

GRAND RIVER, ONTARIO SUMMARY PILOT WATERSHED REPORT

Submitted to
INTERNATIONAL REFERENCE GROUP
ON
GREAT LAKES
POLLUTION FROM LAND USE ACTIVITIES
INTERNATIONAL JOINT COMMISSION

by

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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-US Great Lakes Water Quality Agreement of 1972. Funding was provided through the Ontario Ministry of the Environment and the International Joint Commission. Findings and conclusions are those of the authors and do not necessarily reflect the views of the Reference Group or its recommendations to the Commission.

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8.0 SUMMARY

The major sources of pollution in the predominantly agricultural Grand River basin have been identified from the Task C studies conducted under the PLUARG program as follows:

<i>Urban</i>	- <i>metals, organic chemicals, bacteria, phosphorus</i>
<i>Point-sources</i>	- <i>metals, organic chemicals, phosphorus, nitrogen</i>
<i>Transportation</i>	- <i>lead, chloride</i>
<i>Private-waste Disposal</i>	- <i>phosphorus</i>
<i>Agriculture</i>	- <i>sediment, phosphorus, nitrogen</i>

Water-quality monitoring data collected under the PLUARG program during the period 1975-76 in the Grand River watershed suggest that progressive pollution of the Grand River is occurring from the headwaters to its mouth at Lake Erie. The headwater areas are relatively clean. Pollutant loads increase consistently downstream in the central and lower regions of the watershed reflecting the impacts of both the intensive agricultural activity and urban sprawl on the water quality of the receiving waters in these portions of the watershed.

The urban impact on the pollution load at the mouth of the Grand River is significantly greater than the urban land use of 3% in the basin (up to 20% of the load). Highway deicing agents were identified as being the major contributor of the chloride at the mouth of the Grand River. The chloride load due to deicing agents is estimated to be in the order of 50-60% of the total load at the mouth.

In addition to significant inputs of phosphorus, agricultural activities and private-waste disposal systems may contribute to increased levels of nitrogen creating localized ground-water problems. Private-waste disposal systems which are properly constructed are of minor concern.

Minimal impacts on stream-water quality have been monitored from waste disposal practices such as sanitary landfills, processed organic waste disposal and spray irrigation. This is in part due to the limited areal extent of these land uses and practices in the watershed. Increased land usage of these practices could create an ultimate environmental concern if proper design and management of the sites are not observed. Generally the major concern is with respect to the contamination of ground water by pollutants such as nitrate, phenolic compounds, industrial chemicals, pesticides and other chemicals that may be present in the waste.

Monitoring data suggest that the mining of aggregates for the construction industry (sand, gravel,

crushed stone, lime, etc.) does not affect receiving-stream water quality provided some method of waste-water treatment is used (i.e. settling ponds).

Monitoring data suggest that the bulk of the river loads (up to 80%) are transported during the months of February, March, April and May. Toxic materials such as heavy metals, pesticides and organic chemicals have a strong affinity for the clay-size sediment fraction which is transported as suspended material in the water. PLUARG monitoring data indicate that the percentage of the total load due to the particulate fraction varies from 10 to 50% for copper, 50 to 70% for lead and 20 to 70% for zinc. Management strategies for these toxic elements should consider sediment control.

Monitoring data demonstrate that in-stream transport of pollutants can be extremely variable and less than 100% in some river reaches, particularly the sediment-associated parameters such as the heavy metals group. Gross estimates of in-stream transport functions to determine the proportion of the pollutant input that is transported downstream were prepared for subwatersheds in the Grand River basin. These functions ranged from 32-100% for in-stream transport of pollutants within selected river reaches. Data from a small river reach near the headwaters of the Grand River watershed suggest that up to 50% of the soluble phosphorus can be retained by the aquatic weeds on a daily basis due to biological uptake during growth periods. In terms of the Grand River basin, aquatic weed growth may have a significant impact on the phosphorus export from the watershed during the active growth periods of the biomass.

Extrapolation of the pilot watershed data to unmonitored areas in the Great Lakes basin is possible provided the characteristics of the unmonitored areas are similar to those in the pilot watershed. In terms of extrapolation to other parts of the Great Lakes basin, the critical diffuse sources of pollutant contribution have been identified as being agricultural and urban land uses and practices. Based on the Grand River watershed information, the most cost-effective remedial measures to moderate non-point sources of pollution in the Great Lakes basin will be those that control pollutant runoff from agriculture and urban areas.

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 River basin was chosen as a pilot watershed for intensive study under Task C in Canada. The Grand River basin is the largest river basin in southwestern Ontario, and has a predominantly varied and extensive agricultural use and an extensive urban population in the central part of the basin.

The land uses not adequately represented in the pilot watersheds were incorporated into the study by including additional subwatersheds in different parts of the Great Lakes basin. The magnitude and significance of material inputs from the following land uses and practices were identified for further 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.

9.2 STUDY APPROACH

Monitoring networks were established in the Grand River basin for the purpose of collecting quality and quantity data to derive pollutant loading estimates from various land uses in the watershed. Monitoring stations were established upstream and downstream of selected land uses, at the outlets of sub-watersheds with relatively homogeneous land uses, at downstream main-stem localities and at the mouth of the pilot watershed. The water-quality data that were collected at these stations were utilized as part of a mass-balance approach to answer the PLUARG reference:

- "1) Are the boundary waters of the Great Lakes system being polluted by land drainage from?*
- 2) to what extent, by what causes, and in what localities is the pollution taking place?*
- 3) what remedial measures be most practicable, andthe probable cost thereof?"*

Some of the land-use studies were conducted outside of the pilot watershed and the information thus generated was extended to the basin using unit-area loads and land-use inventories. Land-use inventories of the basin were assembled using the Canada Land Inventory (CLI) system, which is based on census (enumeration) data from 1968-1974.

In order to answer the PLUARG reference; the causes, sources and extent of pollutant contribution have been identified in the Grand River basin. The relative significance of the sources in the basin have also been identified by proportioning the monitored load at the mouth of the Grand River and attributing these loads to the various land uses in the basin. A simple mass-balance approach was utilized by assigning unit-area loads from PLUARG monitoring data to the land-use inventory compiled for the basin. This approach assumes that the long-term delivery is unity; which therefore implies that all land-use activities regardless of their distance from the lakes or the receiving waters will have an impact upon the boundary waters. Information on overland and in-stream transport processes are generally lacking and only general observations from the pilot watershed studies are applicable to other parts of the Great Lakes basin where similar conditions exist.

Possibilities for pollutant control from various land uses and practices have been tabulated (Task A) and the technical feasibility of these measures have been assessed, where applicable, using information from the Task C studies. Detailed demonstration projects will be required if further assessment of control management strategies and their cost effectiveness are necessary.

9.3 METHODS

9.3.1 WATER QUANTITY MEASUREMENT

Continuous records of water level (stage) were obtained from newly constructed streamflow gauging stations for the PLUARG program. Where possible existing Water Survey of Canada and Grand River Conservation Authority gauging stations were into the PLUARG water-quantity network.

Field staff developed relationships between stage and discharge for all of the streamflow gauging stations that were newly constructed for the PLUARG program. Standard procedures for discharge measurements and rating of controls as outlined in Corbett et al (1962) were implemented for the PLUARG Task C study.

Streamflow gauging was not feasible at the Grand River watershed outlet (site GR-15) located 8 km upstream of Lake Erie. Approximately 90% of the basin is gauged and reliable estimates of mean daily discharges were synthesized at site GR-15 by a combination of simple prorating and statistical routing schemes. Similar means were employed to augment flow data at other sites during periods of missing records.

9.3.2 WATER QUALITY COLLECTION

In conjunction with the streamflow data, event-oriented surface water samples were collected for chemical analyses to provide pollutant loadings for the Task C study. Representative samples of suspended sediment and sediment-associated pollutants were usually collected by the "equal transit rate method" as described in Guy and Norman (1970). Uniformity in sample-container storage, sample preservation and handling techniques were maintained throughout the duration of the Task C study.

Automatic water-quality samplers (CAE Model 304 pumping type) housed in all-weather shelters, were installed at selected sites to ensure frequent sampling throughout the rising and falling limbs of the streamflow hydrograph. Manual samples were collected at these sites over a wide range of flow conditions to assist in the calibration of the automatic samplers.

9.3.3 SEDIMENT COLLECTION

Studies involving the chemical and physical characterization of fluvial suspended sediment were carried out at selected stations in the Grand River basin during 1976 and 1977. A minimum of 5 grams of material was required to perform all the analyses on the lengthy PLUARG parameter list (IJC-PLUARG, Quality Control Handbook for Pilot Watershed Studies, 1976). This precluded the use of conventional suspended-sediment sampling techniques. A special large-volume sampling system was used in order to recover a sufficient quantity of suspended material for the required chemical and physical analyses.

The sampling system, which was made available through the Canada Centre for Inland Waters (CCIW), consisted of a sample collection unit and a processing unit. Using a submersible pump, approximately 1000 litres of stream water, including the suspended sediment (referred to as a bulk suspended-sediment sample), was collected at each station and stored in plastic sample containers (40 litre volume). All the usual sample-handling precautions were observed in order to ensure the collection of a representative, uncontaminated sample. The bulk suspended-sediment sample was transported to the processing unit which consisted of a continuous-flow centrifuge and supporting equipment. The bulk suspended- sediment sample was processed through the centrifuge and the

sediment recovered for chemical and physical analyses. The supernatant (decanted water sample) was also analysed.

In addition to the bulk suspended-sediment sample, routine water-quality samples were also collected for chemical analyses to verify those concentrations derived from the bulk suspended sediment and supernatant samples.

Bed-material samples were also collected at selected sites in the Grand River basin. A 1 ½" I.D. coring device (Sutton, 1974) was used to collect the sample. A minimum of five sub-samples from the top 5-10 cm of the stream bed were collected at equally-spaced intervals in the sampling cross section. These sub-samples were composited to form a single sample for chemical and physical analyses.

9.3.4 POINT SOURCE ESTIMATES

9.3.4.1 Municipal

Studies were undertaken to supplement the existing effluent-quality information on file with the Ontario Ministry of the Environment for municipal sewage treatment plants in the Grand River basin. Municipal effluents were sampled at nine major sewage treatment plants representing 94% of the municipal sewage treated in the Grand River basin. The effluent discharges were sampled after a prolonged dry spell to ensure that sewage quality and quantity were not influenced by infiltration into the sanitary sewage system, and also during a basin-wide rainfall event to examine changes in sewage effluent quality. Loadings were calculated, on the two survey days in question, by determining the product of actual sewage flow and an average concentration from samples collected every six hours during a 24-hour period. An annual loading estimate was obtained by multiplying the daily estimates for both the wet and dry surveys by the reported, annual waste volume at each sewage treatment plant. These values were arithmetically averaged to provide an estimated annual load.

The historic information that exists on the quality of municipal effluent varies with each sewage treatment plant. The effluent discharges from all sewage treatment plants are routinely analysed for total phosphorus, suspended solids and biochemical oxygen demand. Some of the treatment plants also have the effluent analysed for Kjeldahl nitrogen, nitrate + nitrite nitrogen and ammonium nitrogen. Data were compiled for 1975 and 1976 and loads were calculated for each of the measured parameters on an annual basis (tonnes per year). Total annual flow (cubic metres per year) and average concentration (milligrams per litre) of the effluent samples for each sewage treatment plant were used in calculating the annual loads. Good agreement was found between the annual loading estimates derived from the routine Ministry monitoring and the two PLUARG surveys in that the year-round routine monitoring value lies between the values obtained for the wet and dry surveys.

Loads for the parameters that were not analysed under the regular monitoring program were averaged from the PLUARG survey results and reported as the best estimate available.

9.3.4.2 Industrial

All known sources of liquid waste being discharged to the storm sewer systems or directly into surface watercourses from non-municipal sources (i.e. industrial) were also sampled in the Grand River basin. This study did not address the large portion of water-borne industrial waste which enters the sanitary sewer system. All treated wastes from the sanitary sewer systems were measured as part of the municipal-effluent sampling in the point-source studies conducted under PLUARG (Section 9.3.4.1). As part of the industrial sampling program, cooling, process and general purpose waters were collected from 95 commercial, institutional and industrial sources in the basin.

Historic monitoring records, consisting of a unique parameter for each outfall list and a sample collection frequency that ranged from 4 to 50 times per year, were available for many of the industrial discharges from the files of the Ontario Ministry of the Environment and municipalities in the basin. Chemical analyses of supplementary samples which were collected at each of the 95 industrial outfalls when effluent discharges were high were undertaken for the complete PLUARG water- quality parameter listing.

Loading estimates were calculated by obtaining a product of total annual discharge and average pollutant concentrations from the routine Ministry and supplementary PLUARG monitoring that was undertaken in 1976. The quality and quantity of these industrial effluents were extremely variable with time and some parameters were analysed for the first time as part of the PLUARG study. As a result, the reliabilities of these loading estimates vary with each specific source but generally are considered to be poor. The supplementary PLUARG monitoring was conducted when industries were experiencing full production and waste volumes were high. As a result these loading estimates may be significantly higher than the actual long-term load.

