion from relatively undisturbed land no doubt occurs to a limited extent, but it is not considered to be a major source of sediment in the basin. Similarly, runoff from impervious surfaces is not a major source of sediment; however, the sediment from streets, roofs, parking lots, etc. may be highly contaminated from a variety of urban sources such as litter, vehicle emissions and animal wastes.

11.1.9 NITROGEN

Nitrogen is not considered to be a major pollutant in surface waters or bed materials at any of the urban study areas. The mean annual filtered (nitrate plus nitrite) - nitrogen concentrations were less than the MOE guideline criterion for all seven study areas (Table 1). Montgomery Creek, the Kitchener-Waterloo-Cambridge area and Schneider Creek exhibited the greatest mean annual levels, namely: 10, 9 and 6 times greater, respectively, than background levels at the EX-1, Aberfoyle site (Table 4). Nitrogen levels in suspended sediment (Table 2), exceeded the EPA criterion of 2000 µg/g at Schneider Creek, Montgomery Creek and Guelph (data unavailable for other studies). The main source of nitrogen in these urban areas is thought to be the degradation of organic debris contained in urban runoff.

11.2 EXTENT OF POLLUTANT CONTRIBUTIONS IN UNIT AREA LOADINGS FROM URBAN LAND DRAINAGE

The extent of pollutant contribution from a specific land use or practice is dependent on the proportion of land in that particular use or practice and the magnitude of the input (unit-area load) during a given period of time. In general, if the proportion of a particular land use in any watershed is large, the contribution from that land use will be relatively large even if the unit-area load is small. Unit-area loads can also assist in determining which land-uses or practices are suitable for cost-effective control measures.

Annual unit-area loads for those parameters which were considered to be important by PLUARG, in terms of the impairment of Great Lakes' water quality, were tabulated for the seven, urban study areas and are presented in Table 5. The annual unit-area loads for Aberfoyle are included for comparative purposes. The unit-area load estimates were derived by the method described in Section 9.3.5. At New Hamburg, Durham and Allan Park, the subtraction of inflow loads and loads due to point sources, etc. from the outflow load frequently resulted in net loads that were negative (e.g. the deposition of pollutants may have occurred between the inflow and outflow stations). In the cases where negative net loads were obtained, unit-area loads were not recorded in Table 5.

The most notable feature of the data in Table 5 is the lack of pollutant contributions from small urban watersheds (i.e. New Hamburg, Durham and Allan Park) which suggests that the size of an urban area is an important factor in pollutant contribution. Furthermore, the unit-area loads of total phosphorus range from 8 to 132 times greater at large urban areas (i.e. cities the size of Guelph and larger) than at Aberfoyle which is considered to represent background conditions. The same pattern is observed for the other parameters.

Since the PLUARG monitoring data were insufficient to derive unit-area loads for specific subcategories of urban land use (e.g. commercial, industrial, residential and other), estimates from other, non - PLUARG studies (Singer, 1977) are presented below for sediment and nutrient parameters. Values for an "urban-general" category were derived, where possible from PLUARG data by calculating the arithmetic average of the unit-area loads in Table 5 and are included below for comparative purposes.

	Unit-Area Loads (kg/ha/yr)				
	Urban-General *	Commercial**	Industrial**	Residential**	Other**
suspended sediment:	993	825	1,082	619	14
total phosphorus:	1.123	0.917	0.855	0.416	0.180
total nitrogen:	no data	11.0	14.0	5.0	0.3

* PLUARG data

** Singer, 1977

On the basis of the above unit-area load data, industrial and commercial land uses appear to be the major diffuse sources of sediment and nutrients in urban areas. Residential and other urban land uses appear to be secondary sources. The unit-area loads for suspended sediment and total phosphorus derived from the PLUARG monitoring data for the "urban-general" category are in general agreement with Singer's results (1977).

11.3 RELATIVE SIGNIFICANCE OF SOURCES WITHIN URBAN AREAS

An attempt was made to evaluate the relative significance of the sources of suspended sediment, total phosphorus, and total nitrogen in the Schneider Creek and Montgomery Creek watersheds by ranking the loads from these areas. These watersheds were considered to be representative of urban land in that the dominant land use in each watershed is urban (i.e. 60% and 96%).

The mean annual loads from diffuse sources in Tables 6 and 7 were estimated by multiplying the unit-area load for a particular land use by the area devoted to that land use. The unit-area load values for commercial, industrial, residential and other land-use categories were obtained from

Singer (1977). Unit-area loads for agriculture and wooded/idle land-uses were obtained from Avadhanula (in press). Estimates of loads from point sources were obtained from the "waste disposal" technical report (in press). In the absence of quantitative data on streambank erosion in the urban study areas, estimates of the sediment yield from streambank erosion were not included separately in Tables 6 and 7. The reported values for the other land uses in these tables are assumed to include the effects of streambank erosion.