9.3.5 LOAD ESTIMATES

In order to evaluate the significance of pollution from land drainage, the water quality and quantity data generated at the sampling sites were translated into quantitative estimates of pollutant mass transport (i.e. loadings). Although both streamflow and concentration are variables, only flow was normally monitored continuously. Differences in sampling frequency from site-to-site created problems in obtaining an unbiased estimation of loads. PLUARG sampling frequencies ranged from intensive event-oriented monitoring, with up to 400 samples being collected during 1975 and 1976, to surveillance-type sampling, with approximately 25 samples being taken over the same two-year period.

9.3.5.1 IJC Recommended 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. This method provides estimates of both mean and variance and was recommended in order to make broad comparisons across the entire Great Lakes basin.

The model assumes that random sampling has been conducted within non-overlapping sub-populations or strata and that supplemental information in the form of a continuous flow record is available. While the latter condition (i.e. continuous flow) was readily satisfied; the former (i.e. random sampling) was not generally met, largely because of the emphasis directed towards event sampling at most sites.

In light of these considerations, a simplified scheme involving the subdivision of concentration records according to an arbitrary classification of high and low flows was applied wherever possible. Based on duration analysis of mean daily-flow records, high flows were assumed to be those equalled or exceeded 15% of the time. The results of this approach are not entirely satisfactory, as in many instances the estimates appear biased towards the high-flow data (i.e. loads are overestimated) as a result of the event-sampling nature of the program. At the surveillance sites, bias may be towards high or low-flow conditions according to the presence or absence of event samples in these limited data records.

9.3.5.2 Regression Method

In an effort to obtain a better appreciation of the potential bias inherent in the previously discussed method of load estimation, alternative means of computation were sought. Developing regression relationships between flow and concentration or possibly flow and loading appeared to be an obvious choice since it was desirable to examine the temporal export of materials within the year (i.e. provide seasonal and monthly estimates). The regression relationships can be applied to the mean- daily flow records to yield daily load estimates which can be summed to produce monthly, seasonal or annual estimates. The assumption inherent to this approach is that either concentrations or loads obey a fixed relationship with respect to flows. For most parameters this assumption holds only to a limited degree and individual daily load estimates may have little meaning; however, over a longer term it may be reasonably assumed that deviations from the regression model tend to average so that, cumulative estimates for longer time periods may be reasonable estimates. Regression on the logarithms of the variables was considered most appropriate because both concentration and flow data generally span several orders of magnitude. Initial results were not altogether satisfactory; however, manipulation of the data set into high and low flow categories yielded acceptable relationships in most cases.

At this time only a few preliminary loading estimates have been derived using the regression method. The comparison data (in kg/ha/yr) are presented below and illustrate the best and worst-case situations:

Site	Method	Total Phosphorus	Filtered Reactive Phosphate	Nitrate + Nitrite	Suspended Sediment
GR-15 (1976)	IJC	0.930	0.161	9.57	464
GR-15 (1976)	Regression	0.819	0.151	9.49	408
GR-20 (1975-76)	IJC	2.333	0.228	9.46	2235
GR-20 (1975-76)	Regression	1.040	0.216	11.37	655

Good agreement between the two methods was observed at site GR-15 which is located at the outlet of the Grand River and possesses an excellent sampling record.

Site GR-20, located on the Nith River tributary, demonstrates the problems encountered at some of the other sites in the PLUARG network. Loads were first calculated by the IJC recommended method as described previously. When compared with data from other main-stem monitoring stations, the loads obtained at GR-20 appeared to be high for suspended sediment and total phosphorus as well as the other sediment-associated parameters not shown herein. Examination of the calculations revealed the estimates to be contingent on a few extremely high-concentration values observed only on the highest flow days of the two year period.

Very good regression relationships were developed for the GR-20 data to yield load estimates that are considered to be quite reliable. Comparison of the two methods as shown above reveals that discrepancies are negligible for soluble parameters such as filtered reactive phosphate and nitrate plus nitrite; however, estimates for suspended sediment and sediment-associated parameters may be biased upwards by a factor of two or three in the worst instances if the IJC recommended method is arbitrarily applied.

9.3.5.3 SEDCON Method

A further method of load calculation was developed specifically for the suspended-sediment parameter. This essentially semi-graphical procedure (SEDCON) was devised by the Water Survey of Canada. Sediment concentrations are plotted directly on the water-level recording chart and then subjectively interpolated to produce a continuous record of sediment concentration. An integration procedure is then used to generate mean daily concentrations or loads, as required. This method was applied at a few PLUARG sites where there were sufficient data for detailed analyses of

intensively monitored events. Aside from the subjective element, this method lacks a variance estimate; however, where the sampling record is good, the results appear to be reasonably close to those derived by the IJC recommended or regression methods.

9.3.5.4 Unit Load Estimates

Monitoring data from predominantly homogeneous land-use areas were used to estimate the unit-area loads for rural, urban and wooded areas. A watershed was considered to be homogeneous when the major land use occupied more than 70% of the area for the wooded, 80% for the rural and more than 60% for the urban categories. The total load at each of the selected land-use stations was calculated according to the IJC recommended method.

The unit-area loads from 12 stations having more than 80% of the area in agricultural land were averaged to determine unit-area loads for the rural category. Similarly, the loads from predominantly urban and wooded areas (two stations in each land-use category, respectively) were used to estimate the unit-area loads for these land uses. With the exception of one station in the Saugeen River basin which is predominantly wooded, all the data for the unit-area load calculations were derived from stations located in the Grand River watershed.

The unit-area loads for residential, commercial, industrial and other urban land use (open space, parks, cemeteries, etc.) categories were obtained from urban-runoff modelling conducted by the Ontario Ministry of the Environment and the federal Environmental Protection Service under the Canada/Ontario Agreement on Great Lakes water quality. The original values (Sullivan R. H. et al 1976) were modified by combining sewered and unsewered unit-area loads for the urban areas in the Grand River basin (i.e. 87% and 13% respectively).

9.3.5.5 Other Methods

In addition to the tributary loading estimates, a number of generalized loading estimates have been drawn together for specialized land uses and practices. Loadings were estimated for sanitary landfills, processed organic waste disposal, private-waste disposal and spray irrigation land uses and practices using land-use inventories of these practices in the basin coupled with data from specific Task C studies conducted by the Ontario Ministry of the Environment. These land uses and practices are ground-water associated and involve certain worst-case assumptions concerning the attenuation of pollutants within the ground-water flow system. The private-waste disposal estimate further assumes that 30% of the septic systems are faulty and discharge eventually to receiving streams.

Load estimates for road deicing salts were based on a comprehensive PLUARG Task C survey of salt usage by municipalities and the Ontario Ministry of Transportation and Communications across southern Ontario during the winter of 1975-76.

9.3.6 DATA TRANSFERABILITY

Data transfer within the Grand River basin was tested on a subwatershed basis. The land-use distribution, physiography and the tributary monitoring network were used to divide the basin into eight subwatersheds comprised of four tributaries and four, main river-stem, drainage sections. Pollutant loads from the diffuse sources in each subwatershed were estimated using the unit-area load values compiled for the pilot watershed study (Section 9.3.5.4). All the inputs, including the point sources and upstream loads, were added to the total estimated diffuse-source loads for the subwatershed and compared with the monitored load at the outlet of the subwatershed, for each of the key parameters considered.

As a rough approximation, the ratio between measured load and estimated load is an indicator of the pollutant transport phenomenon; however, the reliability of this ratio would depend upon the accuracy of the unit-area load values used in the computation of the estimated load.

9.3.7 IN STREAM POLLUTANT TRANSPORT

Investigations of the annual, in-stream, pollutant transport functions in the Grand River watershed are based on a mass-balance approach. The monitored load of a pollutant at the outlet of a watershed or subwatershed is assumed to be equal to the sum of the loads from the inflow, point sources and diffuse land-drainage sources in the watershed. The total input load to the stream is modified by a transport function which consists of physical, chemical and biological processes that often results in an entrapment of a portion of the input load.

The mass balance equation is expressed below:

$$LO_a = f(T_a) \cdot (\sum LI_a + \sum PS_a + \sum D_a + C_a)$$

where: LO_a is the monitored pollutant load at the outlet of watershed A.
 $f(T_a)$ is the in-stream transport function of a pollutant in watershed A.
 $\sum LI_a$ is the sum of the monitored pollutant loads influent to watershed A.
 $\sum PS_a$ is the sum of the pollutant loads from point sources in watershed A.
 $\sum D_a$ is the sum of the pollutant loads from diffuse land-drainage sources in watershed A.
 C_a is the pollutant from the stream channel in watershed A (streambank erosion, scour, etc.).

Rearranging the above equation to isolate the transport function yields:

$$f(T_a) = \frac{LO_a}{(\sum LI_a + \sum PS_a + \sum D_a + C_a)}$$

Values for the monitored load at the outlet of the subwatershed (LO_a) and some of the monitored pollutant loads influent to the subwatershed (LI_a) including the point source inputs in the subwatershed (PS_a) are obtained from monitoring data. The load from the diffuse sources (D_a) is estimated using unit-area load functions derived from monitoring data (Section 9.3.5.4) and the land-use inventory for the subwatershed. The streambank erosion and channel scour parameter (C_a) is generally unknown at this time. For the purpose of obtaining a gross initial estimation of the annual pollutant transport function, streambank scour and erosion (C_a) were assumed to be zero. Studies by other PLUARG investigators indicate that streambank erosion may contribute a significant load, locally.

The Grand River was subdivided into eight segments based on the location of monitoring stations in the watershed. The transport function was calculated for each segment using the equation stated above and was assumed to be linear along each river segment. A more realistic transport function such as a time decay function incorporating particle size, peak flow and time of travel parameters has been suggested by Williams (1975) but, in consideration of the PLUARG time constraints, was not developed for the Grand River.

9.14 PARAMETERS

To date, the two major in-lake problems have been identified as being: 1) the acceleration of the natural aging processes in the lakes (eutrophication) and 2) those toxic materials which constitute an environmental health hazard (human and/or biological). Eutrophication is principally controllable by phosphorus and to a lesser extent by nitrogen. As a result of its capacity to adsorb phosphorus and other contaminants, sediment is an important aspect of eutrophication and toxicity problems. Materials may either be removed from solution ("scavenged") by adsorption to the sediment and deposited on the lake bottom or they may be released from the sediment (desorption) and become available to the lake biota. The hazardous lake problems are attributable to pesticides, organic chemicals, heavy metals and bacterial contamination.

The parameters identified for intensive study in the Grand River pilot watershed are as follows:

Total Phosphorus (TP)
Filtered Reactive Phosphate (FRP)
Filtered Nitrite + Nitrate F(NO₂ + NO₃)
Total Kjeldahl Nitrogen (TKN)
Total Nitrogen (TN)
Suspended Sediment (SS)
Lead (Pb)
Copper (Cu)
Zinc (Zn)
Chloride (Cl)
Polychlorinated Biphenyls (PCBs)

Although not discussed in this report, additional information is available on the major cations and anions, phenols, carbon, mercury, chromium, arsenic, nickel, cadmium and cobalt. These data are summarized in the detailed technical reports as part of the supporting documentation for this pilot watershed report.

10.0 TABULATED RESULTS OF DATA COLLECTION

- Table 1. Mean Loading Estimates For The Combined 1975 And 1976 Period At Main Stem Monitoring Sites.
- Table 2. Sources, Extent And Relative Significance Of Pollutant Contributions.
- Table 3. Monthly Loading Estimates At Montgomery Creek, Kitchener.
- Table 4. Land Uses And Unit Area Load Estimates.
- Table 5. Estimated Percentage Of The Total Annual Load Delivered Monthly For 1975 And 1976.
- Table 6 Total, Dissolved And Sediment Associated Loads At The Watershed Outlet, 1976.

TABLE 1: Mean Loading Estimates For The Combined 1975 And 1976 Period At Main Stem Monitoring Sites

Column 1 Monitoring Site

LOCATION CODE lists the monitoring site, as depicted in Figure 4.

DRAINAGE AREA (ha) is the surface area of the land drained by the monitoring site in hectares.

MEAN ANNUAL STREAM FLOW (m³/s) is the annual flow for 1975 and 1976 expressed as the average daily flow rate.

Column 2 Pollutant Loading Estimates

TOTAL ANNUAL LOAD (t/yr) is the estimate of total mass transport computed by the IJC recommended method based on monitoring data from 1975 and 1976.

UNIT AREA LOAD (kg/ha/yr) is the total annual load averaged over the drainage area upstream of the monitoring site.