On the basis of the estimates contained in tables 6 and 7 the following ranking of major sources (those which account for more than 10% of the total estimated load) within the two Kitchener study watersheds is presented below:

<u>Schneider Creek</u>

suspended sediment:	residential, agriculture
total phosphorus:	point sources, agriculture, residential
total nitrogen:	point sources, agriculture, residential

<u>Montgomery Creek</u>

suspended sediment:	residential, commercial
total phosphorus:	residential, commercial
total nitrogen:	residential, commercial

The percentages of the total estimated loads presented in tables 6 and 7 indicated that the major source of suspended sediment in the Schneider Creek and Montgomery Creek watersheds was residential land use. This source accounted for 46% and 77%, respectively, of the estimated, annual suspended-sediment load. Secondary sources were: agriculture in Schneider Creek and commercial in Montgomery Creek.

The sources of the nutrient parameters, i.e. total phosphorus and total nitrogen, are different in the Schneider Creek and Montgomery Creek watersheds. In the Schneider Creek watershed, point sources are the major contributors to the estimated, annual nutrient loads (total phosphorus 41% and total nitrogen 50%). Agriculture and residential land are secondary sources of nutrients. In the Montgomery Creek watershed, residential land is the major contributor to the estimated, annual nutrient load (total phosphorus 63% and total nitrogen 60%). Commercial land is a secondary source of nutrients.

The differences in the estimated contributions from sources in Schneider and Montgomery creeks are primarily due to differences in land use in these watersheds. For example, there are seven industrial point sources in the Schneider Creek watershed compared to one in the Montgomery Creek watershed. In addition, agriculture occupies 35% of the Schneider Creek watershed but is absent in the Montgomery Creek watershed and, as a result, agricultural runoff is a significant source only in the Schneider Creek basin.

The annual, suspended-sediment, total-phosphorus and total-nitrogen loads, which were estimated using unit-area loads, were compared to the 1976 measured loads. The estimated loads, contained in tables 6 and 7, and the 1976 measured loads, contained in tables 8 and 9, are presented below. The 1976 measured loads were derived by summing the dissolved loads and the suspended loads in tables 8 and 9, and do not include bed load. The methodology for deriving suspended and dissolved loads is discussed in Section 9.3.6.

	Schneider Creek		Montgomery Creek	
	estimated	measured	estimated	measured
suspended sediment load (tonnes):	2,016	6,242	491	383
total phosphorus load (tonnes):	3.582	7.679	0.405	0.706
total nitrogen load (tonnes):	54.11	36.64	5.12	6.29

Assuming that the measured loads are reliable, the possible reasons for the difference in the estimations of loads are: a failure to consider the specific contributions from streambank erosion, errors in the estimation of point source loads and errors in the determination of unit-area loads of the urban subcategories.

11.4 TRANSMISSION OF POLLUTANTS FROM SOURCE AREAS TO BOUNDARY WATERS

An understanding of the in-stream transport of pollutants is essential if the importance of upland source areas to the degradation of boundary waters is to be assessed. PLUARG technical committees have recognized that deficiencies in existing land-use loading models and process-response studies exist in linking water quality at upstream source areas to river-mouth loadings. Although the principles of sediment transport mechanics are well known, the downstream movement and modification of sediment-associated pollutants from upstream source areas is poorly understood.

In-stream chemical and biological processes operating in addition to the physical processes tend to confound a clear understanding of the pollutant transport phenomena. As an example, phytoplankton growth converts nutrients from soluble to solid form which may be released again when the biomass decays. Other processes such as chemical precipitation under favourable conditions or colloidal coalescence may also occur.

11.4.1 PHYSICAL PROCESSES

Pollutants may be transported in solution or in association with particulate matter (i.e. suspended and bed load). Dissolved materials and clay-sized particles are rapidly transported through the watershed system and will have an immediate impact on boundary waters. A 100% in-stream delivery for dissolved and clay-sized particles seems reasonable both on an annual and long-term (50-year) delivery basis. In the Grand River system for example, the time of travel from the headwaters to the mouth of the river, excluding reservoir-residence time, is estimated to be in the order of a week at low-flow conditions (i.e. 10 cubic meters per second at the mouth).

The coarse particulates (silt and sand) are transported intermittently by suspension and bed-load movement. Flow-regulation structures and stream reaches with low stream velocity may temporarily trap coarse sediment. Subsequent high flows often result in remobilization of the coarser materials.

In the absence of detailed information on the in-stream transport of coarse sediment and sediment-associated pollutants, a technical committee of the PLUARG assumed that the long-term (50-year) delivery of material to the lakes is 100%. This implies that urban areas regardless of their distance from the Great Lakes will have an impact on Great Lakes' water quality. On an annual basis, however, monitoring data in the Grand and Saugeen watersheds demonstrate that the in-stream delivery of contaminants can be extremely variable and substantially less than 100% in some areas, especially for sediment-associated contaminants ("Grand River Summary Pilot Watershed Report", Ontario Ministry of the Environment, 1978).

Water quality, suspended-sediment and bed-material samples were analyzed at the two Kitchener sites (Schneider Creek and Montgomery Creek) in an attempt to identify the primary method of in-stream transport of the major urban pollutants. Total annual loads (1976) were calculated from water-quality monitoring data for each parameter and then the dissolved, suspended-sediment associated and bed-load associated components (tables 8 and 9) were estimated using sediment chemistry data (Section 9.3.6). The mechanisms of pollutant transport derived in tables 8 and 9 are summarized below:

Primarily Dissolved State	Primarily Suspended Sediment Phase
chloride (100%)	phosphorus (88-92%)
cadmium 88-91%)	PCBs (97-100%)
arsenic (80%)	organochlorine pesticides (100%)
nitrogen (42-73%)	zinc (72-73%)
nickel (57-58%)	chromium (59%)
copper (50-51%)	lead (53-54%)

11.4.1.1 Dissolved State

Chloride is transported in the dissolved state. The parameters arsenic and cadmium were found to be transported mainly in solution as well (80-91%). Nitrogen and the metals, nickel and copper, appear to be transported mainly in solution, but to a lesser extent (42-73%) than the parameters mentioned above. The secondary mechanism of transport of these parameters is in association with suspended sediment.

11.4.1.2 Suspended Sediment Phase

Polychlorinated biphenyls and organochlorine pesticides were observed to be transported almost exclusively in association with suspended sediment (97-100%) Similarly, the majority of the phosphorus and zinc loads were carried by suspended sediment (88-92% and 72-73%, respectively). Chromium and lead were primarily transported in the sediment phase as well (59% and 53-54%, respectively).

11.4.1.3 Bed Material

The parameters which exhibit strong affinities for suspended sediment were also found in bed materials but at lower concentrations. Since the discharge of bed material (bed load) is estimated to be only about 10% of the total sediment load, the quantity of pollutants delivered by bed load constitutes a very small percentage of the total pollutant load. For example, it is estimated that bed load accounts for only 3% of the total phosphorus load from Schneider Creek.

11.4.2 BIOCHEMICAL PROCESSES

Studies of the biochemical processes involved in pollutant transport were not conducted at any of the urban studies; however, an investigation was conducted in a rural watershed in the Grand River above the confluence of the Conestogo River (Figure 1). This study was undertaken by the Ontario Ministry of the Environment as part of an ongoing Ministry program for the "Grand River Basin Water Management Study". A mass-balance approach was utilized in assessing the data collected for the above-mentioned study. A significant reduction in phosphorus over the small river reach suggests that the entire attached plant community within the river basin can act to assimilate considerable quantities of nutrients daily throughout the late spring and summer. The nutrients will be released when the plants die in the late summer and fall.

11.5 TEMPORAL VARIABILITY OF IN-STREAM POLLUTANT TRANSPORT

PLUARG monitoring data at Schneider and Montgomery creeks indicated that the bulk of the pollutant loads were transported during runoff events. The integration method (SEDCON) described in Section 9.3.4 was used to estimate total, base and runoff loads of suspended sediment and phosphorus at Schneider Creek (Tables 10 and 11) and Montgomery Creek (Tables 12 and 13). The base load is considered to be the load which occurs as a result of baseflow conditions. The runoff load is considered to be the load due to surface-runoff conditions (overland flow during storm "events" and melt "events"). The total load is equal to the sum of the base load and the runoff load.

At Schneider and Montgomery creeks it was estimated that 90-91% of the total phosphorus load and 96% of the suspended-sediment load during the period July 1976 to June 1977 occurred as a result of runoff events. Furthermore, the greatest proportion (50-66%) of the total runoff load occurred during the spring-melt period (February, March and April). Approximately 16-37% of the total load occurred as a result of summer storms during August and September. This marked seasonal dependency of pollutant transport at Schneider Creek and Montgomery Creek is illustrated in figures 4,5,6 and 7 for the total phosphorus and suspended-sediment parameters.

The monitoring sites at Schneider and Montgomery creeks were equipped with automatic samplers in an effort to obtain an event-oriented sample record. As a result, several storm events were sampled intensively and graphs constructed depicting concentration versus time and load versus time. A storm hydrograph, concentrations, and loads for total phosphorus and suspended sediment are plotted in Figure 8 for a medium-flow event which occurred at Montgomery Creek. The water quality and quantity record for this event is one of the best obtained during the study.