Table 1

Monitoring Site			Pollutant Loading Estimates									
Location Code	Drainage Area (ha)	Mean Annual Stream Flow (m ³ /s)	Suspended Sediment		Total Phosphorus		Filtered Reactive Phosphate -P		Kjeldahl - N		Filtered (Nitrate+nitrite) -N	
			Total Annual Load (t/yr)	Unit Area Load (kg/ha/yr)	Total Annual Load (t/yr)	Unit Area Load (kg/ha/yr)	Total Annual Load (t/yr)	Unit Area Load (kg/ha/yr)	Total Annual Load (t/yr)	Unit Area Load (kg/ha/yr)	Total Annual Load (t/yr)	Unit Area Load (kg/ha/yr)
GR-3	67,600	8.1	3,670 ±2,510	54	28 ± 38	.407	1.8 ± 0.7	.027	167 ± 17	2.48	149 ± 23	2.20
GR-13	79,500	9.2	5,120 ± 1,700	64	18 ± 4	.226	3.5 ± 0.9	.043	218 ± 11	2.74	175 ± 16	2.20
UL-21	141,000	13.6	34,300 ± 24,700	243	72 ± 34	.508	13.3 ±3.8	.094	428 ± 90	3.03	755 ± 98	5.35
UL-22	351,000	43.4	536,000 ± 961,343	1,530	423 ± 324	1.21	74.6 ±17.3	.213	2,490 ±1,220	7.10	2,870 ± 272	8.18
GR-11	521,000	65.3	757,000 ± 734,000	1,450	821 ± 682	1.58	84.6 ±22.6	0.163	3,840 ±2,790	7.38	4,470 ± 685	8.58
GR-5	598,000	70.1	562,000 ± 592,000	940	582 ± 509	0.974	88.7 ±26.8	.148	3,690 ±1,960	6.17	4,830 ± 774	8.09
GR-15	667,000	78.0	254,000 ± 45,900	380	510 ±67	0.765	92.7 ± 6.7	0.139	2,640 ±156	3.96	5,580 ± 292	8.79

TABLE 2: Sources, Extent And Relative Significance Of Pollutant Contribution

Column 1 Water Quality Parameter

ANNUAL MEAN STREAM FLOW (m³/s) is the annual flow expressed as the average daily flow rate.

FLOW WEIGHTED MEAN CONCENTRATION (mg/L) is the product of the total annual load (concentration x flow) divided by the total annual flow.

MONITORED/ESTIMATED LOAD RATIO is the ratio of mean annual load (t/yr) measured at the watershed outlet to the estimated total load (t/yr), based on the addition of best annual loading estimates reported (in column 3) for all watershed sources.

DRAINAGE AREA (hectares) is the total watershed area including the area downstream of the outlet monitoring station at GR-15.

UNIT AREA LOAD (kg/ha/yr) at the watershed outlet (column 2), is the total annual load averaged over the basin area.

UNIT AREA LOAD (kg/ha/yr) at the watershed sources (column 3), is the best estimate of average unit-area contributions from each diffuse source in the basin.

TOTAL ANNUAL LOAD (t/yr) at the watershed outlet (column 2) is the estimate of total mass transport at the outlet computed by the IJC recommended method.

TOTAL ANNUAL LOAD (t/yr) at the watershed sources (column 3) is the best estimate of total mass transported due to runoff from the land uses in the basin.

Column 2 Watershed Outlet

MONITORED 1975 AND 1976 are data reported for those respective years, based on the monitoring activities undertaken in support of Task C studies at the outlet monitoring station GR-15 including all point sources downstream of this station.

Column 3 Watershed Sources

TOTAL is the estimated pollutant contribution from all of the watershed sources.

POINT SOURCES

MUNICIPAL is the final liquid effluent from 22 sewage treatment plants that treat domestic and industrial waste entering the sanitary sewer system in the basin.

INDUSTRIAL is the cooling, process and general purpose waters discharged after any required treatment from 95 commercial, industrial and institutional sources, directly into a storm sewer system or surface watercourse in the basin.

DIFFUSE SOURCES

URBAN GENERAL is commercial, industrial, residential and recreational land, parking lots and all road systems in the urban areas.

PRIVATE WASTE (urban) is the septic tank systems within urban boundaries, (i.e. unsewered).

AGRICULTURAL GENERAL is the actively farmed areas, row crops including livestock, barnyard areas and rural dwellings.

PRIVATE WASTE (rural) is the septic tank systems outside urban boundaries (rural or farm areas).

WOODED/IDLE is the perennial vegetative cover, woodlots, swamps and idle land (unimproved pasture).

TRANSPORTATION is the rural land devoted to all road systems. Note: Table 2g (chloride estimate) includes all (rural and urban) road systems.

PROCESSED ORGANIC WASTE is the agricultural land on which sewage sludge is spread.

SANITARY LANDFILL is domestic and industrial solid waste disposal (buried and covered) areas.

EXTRACTIVE is comprised of sand and gravel pits and limestone quarries.

SPRAY IRRIGATION is industrial liquid waste disposal on land.

STREAM BANK EROSION is the amount of sediment estimated from the Canadian Agricultural Studies to have been produced by the erosion of stream banks in the Grand River basin.

TABLE 2a

Water Quality Parameter	WATERSHED OUTLET		WATERSHED SOURCES												
	Monitored 1975	Monitored 1976	Total	Point Sources		Diffuse Sources									
Suspended Sediment															
Annual Mean Stream Flow (m ³ /s)	69.2	86.8	<i>Estimate based on the sum of all Point and Diffuse Sources</i>	Municipal	Industrial	Urban General	Private Waste (Urban)	Agricultural General	Private Waste (rural)	Wooded / Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Stream Bank Erosion
Number of Samples	60	246													
Flow Weighted Mean Concentration (mg/L)	100	111													
Monitored/Estimated Load Ratio	0.64	0.89													
Drainage Area (hectares)	668,000	668,000	668,000	379,000	/	20,000	**	504,000	**	127,000	11,300	5,110	530	130	/
Percentage of Watershed Drainage Area	100	100	100	***	***	3	***	75	***	19	2	< 1	< 1	< 1	/
Unit Area Load (kg/ha/yr)	329	457	512	/	/	1,070	/	569	/	41	/	/	/	/	40
Total Annual Load (t/yr)	220,000 ± 178,000	305,000 ± 56,900	342,000	2,090	410	21,500	/	286,000	/	5,200	/	/	/	IC	26,700
Percentage Contribution of (Total Estimated Load	/	/	100	0.6	0.2	6.3	/	83.6	/	1.5	/	/	/	IC	7.8

* sewered population, ** unsewered population,*** number of systems; IC - insignificant contribution (<0.1%), / not estimated
 † Other methods and results of estimating the agricultural load are discussed in the Final Summary Report, Canadian Agricultural Watershed Studies, May 1, 1978.

TABLE 2b

Water Quality Parameter	Watershed Outlet		Watershed Sources												
	Monitored 1975	Monitored 1976	Total	Point Sources		Diffuse Sources									
Total Phosphorus															
Annual Mean Stream Flow (m ³ /s)	69.2	86.8	<i>Estimate based on the sum of all Point and Diffuse Sources</i>	Municipal	Industrial	Urban General	Private Waste (Urban)	Agricultural General	Private Waste (rural)	Wooded / Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Stream Bank Erosion
Number of Samples	62														
Flow Weighted Mean Concentration (mg/L)	0.190	0.221													
Monitored/Estimated Load Ratio	0.62	0.88													
Drainage Area (hectares)	668,900	668,000	608,000	*	/	20,000	**	504,000	**	127,000	11,300	5,110	530	130	100
Percentage of Watershed Drainage Area	100	100	100	***	**	3	***	75	***	19	2	< 1	< 1	< 1	< 1
Unit Area Load (kg/ha/yr)	0.655	0.927	1.05	/	/	1.39	/	0.899	0.9	0.083	/	0.19	/	/	0.9
Total Annual Load (t/yr)	438 ± 162	619 ± 87.4	701	114	60	28	15	452	20	11	/	1	IC	/	0.1
Percentage Contribution of Total Estimated Load	/	/	100	16.2	8.6	4.0	2.1	64.5	2.9	1.6	/	0.1	IC	/	IC

* sewered population, ** unsewered population, *** number of systems, IC - insignificant contribution (<0.1%), / not estimated

† Other methods and results of estimating the Agricultural load are discussed in the Final Summary Report, Canadian Agricultural Watershed Studies, May 1, 1978.

TABLE 2c

Water Quality Parameter	Watershed Outlet		Watershed Sources												
	Monitored 1975	Monitored 1976	Total	Point Sources		Diffuse Sources									
Filtered Reactive Phosphate-P															
Annual Mean Stream Flow (m ³ /s)	69.2	86.8	<i>Estimate based on the sum of all Point and Diffuse Sources</i>	Municipal	Industrial	Urban General	Private Waste (Urban)	Agricultural General	Private Waste (rural)	Wooded / Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Stream Bank Erosion
Number of Samples	57	229													
Flow Weighted Mean Concentration (mg/ L)	.041	.039													
Monitored/Estimated Load Ratio	0.53	0.57													
Drainage Area (hectares)	568,090	668,000													
Percentage of Watershed Drainage Area	100	100	100	***	***	3	***	75	***	19	2	< 1	<1	< 1	<1
Unit Area Load (kg/ha/yr)	0.166	0.178	0.311	/	/	.085	/	.202	/	.007	/	0.006	/	/	/
Total Annual Load (t/yr)	111. ± 15.4	119. ± 7.95	206	43.3	33.4	1.7	11.6	102	15.4	n 0.9	/	10	IC	/	IC
Percentage Contribution of Total Estimated Load	/	/	100	20.8	10.1	0.8	5.6	48.0	7.4	0,1	/	IC	IC	/	IC

* sewered population, ** unsewered population, *** number of systems, IC - insignificant contribution (<0.1%), / not estimated

TABLE 2d:

Water Quality Parameter	Watershed Outlet		Watershed Sources																									
	Monitored 1975	Monitored 1976	Total	Point Sources		Diffuse Sources																						
Total Nitrogen			<i>Estimate based on the sum of all Point and Diffuse Sources</i>	Municipal	Industrial	Urban General	Private Waste (Urban)	Agricultural General	Private Waste (rural)	Wooded / Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Stream Bank Erosion													
Annual Mean StreamFlow (m ³ /s)	69.2	86.8																										
Number of Samples	57	228																										
Flow Weighted Mean Concentration (mg/L)	3.50	3.39																										
Monitored/Estimated Load Ratio	0.88	1.07																										
Drainage Area (hectares)	668,003	668,000	668,900	* 379,000	/	20,000	** 56,100	504,000	** 78,800	127,000	11,300	5,110	530	130	130													
Percentage of Watershed Drainage Area	100	100	100	*** 22	*** 95	3	*** 15,200	75	*** 21,300	19	2	< 1	< 1	<1	<1													
Unit Area Load (kg/ha/yr)	11.3	14.0	13.0	/	/	8.45	/	11.7	/	5.15	/	11.1	/	/	3.66													
Total Annual Load (t/yr)	7,687 ± 1,320	9,330 ± 599	8,700	1,580	146	169	125	5,860	175	654	/	IC	IC	/	IC													
Percentage Contribution of Total Estimated Load	/	/	100	18.2	1.7	1.9	1.4	67.3	2.	7.5	/	IC	IC	/	IC													

* sewered population, ** unsewered population, *** number of systems, IC - insignificant contribution (<0.1%), / not estimated

TABLE 2e

Water Quality Parameter	Watershed Outlet		Watershed Sources																									
	Monitored 1975	Monitored 1976	Total	Point Sources		Diffuse Sources																						
Kjeldahl-N			<i>Estimate based on the sum of all Point and Diffuse Sources</i>	Municipal	Industrial	Urban General	Private Waste (Urban)	Agricultural General	Private Waste (rural)	Wooded / Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Stream Bank Erosion													
Annual Mean Stream Flow (m3/s)	69.2	86.8																										
Number of Samples	57	228																										
Flow Weighted Mean Concentration (mg/L)	1.16	1.08																										
Monitored/Estimated Load Ratio	0.85	0.99																										
Drainage Area (hectares)	668,000	668,000	668,000	*	/	20,000	*	504,000	**	127,000	11,300	5,110	530	130	130													
Percentage of Watershed Drainage Area	100	100	100	***	***	3	***	75	***	19	2	< 1	< 1	< 1	< 1													
Unit Area Load (kg/ha/yr)	3.82	4.46	4.51	/	/	5.4	/	2.78	/	1.85	/	0.19	/	/	/													
Total Annual Load (t/yr)	2,550 ±471	2,980 ±197	3,010	1,140	130	108	IC	1,400	IC	235	/	IC	IC	/	IC													
Percentage Contribution of Total Estimated Load	/	/	100	37.9	4.3	3.6	IC	46.5	IC	7.8	/	IC	IC	/	IC													

* sewered population, ** unsewered population, *** number of systems, IC insignificant contribution (<0.1%), / not estimated

TABLE 2f

Water Quality Parameter	Watershed Outlet		Watershed Sources												
	Monitored 1975	Monitored 1976	Total	Point Sources		Diffuse Sources									
Filtered (Nitrate + Nitrite)-N															
Annual Mean Stream Flow (m ³ /s)	69.2	86.8	<i>Estimate based on the sum of all Point and Diffuse Sources</i>	Municipal	Industrial	Urban General	Private Waste (Urban)	Agricultural General	Private Waste (rural)	Wooded / Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Stream Bank Erosion
Number of Samples	57	228													
Flow Weighted Mean Concentration (mg/L)	2.34	2.31													
Monitored/Estimated Load Ratio	0.90	1.11													
Drainage Area (hectares)	668,000	668,000													
Percentage of Watershed Drainage Area	100	100	100	***	**	3	***	75	**	19	2	< 1	< 1	< 1	< 1
Unit Area Load (kg/ha/yr)	7.68	9.51	8.53	/	/	3.03	/	8.86	/	3.3	/	10.9	/	/	/
Total Annual Load (t/yr)	5,130 ± 852	6,350 ± 362	5,700	440	16	61	125	4,460	175	419	/	IC	IC	/	IC
Percentage Contribution of Total Estimated Load			100	7.7	0.3	1.1	2.2	78.2	3.1	7.4	/	IC	IC	/	IC

* severed population, ** unsewered population, *** number of systems. IC insignificant contribution (<0.1%), / not estimated

TABLE 2g

Water Quality Parameter	Watershed Outlet		Watershed Sources												
	Monitored 1975	Monitored 1976	Total	Point Sources			Diffuse Sources								
Chloride															
Annual Mean Stream Flow (m ³ /s)	69.2	86.8	<i>Estimate based on the sum of all Point and Diffuse Sources</i>	Municipal	Industrial	Urban General	Private Waste (Urban)	Agricultural General	Private Waste (rural)	Wooded / Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Stream Bank Erosion
Number of Samples	56	224													
Flow Weighted Mean Concentration (mg/L)	29.5	25.3													
Monitored/Estimated Load Ratio	0.81	0.87													
Drainage Area (hectares)	668,000	668,000	668,000	*	/	20,000	**	504,000	**	127,000	11,300	5,110	530	130	100
Percentage of Watershed Drainage Area	100	100	100	***	***	3	***	75	***	19	2	< 1	< 1	< 1	< 1
Unit Area Load (kg/ha/yr)	97.4	105	121	/	/	/	/	20	/	20	/	8.0	2,640	/	/
Total Annual Load (t/yr)	65,100 ±15,400	69,900 ± 3,580	80,600	21,900	2,140	/	280	10,100	390	2,540	41,800	1c	1,400	/	1c
Percentage Contribution of Total Estimated Load	/	/	100	27.2	2.7	/	0.3	12.5	0.5	3.2	51.9	1c	1.7	/	1c

* sewer population, ** unsewered population, *** number of systems, IC insignificant contribution (<0.1%), / not estimated

TABLE 2h

Water Quality Parameter	Watershed Outlet		Watershed Sources												
	Monitored 1975	Monitored 1976	Total	Point Sources		Diffuse Sources									
Lead															
Annual Mean Stream Flow (m3/s)	69.2	86.8	<i>Estimate based on the sum of all Point and Diffuse Sources</i>	Municipal	Industrial	Urban General	Private Waste (Urban)	Agricultural General	Private Waste (rural)	Wooded / Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Stream Bank Erosion
Number of Samples		205													
Flow Weighted Mean Concentration (mg/L)		0.005													
Monitored/Estimated Load Ratio		0.77													
Drainage Area (hectares)	668,000	668,000	668,000	*	/	20,000	**	504,000	**	127,000	11,300	5,110	530	130	100
Percentage of Watershed Drainage Area	100	100	100	***	***	3	***	75	***	19	2	<1	< 1	< 1	<1
Unit Area Load (kg/ha/yr)		0.022	0.229	/	/	0.40	/	0.015	/	0.012	/	0.006	/	/	/
Total Annual Load (t/yr)		14.8 ± 3.02	19.1	0.8	1.3	8.0	IC	7.5	IC	1.5	/	IC	IC	/	IC
Percentage Contribution of Total Estimated Load	/	/	100	4.2	6.8	41.9	IC	39.3	IC	7.8	/	IC	IC	/	IC

* sewer population, ** unsewered population, *** number of systems, 1975 lead data not reported due to biased analytical technique.

IC insignificant contribution (<0.1%), / not estimated

TABLE 2i

Water Quality Parameter	Watershed Outlet		Watershed Sources																									
	Monitored 1975	Monitored 1976	Total	Point Sources		Diffuse Sources																						
Zinc			<i>Estimate based on the sum of all Point and Diffuse Sources</i>	Municipal	Industrial	Urban General	Private Waste (Urban)	Agricultural General	Private Waste (rural)	Wooded / Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Stream Bank Erosion													
Annual Mean Stream Flow (m ³ /s)	69.2	86.8																										
Number of Samples	55	205																										
Flow Weighted Mean Concentration (mg/L)	0.029	0.032																										
Monitored/Estimated Load Ratio	0.72	1.01																										
Drainage Area (hectares)	668,000	668,000	668,000	* 379,000	/	20,000	** 56,100	504,000	** 78,800	127,000	11,300	5,110	530	130	100													
Percentage of Watershed Drainage Area	100	100	100	*** 22	*** 95	3	*** 15,200	75	*** 21,300	19	2	< 1	< 1	< 1	< 1													
Unit Area Load (kg/ha/yr)	0.097	0.136	0.134	/	/	0.48	/	0.107	/	.02	/	0.23	/	/	/													
Total Annual Load (t/yr)	65.0 ± 22.2	91 ± 11.4	89.8	17.6	5.1	9.6	IC	53.8	IC	2.5	/	1.2	IC	/	IC													
Percentage Contribution of Total Estimated Load	/	/	100	19.6	5.7	10.7	IC	59.9	IC	2.8	/	1.3	IC	/	IC													

* sewered population, ** unsewered population, *** number of systems, IC insignificant contribution (<0.1%), / not estimated

TABLE 2j

Water Quality Parameter	Watershed Outlet		Watershed Sources												
	Monitored 1975	Monitored 1976	Total	Point Sources		Diffuse Sources									
Copper															
Annual Mean Stream Flow (m ³ /s)	69.2	86.8	<i>Estimate based on the sum of all Point and Diffuse Sources</i>	Municipal	Industrial	Urban General	Private Waste (Urban)	Agricultural General	Private Waste (rural)	Wooded / Idle	Transportation	Processed Organic Waste	Sanitary Landfill	Extractive	Stream Bank Erosion
Number of Samples	54	199													
Flow Weighted Mean Concentration (mg/L)	0.013	0.010													
Monitored/Estimated Load Ratio	0.98	0.96													
Drainage Area (hectares)	668,000	668,000	668,000	*	/	20,000	**	504,000	**	127,000	11,300	5,110	530	130	100
Percentage of Watershed Drainage Area	100	100	100	***	***	3	***	75	***	19	2	< 1	< 1	< 1	< 1
Unit Area Load (kg/ha/yr)	0.044	0.043	0.045	/	/	0.092	/	0.036	/	0.029	/	0.0045	/	/	/
Total Annual Load (t/yr)	29.3 ± 10.2	28.6 ± 4.87	29.8	2.7	3.5	1.8	IC	18.1	IC	3.7	/	IC	IC	/	IC
Percentage Contribution of Total Estimated Load	/	/	100	9.1	11.8	6.0	IC	60.1	IC	12.4	/	IC	IC	/	IC

* sewer population, ** unsewered population, *** number of systems, IC insignificant contribution (<0.1%), / not estimated

TABLE 3: Monthly Loading Estimates At Montgomery Creek, Kitchener

Column 1 Survey Time Period

SURVEY TIME PERIOD denotes when the monitoring data were collected at the Montgomery Creek site (UL-24) which drains an urban (96%) subwatershed in the Grand River. Estimates were reported for the months July, 1976 and June 1977, since no monitoring data were available for those time periods.

Column 2 Runoff

RUNOFF LOAD is considered to be the loading occurring as a result of surface runoff and was determined by subtracting the base load (Column 3) from the total load (Column 4).
RUNOFF, PERCENTAGE OF TOTAL was determined by dividing the runoff load by the total load (Column 4) and multiplying by 100.

Column 3 Base Load

BASE LOAD is the loading occurring as a result of ground-water and point-source discharges. During non-runoff conditions base load is equal to the total load. During surface-runoff conditions the base load was estimated graphically by assuming that the base load changes linearly from the pre-event level to the post-event value. Once the base loads were separated graphically, the monthly totals were determined by the integration method (SEDCON, Section 9.3.5.3).

Column 4 Total Load

TOTAL LOAD is the sum of the base load and the runoff load, and was determined by the integration method (SEDCON, Section 9.3.5.3).

TABLE 3a

Survey Time Period	Suspended Sediment			
	Runoff		Base Load (t)	Total Load (t)
	Load (t)	Percentage Of 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	95.7	4.6	108.2
Monthly Mean	8.6	95.6	0.4	9.0
Monthly Minimum	0.0	0.0	0.2	0.2
Monthly Maximum	27.9	98.2	0.7	28.4

TABLE 3b

Survey Time Period	Total Phosphorus			
	Runoff		Base Load (Kg)	Total Load (Kg)
	Load (Kg)	Percentage Of 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	1.4	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	79.7	1.5	7.4
June	8.2	86.3	1.3	9.5
Total Annual	169.7	90.5	17.9	187.6
Monthly Mean	14.1	90.4	1.5	15.6
Monthly Minimum	0.0	0.0	0.5	0.5
Monthly Maximum	58.5	94.4	3.5	62.0

TABLE 4: Land Uses And Unit Area Load Estimates

Column 1 Land Use Category

URBAN GENERAL is commercial, industrial, and residential land, parking lots and all road systems in the urban area.

URBAN COMMERCIAL is commercial land only

URBAN INDUSTRIAL is industrial land only

URBAN RESIDENTIAL is residential land only

URBAN OTHER is open space, parks, cemeteries, etc.

RURAL GENERAL is the actively farmed areas, row crops including livestock, barnyard areas and rural dwellings.

WOODED/IDLE is the perennial vegetative cover, woodlots, swamps and idle land (unimproved pasture).

Column 2 Unit Area Loading (UAL) Estimation Method

MEAN AND RANGE are estimates based on PLUARG Task C monitoring of selected sites (figure 4) using the IJC recommended method for computing loads. Monitoring sites UL-23 and UL-24, draining subwatersheds with more than 6% urban land, were used to estimate the urban general contribution. Monitoring sites GR-9, GR-20, TU-3, TU-4, GR-10, GR-12, GR-14, GR-19, AG-4, GR-6, GR-7 and EX-3 draining subwatersheds with more than 80% agricultural land, were used to estimate the rural general contribution. Monitoring site GR-8 and one site from the Saugeen River basin UL-12, draining subwatersheds with more than 70% of the area in perennial cover, were used to estimate the wooded/idle contribution.

$$\text{AREA WEIGHTED MEAN (UAL)} = \frac{\text{sum of monitored loads at each site}}{\text{sum of drainage areas at each site}}$$

SPECIAL STUDIES ARE UAL estimates derived 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 (Contract SS4-0305). Data shown herein were abstracted from data collected at four urban centres in the Grand River basin at Brantford, Galt (Cambridge), Guelph and Kitchener - Waterloo (figure 2). The original values were modified as stated in Section 9.3.5.4.

TABLE 4

Land Use Category	Unit Area Loading Estimation Method	Unit Area Load (Kg/ha/yr)									
		Suspended Sediment	Total Phosphorus	Filtered (Reactive Phosphate -P	Total Nitrogen	Filtered (Nitrate + Nitrite) -N	Chloride	Lead *	Zinc	Copper	
Urban general	Mean	1,070	1.39	0.085	8.45	3.03	200	0.4	0.48	0.092	
	Range	400-1,750	0.73-2.05	0.05-0.12	6.65-10.2	3.00-3.06	132-268	0.33-0.47	0.33-0.62	0.053-0.130	
	Area Weighted Mean	1,380	1.63	0.107	9.48	3.05	239	0.45	0.561	0.114	
	Commercial	Special Studies	825	0.917		11.0					
	Industrial	Special Studies	1,082	0.855		14.0					
	Residential	Special Studies	619	0.416		4.97					
Other	Special Studies	14.3	0.18		0.325						
Rural general	Mean	569	0.899	0.202	11.7	7.70	47.2	0.015	0.107	0.036	
	Range	2.9-2,230	0.05-2.30	0.008-0.533	0.62-23.5	0.198-16.7	5.0-124	0.004-0.037	0.005-0.28	0.002-0.093	
	Area Weighted Mean	961	1.29	0.233	14.3	8.86	51.8	0.019	0.14	0.052	
Wooded / Idle Perennial Cover	Mean	40.7	0.083	0.007	5.15	3.30	33.5	0.0125	0.02	0.029	
	Range	29.8-54.2	0.069-0.099	0.007-0.009	4.76-5.54	0.29-3.52	-	0.012-0.013	0.013-0.03	0.023-0.034	
	Area Weighted Mean	40.6	0.084	0.008	5.05	3.37	33.5	0.012	0.021	0.027	

* 1975 Lead Data Not Reported Due To Biased Analytical Technique

TABLE 5: Estimated Percentage Of The Total Annual Load Delivered Monthly For 1975 And 1976.