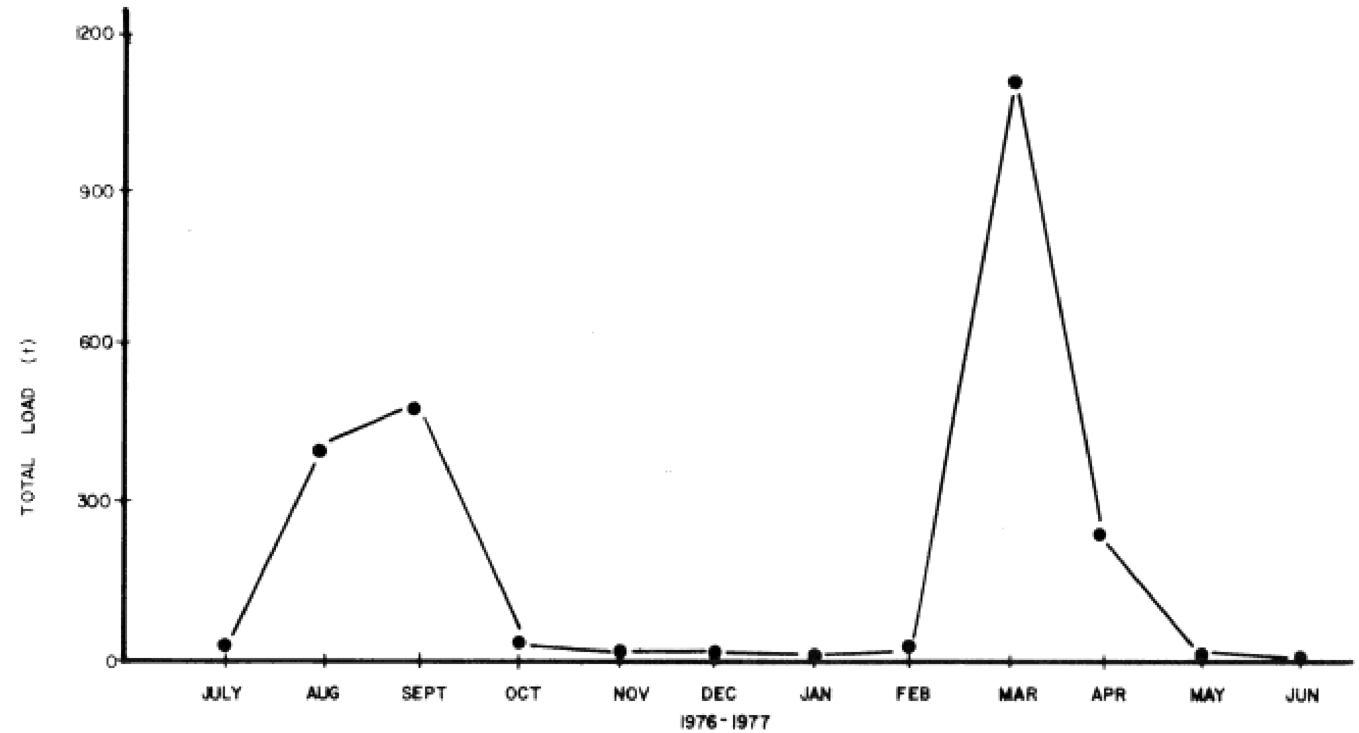

Figure 4: MONTHLY SUSPENDED SEDIMENT LOAD AT SCHNEIDER CREEK, KITCHENER

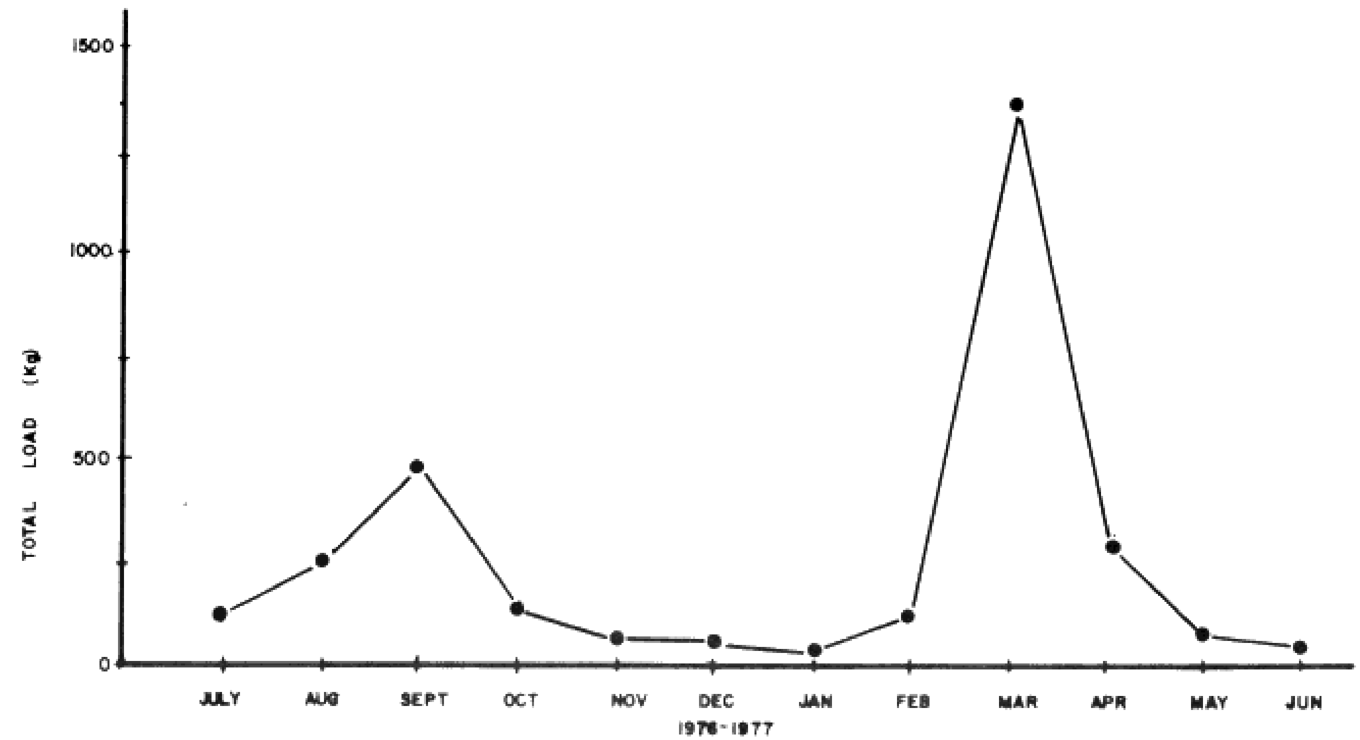

Figure 5 · MONTHLY TOTAL PHOSPHORUS LOAD AT SCHNEIDER CREEK, KITCHENER

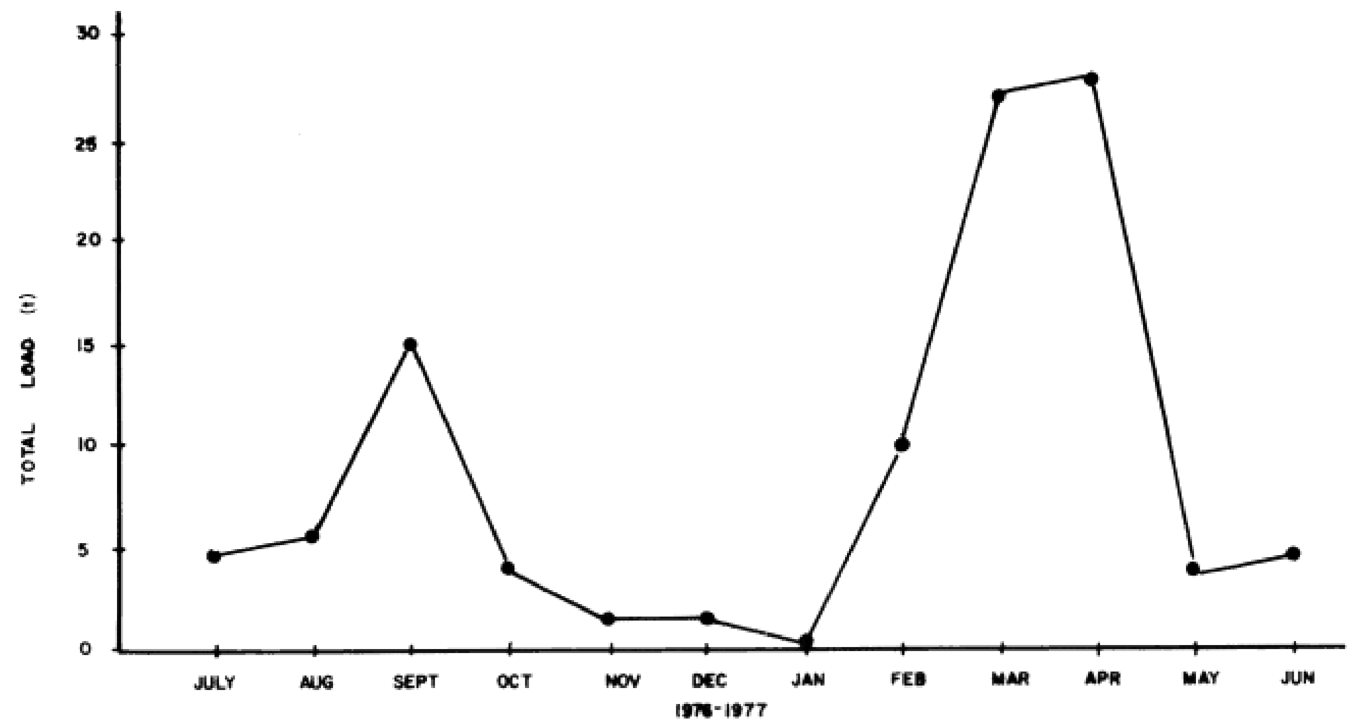

Figure 6 : MONTHLY SUSPENDED SEDIMENT LOAD AT MONTGOMERY CREEK, KITCHENER

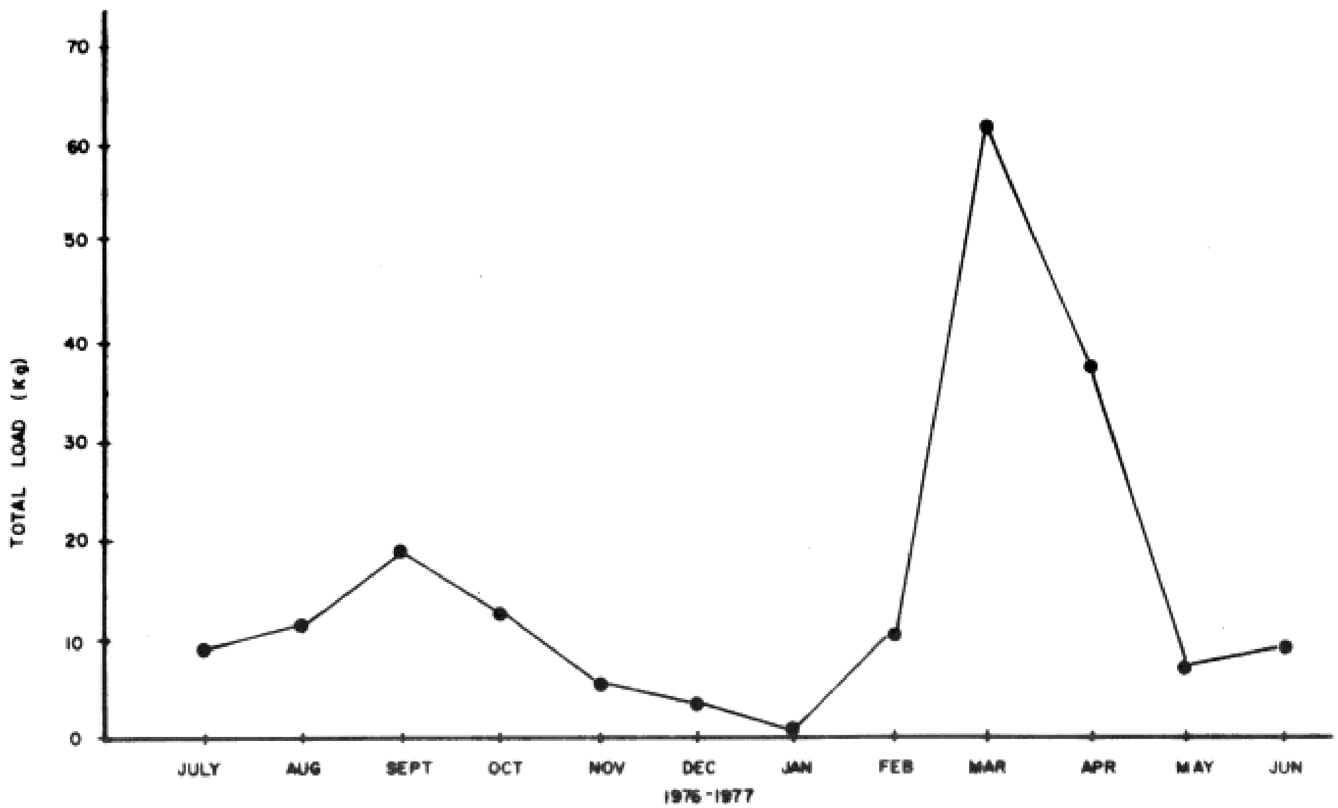

Figure 7: MONTHLY TOTAL PHOSPHORUS LOAD AT MONTGOMERY CREEK, KITCHENER

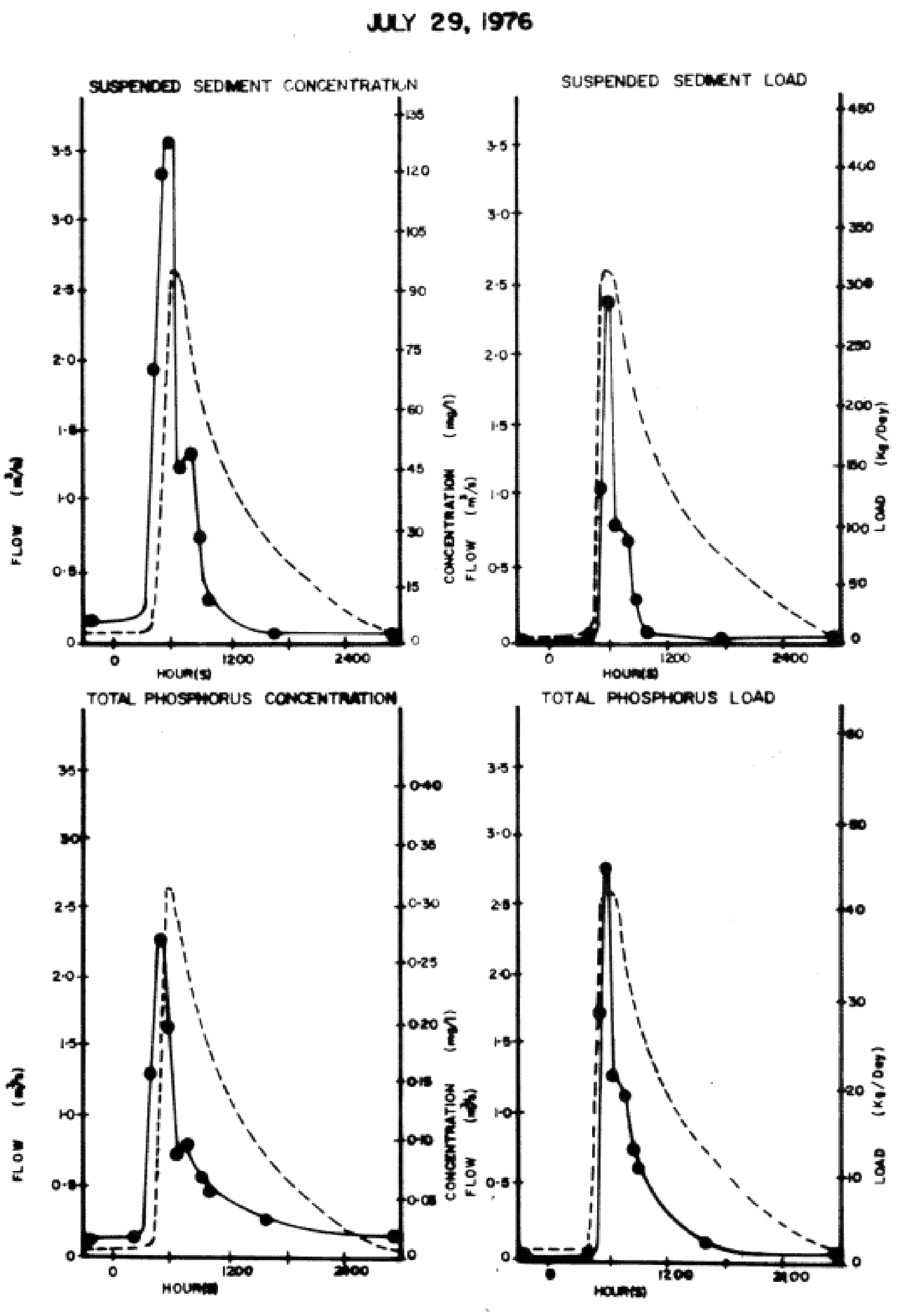

Figure 8 : TOTAL PHOSPHORUS AND SUSPENDED SEDIMENT EVENT LOADS AT MONTGOMERY CREEK, KITCHENER

LEGEND:
- ● SAMPLE POINT
- ---FLOW

Other than differences in magnitude, there are essentially no differences in the characteristics of the concentration graphs of the two parameters presented, (i.e. total phosphorus and suspended sediment, Figure 8). A rapid rise in concentration occurs commensurate with the initial hydrograph rise. The concentration curves peak prior to the flow peaks and then recede very quickly. Small secondary peaks in the concentration curves occur during recession. The secondary peaks may be due to contributions from slower responding branches of the storm-sewer system. The load graphs for total phosphorus and suspended sediment show an initial flush of material which quickly returns to base level in a few hours. This storm event, which is typical of the many that occurred in the watershed during the period of study, supports the findings presented earlier, that approximately 90% of the annual load occurs during runoff events.

11.6 DATA TRANSFERABILITY

Extrapolation of the urban watershed data to unmonitored urban areas in the PLUARG pilot watersheds is possible, provided the characteristics of the unmonitored areas are similar to those in the study areas. The inherent variability of hydrological characteristics (streamflow and precipitation) and the lack of data on sources within urban areas (e.g. streambank erosion, runoff from streets, etc.) are problems for extrapolation.

The unit-area load values derived from PLUARG monitoring data at the urban sites (Table 5) can be used in conjunction with land-use data to estimate total, annual loads for urban areas with characteristics similar to the areas studied (e.g. size, population, etc.). The unit-area loads in this report have been developed on a one-year basis, mainly 1976. Any use of these values for extrapolation should consider the representativeness of the year in terms of flow, precipitation, land-use practices, etc. In addition, the sediment-quality data contained in this report (Tables 3 and 4) have not been fully assessed in terms of differences in particle size, organic matter content, temporal variability (seasonal sampling), etc. Any attempt to estimate pollutant levels in suspended sediment or bed material at other urban areas using the data contained in this report should consider these limitations.

11.7 CONCLUSIONS

The main findings of the urban studies are summarized below.

1. The major pollutants produced from urban areas are: phosphorus, chloride, metals, organic chemicals and bacteria.

2. A significant proportion (50-75%) of the metals load and the majority (greater than 85%) of the phosphorus and organic chemicals loads are transported by suspended sediment.

3. More than 90% of the suspended-sediment load (and sediment-associated load) occurs during surface runoff conditions (i.e. rain storms and melts).