Column 1 Survey Time Period

SURVEY TIME PERIOD denotes when the monitoring data were collected at the Grand River Watershed outlet, site GR-15 (Table 5a) and at the Canagagique Creek subwatershed outlet, site AG-4 (Table 5b).

Column 2 Annual Load Percentage Delivered Monthly

ANNUAL LOAD PERCENTAGE DELIVERED MONTHLY was calculated by dividing the monthly load by the annual load and multiplying by 100.

TABLE 5a

	Survey Time Period	Annual Load Percentage Delivered Monthly - (GR-15) Watershed Outlet									
		Flow	Suspended Sediment	Total Phosphorus	Filtered Reactive Phosphate - P	Kjeldahl. -N	Filtered (Nitrate + Nitrite) -N	Chloride	Lead	Zinc	Copper
1975	January	6.5	2.9	3.9	3.2	5.4	4.7	6.9	3.7	4.1	3.7
	February	9.4	11.0	9.5	9.9	9.3	9.8	9.7	8.9	9.5	8.7
	March	17.7	19.0	20.6	23.5	18.5	21.7	14.5	18.8	21.3	20.8
	April	22.3	45.3	35.5	32.5	26.6	27.7	17.1	41.3	34.3	33.5
	May	5.5	3.5	4.0	2.6	5.2	4.0	6.6	3.5	3.9	3.7
	June	5.1	2.5	3.5	3.0	4.7	3.3	6.0	3.1	3.2	3.2
	July	3.3	1.2	1.9	1.1	3.0	1.5	4.5	1.9	1.6	1.6
	August	5.3	2.8	3.6	3.5	4.8	4.7	6.0	3.4	3.9	3.4
	September	5.5	2.4	3.5	2.6	4.8	3.9	6.3	3.4	3.5	3.1
	October	4.1	1.8	2.4	1.5	3.6	2.3	5.3	2.5	2.3	2.3
	November	5.5	3.6	3.8	3.4	4.9	4.6	6.5	3.4	4.3	3.9
	December	10.0	4.6	8.1	13.4	9.1	12.0	10.9	6.3	8.1	12.1
1976	January	4.5	1.7	2.4	1.8	4.0	3.1	5.9	2.2	2.6	2.4
	February	15.2	15.6	16.1	18.8	15.4	20.4	14.2	15.0	17.1	14.9
	March	31.7	51.3	44.2	46.6	35.3	36.8	22.5	53.3	42.2	52.7
	April	12.6	12.6	13.5	13.7	13.2	13.6	11.3	9.0	12.2	10.4
	May	10.2	8.2	8.6	7.8	9.5	9.8	9.1	6.3	12.5	7.6
	June	3.1	2.1	1.9	1.1	2.9	1.6	4.9	1.4	1.5	1.5
	July	4.4	3.0	5.4	3.2	4.1	2.9	5.5	2.9	2.8	2.5
	August	3.2	1.8	2.2	2.6	3.0	1.5	4.6	3.3	1.7	1.6
	September	3.5	1.4	1.9	1.2	3.2	2.0	4.8	1.9	2.1	1.7
	October	4.2	1.5	2.1	1.1	3.4	2.5	5.8	2.1	2.0	2.3
	November	4.2	0.5	0.9	0.7	2.6	3.0	5.8	1.7	1.9	1.4
	December	3.1	0.5	1.0	1.5	3.5	3.0	5.8	1.4	1.7	1.3

TABLE 5b

Survey Time Period	Annual Load Percentage Delivered Monthly - (AG-4) Agricultural Subwatershed Outlet										
	Flow	Suspended Sediment	Total Phosphorus	Filtered Reactive Phosphate -P	Kjeldahl -N	Filtered (Nitrate Nitrite) -N	Chloride	Lead	Zinc	Copper	
1975	January	5.2	1.0	2.2	2.9	4.0	5.3	6.1	5.3	2.2	3.4
	February	6.7	1.1	3.9	5.5	5.3	7.7	7.0	6.3	3.2	5.4
	March	22.1	4.3	17.6	25.0	19.4	25.6	21.6	21.5	17.5	21.2
	April	37.9	81.1	58.4	46.0	47.2	35.6	31.8	39.6	60.2	47.9
	May	1.1	0.1	0.4	0.4	0.9	0.6	1.4	1.0	0.4	0.7
	June	3.1	4.8	2.3	3.0	2.7	2.5	2.8	2.9	1.8	2.6
	July	0	0	0	0	0	0	0	0	0	0
	August	2.1	0.6	0.9	1.1	1.6	1.8	2.5	2.1	0.9	1.4
	September	4.2	1.9	1.9	2.6	3.5	3.3	5.2	4.1	1.8	3.1
	October	1.7	0.3	0.6	0.6	1.4	0.9	2.1	1.5	0.6	1.1
	November	3.8	1.6	1.5	1.6	3.0	2.7	4.6	3.6	1.4	2.5
	December	12.2	3.3	10.4	11.3	11.0	14.0	14.9	12.1	10.1	10.7
1976	January	2.6	0.3	1.0	1.6	1.9	2.0	3.3	2.5	0.6	1.8
	February	14.8	4.1	9.5	15.0	11.5	19.7	19.3	15.3	38.2	22.8
	March	49.5	79.4	68.5	58.1	61.4	44.2	38.8	51.4	51.6	50.2
	April	13.7	7.6	8.7	10.0	9.6	14.9	14.5	12.7	3.7	10.3
	May	7.0	3.5	5.3	5.9	6.4	6.6	6.8	6.3	3.2	5.6
	June	1.9	0.8	0.9	0.9	1.5	2.3	2.4	2.0	0.5	1.8
	July	2.6	1.5	1.2	1.5	1.8	3.0	3.3	2.4	0.6	2.1
	August	0.1	0	0	0	0	0	0.1	0	0	0
	September	0.4	0.2	0.4	0.7	0.5	0.3	0.6	0.5	0.2	0.3
	October	2.2	0.7	1.1	1.5	1.6	2.0	2.9	2.1	0.5	1.5
	November	3.4	1.8	2.8	3.5	2.6	4.2	5.5	3.1	0.7	2.4
	December	1.8	0.2	0.6	0.7	1.3	0.9	2.5	1.6	0.3	1.1

TABLE 6: Total, Dissolved And Sediment-associated Loads At The Watershed Outlet, 1976.

Column 1 Water and Sediment -Quality Parameters

MEAN SEDIMENT-ASSOCIATED LOAD (t/yr) is the product of the mean pollutant concentration measured in the suspended-sediment fraction and the annual sediment load (305,000 t) at the watershed outlet in 1976.

MAXIMUM SEDIMENT-ASSOCIATED LOAD (t/yr) is the product of the maximum pollutant concentration measured in the suspended-sediment fraction and the annual sediment load (305,000 t) at the watershed outlet in 1976.

MINIMUM SEDIMENT-ASSOCIATED LOAD (t/yr) is the product of the minimum pollutant concentration measured in the suspended-sediment fraction and the annual sediment load (355,000 t) at the watershed outlet in 1976.

PERCENTAGE OF TOTAL LOAD is calculated as follows:

$$\begin{array}{l} \text{Sediment associated} \\ \text{percent of total load} \end{array} = \frac{\text{SSC}_w \cdot \text{PC}_{ss}}{(\text{SSC}_w \cdot \text{PC}_{ss}) + \text{PC}_w} \times 100$$

where:

- SSC_w is the mean suspended-sediment concentration in water
- PC_{ss} is the mean pollutant concentration in suspended sediment
- PC_w is the mean pollutant concentration in water

DISSOLVED LOAD (t/yr) is the difference between the mean sediment-associated load and the total load.

TOTAL LOAD (t/yr) is the mean sediment-associated load, divided by the sediment associated percentage of the total load, multiplied by 100. Estimates of total load, computed by the IJC recommended method from water-quality monitoring are included in parentheses for comparison with the appropriate parameters that were analysed in the sediment fraction.

TABLE 6

PARAMETER	1976 Loading At The Watershed Outlet					
	Sediment Associated				Dissolved (t/yr)	Total (t/yr)
	Mean (t/yr)	Maximum (t/yr)	Minimum (t/yr)	Percentage Of Total		
Phosphorus	499.	882.	335.	82	109.	609. (619.)
Nitrogen	1,600.	4,260.	639.	17	7,830.	9,430. (9,330.)
Iron	9,280.	10,000.	7,910.			
Manganese	292.	426.	179.			
Aluminum	5,990.	6,990.	5,170.			
Arsenic	1.7	1.9	0.9	20	6.8	8.5
Chromium	15.6	20.4	12.8	59	10.8	26.4
Selenium	0.3	0.3	0.2			
Nickel	9.5	14.6	7.6	42	13.1	22.6
Cadmium	0.4	0.8	0.2	9	4.0	4.4 (3.6)
Mercury	0.02	0.03	0.003			
Copper	12.2	16.1	7.3	49	12.8	25.0 (28.6)
Lead	18.9	36.5	12.5	54	16.1	35.0 (15.0)
Zinc	88.5	225.	60.8	73	32.7	121.0 (91.0)
Cobalt	3.4	4.8	2.7			
Organic Matter	34,800.	84,500.	18,900.	100	0.0	34,800.
PCBs	0.0189	0.0355	0.0	100	0.0	0.0189
PP DDT	0.0013	0.0061	0.0	100	0.0	0.0013
PP DDD	0.0018	0.0091	0.0	100	0.0	0.0018
OP DDT	0.0004	0.0030	0.0	100	0.0	0.0004
PP DDE	0.0005	0.0061	0.0	100	0.0	0.0005
α-Chlordane	0.0007	0.0030	0.0	100	0.0	0.0007
γ-Chlordane	0.0007	0.0030	0.0	100	0.0	0.0007

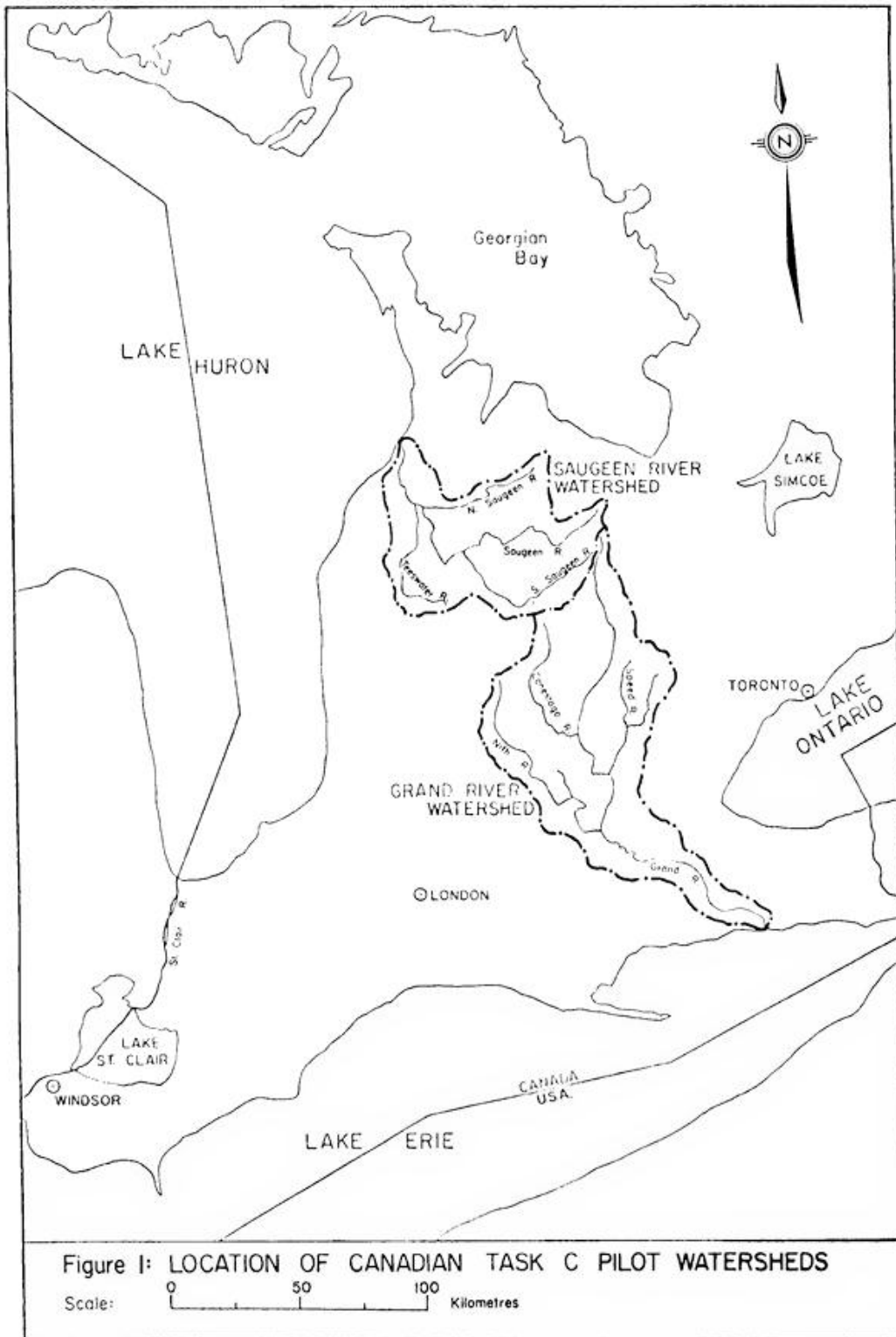
11.0 DATA INTERPRETATIONS AND CONCLUSIONS

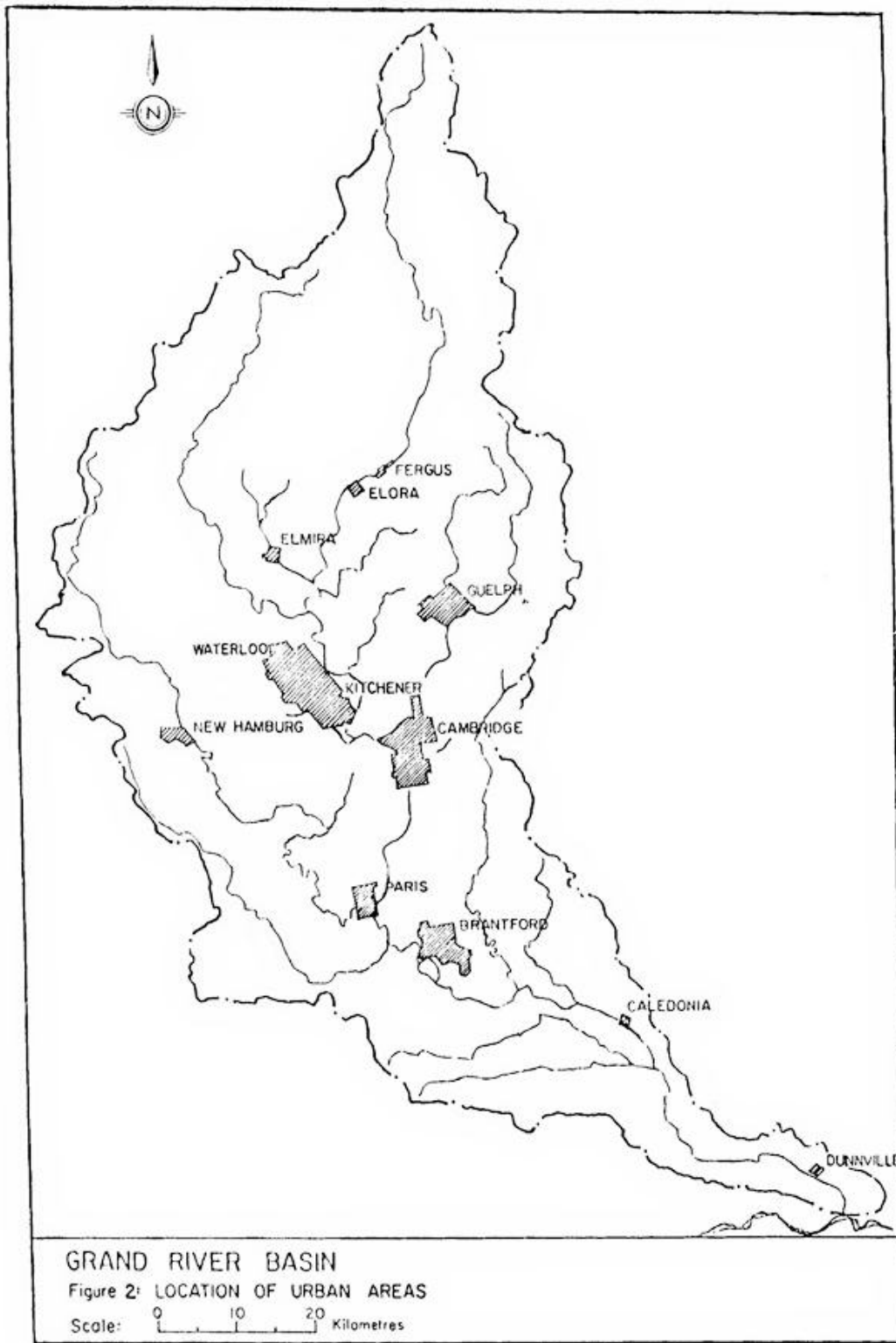
The Grand River is the largest river basin in southwestern Ontario, draining an area of approximately 667,000 hectares (Figure 1). The headwater area of the river is a swampy upland south of Georgian Bay at an elevation of approximately 526 m above sea level. The river runs a course of approximately 290 km to Lake Erie at Port Maitland. The Nith, Conestogo and Speed rivers are the three major tributaries which join the main stem in the middle portion of the basin. The Conestogo River drains the northwestern portion of the basin with the Nith and Speed rivers draining the western and eastern portions of basin, respectively. In the upper part of the basin the river and its three main branches flow, for the most, in previously formed glacial spillway channels. In the lower part, below the City of Brantford, the river has scoured its own channel across glacial lake deposits of silt and clay.

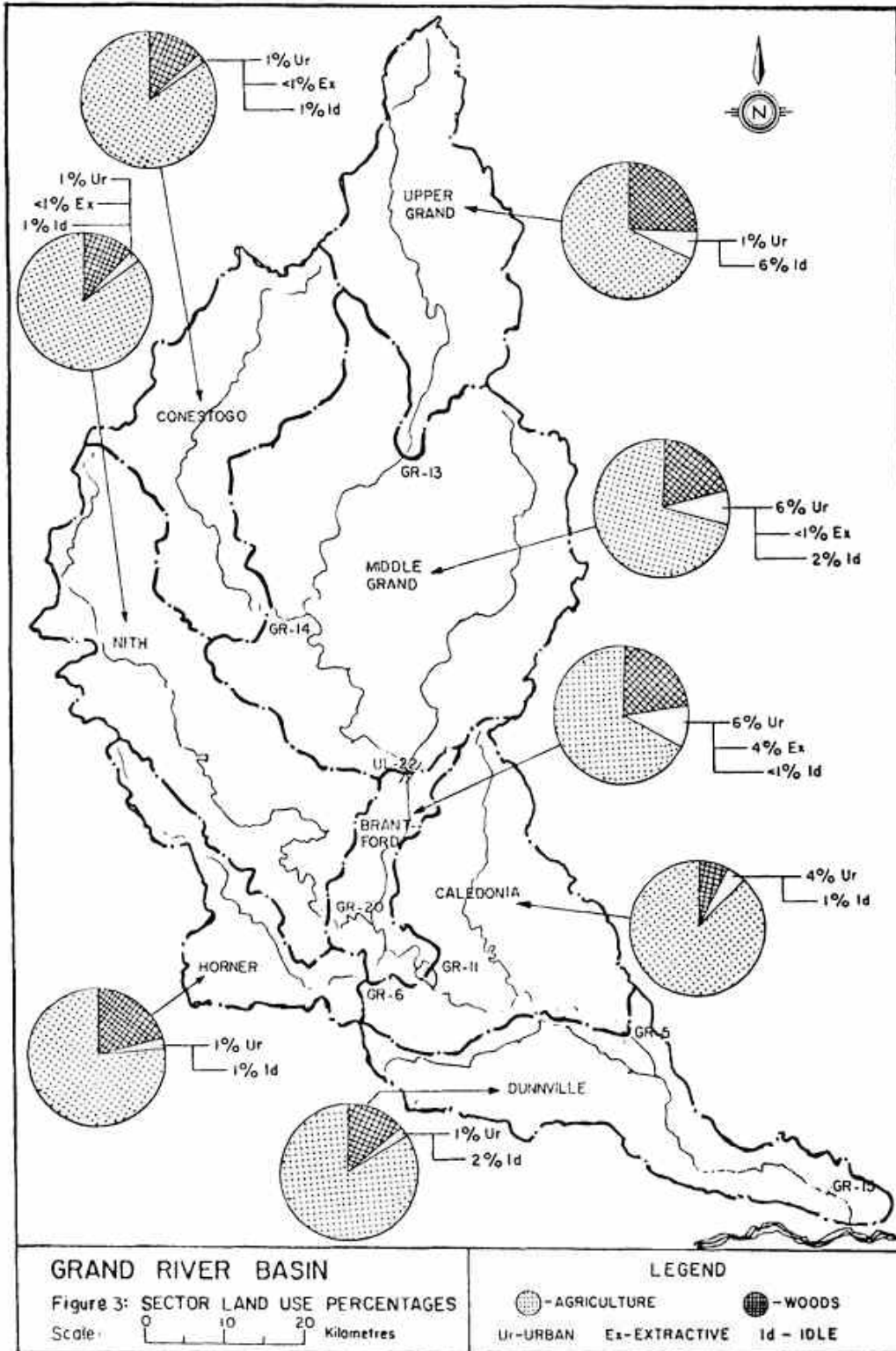
From the headwaters to the City of Brantford (Figure 2), the main stem of the river flows with an average gradient of about 0.00161 metres per metre. Valley cutting for a distance of about 65 km downstream from the headwaters to Elora is inhibited by the limestone bedrock which underlies much of this area at relatively shallow depths. The valley in this reach of the river varies in depth from 18-30 m. In the vicinity of Elora (Figure 2) the river follows a deep gorge in the limestone bedrock which is probably pre-glacial or glacial in origin. Below Elora the valley continues to follow a major glacial spillway complex with the valley deepening to 45 m at Brantford. Below Brantford the valley is cut in glacial lake deposits of silt and clay. The river flows from Brantford, for approximately 65 km to Lake Erie, with a reduced gradient, generally less than 0.000379 metres per metre.

The Grand River basin has been developed extensively for urban and agricultural uses which respectively comprise 3% and 75% of the total basin area. Approximately 19% of the basin area is wooded and/or idle and the remaining 3% lies in other uses. Western sections of the mid-basin, in the vicinity of the Nith and Conestogo river systems, are subject to fairly intensive cultivation (Figure 3). Urban land use (figures 2 & 3) is concentrated primarily in the central portion of the basin in the Kitchener/Waterloo/Cambridge area and with in the cities of Guelph and Brantford. The urban population of the basin is approximately 435,000 out of a total basin population of 514,000.

Climatically the long term, mean annual temperatures vary from 6°C in the headwaters to 9°C at Lake Erie. Long term, mean annual precipitation varies from 84 cm in the lower reaches to 88 cm in the upper reaches of the basin. Numerous flow-gauging sites exist in the basin and continuous flow records have been maintained at a few locations for up to 5 years. Mean annual flow at the outlet of the river is estimated to be 64 m³/s which corresponds to a mean annual runoff of 30 cm of precipitation. Numerous small reservoirs and four major impoundments exist in the basin, so that annual low flows are currently maintained at about 5 to 15 m³/s. Peak discharges range from 500 to 1400 m³/s. Generally, peak discharges occur during the spring melt; however, discharges amongst the highest ever experienced occurred as a result of Hurricane Hazel in November of 1954.







In terms of the study years 1975 and 1976, mean annual flows at the outlet were estimated to be 69.2 and 86.8 m³/s respectively. High flows in the order of 900 m³/s, occurred during the spring-melt period for both years. Frequency analysis was applied to the mean annual flow sequences at two mid-basin sites, GR-11 and UL-22 (Figure 4), which had over 40 years of continuous flow records. Both sites are on the main stem of the Grand River below the largest urban complex in the basin. Results of the frequency analyses indicate that 1975 and 1976 had above average flows, with recurrence intervals of about 2.7 and 11.7 years. The analysis could not be applied to peak discharge records because of anthropogenic interventions such as, clearing of forests for agriculture, streamflow regulation and urbanization.

In conjunction with the long-term flow records at sites UL-22 and GR-11, historical, water-quality data sets obtained from the routine Ministry of the Environment surveillance monitoring records were used to compute loads. Flows and estimated loads for the period 1966 to 1976 are shown in Figure 5. Because the sampling for this period was sparse and not event oriented, the load estimates are considered to be approximately indicative of what may have actually been exported from the basin. Comparison of the 1976 PLUARG estimates with the Ministry's surveillance monitoring network suggests that historical loadings are consistent (same order of magnitude) with the PLUARG observations. The 1974 to 1976 loading estimates for filtered reactive phosphate (Figure 5) appear to reflect the installation of phosphorus-removal practices at the sewage treatment plants in the basin; however, insufficient historical sampling is available to substantiate this observation.