4. The majority of the surface runoff load (50-66%) occurs during February, March and April (i.e. the spring-melt period).

5. The results indicate that the most probable sources of pollutants in urban areas are:

phosphorus	-	runoff of accumulated contaminants from impervious surfaces (commercial, industrial, residential and transportation)
	-	point sources discharged to receiving waters
chloride	-	deicing salt used for highways and roads
metals	-	washoff of accumulated contaminants from impervious surfaces (e.g. lead from automobile exhausts)
	-	industrial point sources discharged to receiving waters.

12.0 RECOMMENDATIONS

12.1 FEASIBLE REMEDIAL MEASURES

A catalogue of remedial measures to control non-point sources of water pollution was prepared under Task A, (IJC, 1977). On the basis of this catalogue and the findings contained in this report, it is suggested that the following remedial measures could be used to reduce pollutant loadings at urban areas such as Schneider Creek, Montgomery Creek, and Guelph:

a) the use of mulches, sedimentation ponds, etc. to reduce sediment loads due to erosion from urban construction sites;

b) the reduction of atmospheric emissions which subsequently accumulate on surfaces and are washed off during rain storm or melt events (e.g. the use of non-leaded gasoline);

c) the reduction of the use of sodium chloride as a deicing agent on highways to lower chloride loads from urban areas;

d) the initiation of public-education programs designed to reduce the accumulation of litter and animal wastes on streets, and to promote the proper use of pesticides and fertilizers on urban and agricultural land would be helpful in reducing the pollution from phosphorus, bacteria, and pesticides;

e) the implementation of street sweeping practices to remove accumulated contaminants from streets.

Techniques which are of a preventative nature are usually cheaper and easier to implement than techniques of a treatment nature, and are consequently preferable.

12.2 FUTURE STUDIES

It is recommended that the following studies be undertaken, where possible, to substantiate and expand the findings contained in this report:

a) The sources of pollutants within urban areas should be investigated in greater detail. Specifically, there is a lack of information on the runoff quality (water and sediment) from construction sites, streets, roofs, parking lots, commercial land, and industrial land. Additionally, the quantity and quality of pollutants derived from streambank erosion in urban areas should be investigated.

b) Unit-area load values should be developed from monitoring data for residential, commercial, industrial, and other subcategories of urban land-use in order to substantiate and expand the results presented by Singer (1977).

c) In-stream pollutant transport in the urban environment should be investigated. For example, studies should be undertaken to determine whether contaminants which accumulate on surfaces are washed off during rain storm events in sediment form, or in dissolved form into receiving waters, where they subsequently become attached to the suspended sediment already present.

13.0 REFERENCES

Avadhanula, M. R., "Pollution from Rural, Transportation, Extractive, and Undisturbed Land Uses in the Grand and Saugeen Watersheds", International Joint Commission PLUARG Technical Report, Windsor. In press.

International Joint Commission, "Quality Control Handbook for Pilot Watershed Studies", PLUARG, Windsor. 1976, (revised 1977).

Marshall Macklin Monaghan Ltd., "Evaluation of Remedial Measures to Control Non-Point Sources of Water Pollution in the Great Lakes Basin", International Joint Commission, PLUARG, Windsor. 1978.

Onn, D., "Data Collection Methodology Used in the Study of Land Use Activities in the Grand River and Saugeen River Pilot Watersheds", IJC-PLUARG Technical Report, Windsor. In press.

Ontario Ministry of the Environment, "Evaluation of the Effect of Some Waste Disposal Practices on Great Lakes Water Quality,", International Joint Commission PLUARG Technical Report, Windsor, In. press.

Ontario Ministry of the Environment, revision to "Guidelines and Criteria for Water Quality Management in Ontario", Toronto. In preparation.

Ontario Ministry of the Environment, "Polychlorinated Biphenyls in the Ontario Environment", Toronto. 1976.

Ontario Ministry of the Environment, "Summary Pilot Watershed Report Grand River Basin, Ontario", IJC, Windsor. 1978.

Ontario Ministry of the Environment, "Summary Pilot Watershed Report Saugeen River Basin , Ontario", IJC, Windsor. 1978.

Ontario Ministry of the Environment, "Task Group C (Canadian Section) - Activities 1, 3 and 4 Studies, International Reference Group on Great Lakes Pollution from Land Use Activities, International Joint Commission - Work Plan", Water Resources Branch, Toronto. 1976.

Singer, S., Unpublished technical memorandum, Ontario Ministry of the Environment, Toronto. 1977.

Sullivan, R. H., Hurst, W. P., Kipp, T. M., Heaney, J. P., Huber, W. C., Nix, S., "Evaluation of the Magnitude and Significance of Pollution Loading from Urban Stormwater Runoff - Ontario", American Public Works Association, 1976.

Qureshi, A. A., Rybakowski, I. M., "Summary Report on Microbiological Studies", Ontario Ministry of the Environment, Toronto. 1978.