In order to present a general overview of pollutant contributions throughout the watershed, loading estimates were prepared at selected sites (Table 1) located along the main stem of the Grand River (Figure 4). These loads were estimated, by the IJC recommended method of calculation, from PLUARG monitoring data collected over the 1975 and 1976 study years. These values were reduced to an annual basis for comparative purposes. The data presented in Table 1 suggest that loads (both total and unit area) increase downstream to the City of Brantford (GR-11) below which a marked load decrease in sediment-associated parameters (total phosphorus and Kjeldahl nitrogen) occurs. Loads for the soluble parameters (filtered reactive phosphate and nitrate plus nitrite-nitrogen) continue to increase below GR-11 to GR-15, suggesting that sediment is being deposited over this river reach (GR-11 to GR-15). Slower moving water as a result of a reduced river gradient from .00161 to .00038 metres per metre below Brantford (GR-11) may be in part responsible for the reduced sediment load of the river.

The reader is cautioned that sampling records for sediment and sediment-associated parameters at sites UL-11, GR-11 and GR-5 appear susceptible to upward biases (previously discussed in Section 9.3.5.2) because of the sampling experienced at these sites (i.e. loads are contingent on a few high concentration values observed on the high flow days of the study period). This

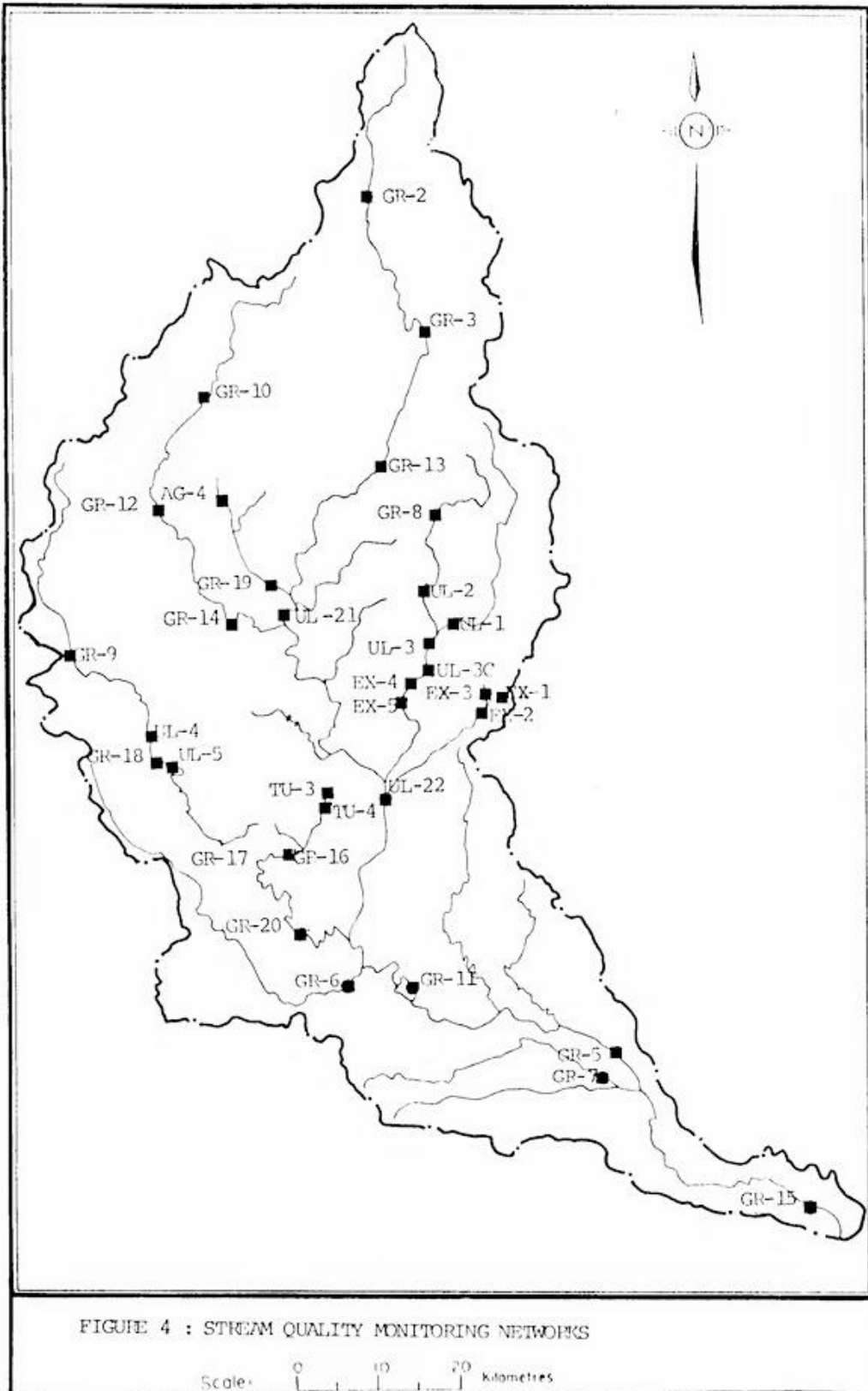
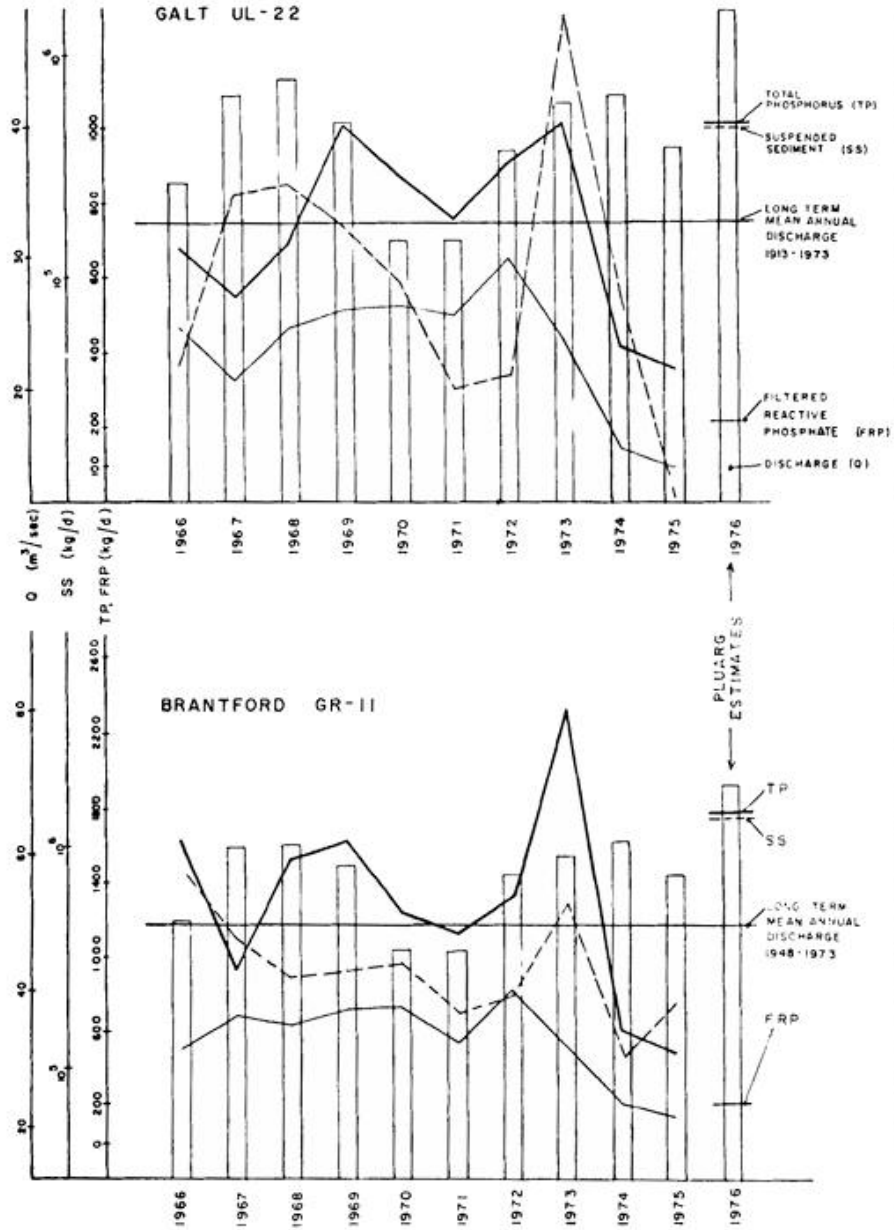


FIGURE 4 : STREAM QUALITY MONITORING NETWORKS

Scale: 0 10 20 Kilometres

FIGURE 5: HISTORIC LOADINGS FROM MOE SURVEILLANCE MONITORING NETWORK (TP, FRP, and SS, 1966-75)



phenomenon may also be contributing to the discrepancies observed in sediment loads below Brantford (GR-11). Estimates for soluble parameters such as filtered reactive phosphate and filtered nitrite plus nitrate-nitrogen appear to be reasonably accurate at all sites. The values for all parameters at site GR-15 are considered to be the most reliable of the data set presented in Table 1.

The progressive degradation of water quality in the Grand River along its course can be illustrated for the soluble parameters (filtered reactive phosphate and filtered nitrite plus nitrate-nitrogen). The data in Table 1 suggest that the upper reaches above GR-13 (Figure 4) are relatively clean and that downstream loads (for soluble parameters) increase consistently from site-to-site. Between GR-13 and UL-21 loads undergo significant increases likely associated with agricultural activities of increasing intensity in this area. A further significant increase is observed from UL-21 to UL-22 reflecting the impacts of both intensive agriculture in the central portion of the basin and the large urban complex of Kitchener/Waterloo/Cambridge (Figure 2). Further downstream, total loads continue to increase but unit contributions appear to be maintained or possibly decrease slightly, reflecting the diminished intensity of agricultural activities towards the lower reaches of the river. The combined pressures of urban, agricultural and attendant activities appear to be responsible for substantial increases in the nutrient and sediment loads in the Grand River watershed.

11.1 CAUSES AND SOURCES OF POLLUTANT CONTRIBUTIONS

In the Grand River pilot watershed, the major sources of pollution from the land uses studied have been tentatively identified as follows:

<i>Urban</i>	<i>metals, organic chemicals, bacteria, phosphorus</i>
<i>Point Sources</i>	<i>metals, organic chemicals, phosphorus, nitrogen, chloride</i>
<i>Transportation</i>	<i>lead, chloride</i>
<i>Private-waste Disposal,</i>	<i>phosphorus, nitrogen</i>
<i>Agriculture</i>	<i>sediment, phosphorus nitrogen</i>

11.1.1 URBAN LAND DRAINAGE

Approximately 3% of the Grand River Basin is urbanized. The major urban concentration in the watershed occurs in the central portion of the basin (Figure 2) commonly referred to as the industrial triangle (Kitchener/ Waterloo/Cambridge complex). This urban/industrial triangle represents the highest density of population (53% of the basin's urban population of 435,000) and industrial activity (more than 650 water-using industries) in the basin. Other urban centres in the basin are Guelph, which is located at the confluence of the Speed and Eramosa rivers, and Brantford, on the main stem of the Grand River approximately 65 km upstream from Lake Erie.

Monitoring data suggest that the major pollutant inputs from urban land drainage are lead, copper, zinc (Table 2) and PCBs. These pollutants are generated as a result of industrial, commercial, residential and automobile emissions, point-source discharges and spills, street litter and construction activities. The major pollutant inputs to receiving streams from urban drainage occur during storm events (Table 3). The particulate build-up on the impervious surfaces in an urban area occurs as a normal accumulation phenomenon from the concentration of industry, population, traffic, etc. The particulate accumulation is then "washed off" by surface runoff during storm events.

Bacteriological pollution (high levels of fecal pollution indicator bacteria probably derived from pets, rodents and birds) may also be a problem in urban runoff. Pathogens (*Pseudomonas aeruginosa* and *Salmonella*) were detected at the downstream outlet of an urban subwatershed under study in the basin and have also been found in combined and sanitary-sewer overflows during heavy rainfall events. These kinds of bacterial pollution, if not treated, can constitute a potential health hazard particularly if the receiving water is to be used for recreational activities or public water supplies.

Total runoff attributed to urban land use in the Grand River watershed does not appear to be a significant factor in the degradation of the Great Lakes water quality. This assessment seems to be reasonable when the Grand River urban areas are compared with large urban areas such as Detroit, Cleveland, Hamilton, and Toronto which are all located on the shores of the Great Lakes with direct runoff to the lakes. Preliminary investigation of pollutant transport in the Grand River indicates that, on an annual basis, less than 100% of the sediment-associated pollutants entering the stream reach Lake Erie. This is an important factor because the majority of urban land in the basin is situated approximately 100 km from the lake. However, this may only be a short-term effect as there are not any large impoundments or reservoirs downstream of the urban areas to the mouth suggesting that sedimentation in the stream channel is probably occurring. Subsequent high or extreme flows in the future will probably resuspend these materials and transport them into Lake Erie. In terms of the proportion of the load attributable to urban runoff at the mouth of the Grand River, a significantly higher proportion than 3% of the basin load (up to 20% of the metals load) is derived from urban runoff. This suggests that urban runoff has a greater impact on the water quality of the Grand River than on the Great Lakes water quality.

11.1.2 POINT SOURCES

Industrial and domestic waste contributed by more than 650 water-using industries and approximately 74% (374,000) of the 514,000 basin population are transmitted via sanitary sewer systems for treatment at one of the twenty-two sewage treatment plants serving the urban areas in the Grand River watershed (Figure 2). Cooling, process and general purpose waters from 95 commercial, industrial and institutional sources are discharged after any required treatment to storm-sewer systems or directly to the receiving streams. Estimates of all these point-source discharges were prepared using the routine monitoring data collected by the Ontario Ministry of the Environment and supplemented by PLUARG monitoring at some locations for parameters not normally sampled by the Ministry.

In 1976, ninety-three million cubic metres of municipal waste were treated by the 22 sewage treatment plants in the watershed. Nine sewage treatment plants located in the urban areas of greatest population (Cambridge, Kitchener, Waterloo, Brantford, Guelph, Elmira and Dunnville) and industrial activity (Figure 3) treated 94% of this water volume. Only a few industries are located in outlying rural districts and smaller urban centres. The types of industries common to the Grand River watershed are textile and rubber manufacturing, metal processing, chemical industries and food processing operations including large abattoirs and meat packing plants. A combined municipal and industrial, point-source discharge quantity of approximately 4 m³/s is a significant proportion of the low flow or baseflow in the Grand River which, based on historic records, ranges from 5 to 15 m³/s.

Separate sewer systems exist throughout almost all of the communities serviced by the 22 sewage treatment plants. A few combined sewer systems are found in relatively small areas of the older urban centres (i.e. Kitchener). Phosphorus removal was instituted in 1974 by all of the sewage treatment plants in the Grand River basin.

The PLUARG monitoring data, obtained from sampling the outfalls of the nine major sewage treatment plants in the basin, suggest that the major pollutant inputs from point sources are phosphorus, nitrogen, metals and chloride. Trace amounts of PCBs (10⁻² to 10⁻⁵ kg/d) were detected at all nine of the sewage treatment plants where supplementary sampling was undertaken for the PLUARG program. Traces of various pesticides (Lindane and DDT derivatives) have also been detected.

11.1.3 TRANSPORTATION CORRIDORS

Provincial, County and Township highways occupy approximately 1.7% of the land (11,300 ha) in the Grand River watershed. The major pollutants produced as a result of the maintenance of these transportation corridors are chloride and sodium from highway deicing operations. Literature studies (Ministry of the Environment, 1974) report that other pollutants such as oil and grease, pesticides and heavy metals may be produced as a result of routine maintenance operations. One study (Laxen *et al*, 1977) reported that airborne lead was accumulating in the soil downwind of major highways.

Monitoring data from a 1.3 km length of 4-lane highway in the basin confirms increased chloride loads as a result of deicing operations. Preliminary results from soil sampling suggest that lead has been accumulating downwind of the highway in the soil. All other water-quality parameters that were monitored in a small stream draining the area alongside the highway, with the exception of filtered nitrite plus nitrate-nitrogen, did not exhibit increased concentrations downstream of the highway. Similarly, levels of heavy metals and pesticides were unchanged downstream of the highway in both suspended sediment and bed sediment samples.

11.1.4 PRIVATE WASTE DISPOSAL

In the Grand River basin, approximately 13% (56,000) of the urban population use private-waste disposal systems (i.e. unsewered) throughout the year. A total (both urban and rural) population of 135,000 people use approximately 36,000 private-waste disposal systems throughout the basin. An additional 7,000 systems are used in seasonal dwellings and their pollutant input to the watershed is minimal in relation to the permanent systems.

Monitoring studies suggest that the only pollutants of concern from private-waste disposal systems are phosphorus and to a lesser extent nitrogen. Bacterial contamination may occur as a result of runoff from faulty private-waste disposal systems (seepage of septic-tank effluent) and create localized problems in the receiving waters.

11.1.5 AGRICULTURAL LAND

Agricultural watershed information indicates that the nature and type of agricultural activity is reflected in the water quality of the receiving streams. Increased sediment loads will occur as a result of disturbance of natural conditions by various agricultural practices. Approximately 75% (Figure 3) of the Grand River watershed is in agriculture of varying intensity which produces significant amounts of phosphorus and sediment from runoff. Elevated phosphorus levels have been reported (Agricultural Watershed Studies, 1977) to be related primarily to soil characteristics or manure-use practices.

Runoff from moderate to high-density livestock operations, manure application and waste from wild animals appears to be the main source of bacterial contamination.

11.1.6 SOLID AND LIQUID WASTE DISPOSAL

Because of their limited areal extent in the basin, minimal impacts on stream-water quality have been monitored from waste-disposal practices (sanitary landfills, processed organic waste and spray irrigation) in the Grand River watershed. Increased land usage of these particular practices could create an impairment in stream-water quality with respect to nutrients and chlorides. If the waste is enriched with heavy metals and organic chemicals, accumulations in the soil could ultimately create an environmental health hazard if proper design and management procedures are not observed.

11.1.7 EXTRACTIVE INDUSTRIES

Sand and gravel pits and limestone quarries occupy only 130 hectares in the Grand River watershed (Figure 3). The major pollutant from these extractive industries is sediment from the washing of the aggregates.

Two extractive operations, (a sand and gravel pit and a limestone quarry) using settling ponds, for treatment of the waste water used to process the aggregates do not affect receiving-stream water quality.

11.1.8 UNDISTURBED LAND

Monitoring data suggest that subwatersheds which are in relatively undisturbed states (woodlots and idle land) have a minimal impact on the receiving streams. Approximately 19% of the Grand River watershed is wooded or idle land (Figure 3). Runoff from these areas of perennial vegetation cover is considered to represent natural conditions. Monitoring at the outlets of subwatersheds with large proportions of their area in an undisturbed state suggest that heavy-metal inputs are occurring naturally from chemical and physical weathering of the limestone and dolomite (carbonate) bedrock in the basin. These carbonate rocks are naturally high in lead, cadmium and zinc. Soils may contain natural levels of phosphorus formed from the decomposition of the parent materials containing minerals such as apatite and collophane.

11.1.9 OTHER LAND USES

Pollutant inputs from land uses and practices such as mine tailings and radiological waste disposal were not studied as these land uses were not located in the pilot watershed.

11.2 EXTENT OF POLLUTANT CONTRIBUTIONS IN UNIT AREA: LOADINGS FROM LAND DRAINAGE WITHIN THE WATERSHED

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 what land uses or practices may yield cost-effective control measures. Examination of the seasonal loading distribution can identify critical periods of the year during which controls should be applied (i.e. spring melt).

Annual unit-area loads for those parameters which are considered to be important by the PLUARG in terms of impairment of Great Lakes water quality, have been tabulated for the land uses in the Grand River watershed. These data are presented in Table 4. Since the PLUARG monitoring data were insufficient to derive the unit-area loads for land use subcategories (i.e. commercial, industrial, etc.), estimates from other non-PLUARG studies were incorporated into Table 4.

Based on the unit-area loads listed in Table 4, pollutant ranking of the three major land-use categories in the watershed has been undertaken. The ranking is based on unit-area load comparison with each of the land uses, using the smallest unit-area load as unity. These ratios are presented below.

	TP	FRP	TN	SS	Cl	Pb	Zn	Cu
Urban	17	12	1	26	6	20	25	3
Rural	10	29	2	14	1	1	5	1
Wooded	1	1	1	1	1	1	1	1

where: TP = total phosphorus; Cl = chloride
FRP = filtered reactive phosphate; Pb = lead
TN = total nitrogen; Zn = zinc
SS = suspended solids; Cu = copper

The above ranking suggests that urban runoff relative to drainage from rural and wooded land is potentially the largest contributor of total phosphorus, sediment, chlorides and metals. The ranking also suggests that rural runoff compared to urban and wooded areas is the major contributor for nitrogen and filtered reactive phosphate.

PLUARG monitoring data suggest that the bulk of the river loads are transported during the months of February, March, April and May which is normally the spring melt or high-flow period of the year. This marked seasonality of pollutant transport is illustrated in Table 5a. The monthly percentages of the load at the watershed outlet (GR-15) are based on daily-load estimates derived from sampling and supplemented by regression estimates where daily samples were not obtained. The values demonstrate that a significant proportion of the total load for all parameters is delivered during the spring melt. In 1975 during the months of February, March, April and May, approximately 55% of the total annual flow occurred and 60 to 70% of the total annual load for each parameter, except chloride, was exported during that period. During the same months in 1976, 70% of the flow occurred resulting in a delivery of 75 to 85% of the total annual load for each parameter, except chloride. Chloride as a conservative parameter tends to decrease in concentration as flow increases; nevertheless, a substantial proportion of the total annual load was delivered during the spring melt (51% for 1975 and 58% for 1976).

Table 5b presents monthly percentages of the annual load for site AG-4, the outlet of a small stream in a predominantly agricultural catchment. The same seasonal dependencies are apparent, but are even more sharply delineated. Local climatic conditions (i.e. intense summer storms) can significantly alter the proportion of the annual load that is delivered monthly or seasonally in a small catchment. Generally, these local conditions are not basin-wide in extent and as a result their effect is not reflected strongly at the outlet of a large basin such as the Grand River watershed. The dominating load from a large watershed such as the Grand River is that from the spring-melt period.

11.3 RELATIVE SIGNIFICANCE OF SOURCES WITHIN THE WATERSHED

Ranking of the critical land-use categories in the Grand River watershed, in terms of total loading, has been established using the data presented in Table 2. These data are summarized as follows:

<i>Phosphorus</i>	- agriculture - point sources - private-waste disposal
<i>Nitrogen</i>	- agriculture - private-waste disposal - point sources
<i>Sediment</i>	- urban (metals, organic chemicals) - agriculture (eutrophication)
<i>Metals</i>	- point sources - urban - processed organic waste - spray irrigation
<i>Organic Chemicals</i>	- point sources - urban
<i>Pesticides</i>	- agriculture - urban
<i>Chloride</i>	- transportation - point sources - sanitary landfills - processed organic waste - private-waste disposal
<i>Bacteria</i>	- agriculture - urban

Assuming that runoff from undisturbed areas (wooded and idle land) is a natural input, subwatersheds with a high proportion of these areas (such as in the headwaters of the Grand River) can be used comparatively to rank the anthropogenic inputs discussed above. In addition, loading estimates from the land uses represented in the Grand River watershed were totalled and compared with the monitored load in 1975 and 1976 at the watershed outlet (GR-15). Percentages of the total load at the mouth of the Grand River were assigned to the respective land uses in the watershed (Table 2). The ratio of the monitored to estimated load is a gross approximation of the in-stream transport effects (Table 2).

11.3.1 PHOSPHORUS

Agriculture, point-source discharges and private-waste disposal systems are the primary contributors of phosphorus as indicated by the proportion of the total estimated load (Table 2b) at the mouth of the Grand River for these land uses. However, in terms of available phosphorus for biological uptake (filtered reactive phosphate); point-source estimated increased to 37% from 25%, agriculture decreased to 49% from 64% and private waste disposal increased to 13% from 5% of the total phosphorus load at the mouth. The significance and control of phosphorus from these three land uses and practices appears to be critically important in terms of boundary-water impairment.

11.3.2 NITROGEN

Agriculture, point-source discharges and private-waste disposal are the major contributors of various nitrogen forms (Table 2). Both agricultural practices and private-waste disposal systems may contribute significant amounts of nitrite + nitrate - nitrogen to the ground-water system. This form of nitrogen is highly soluble and once in the ground water can be transported rapidly. Fortunately most problems with the pollution of ground water by nitrogen are usually localized in areal extent at the present time; however, the number of occurrences appears to be increasing.

Nitrogen from point-source discharges is predominantly in the form of Kjeldahl and ammonia. Biochemical transformations (nitrification/denitrification) normally take place downstream of the point-source outfalls and supplement the dilution effects of the receiving streams in assimilating the waste effluent.

11.3.3 SEDIMENT

Excessive sediment will impact on receiving waters in terms of aesthetics, photosynthesis and ecosystems (inhibiting bottom organisms and fish spawning). In addition, the adsorptive capability of finer-grained sediment is extremely important in scavenging and transporting potentially hazardous materials (i.e. organic chemicals, metals, etc.). Accumulation and later release of these materials may occur under changing equilibrium conditions.

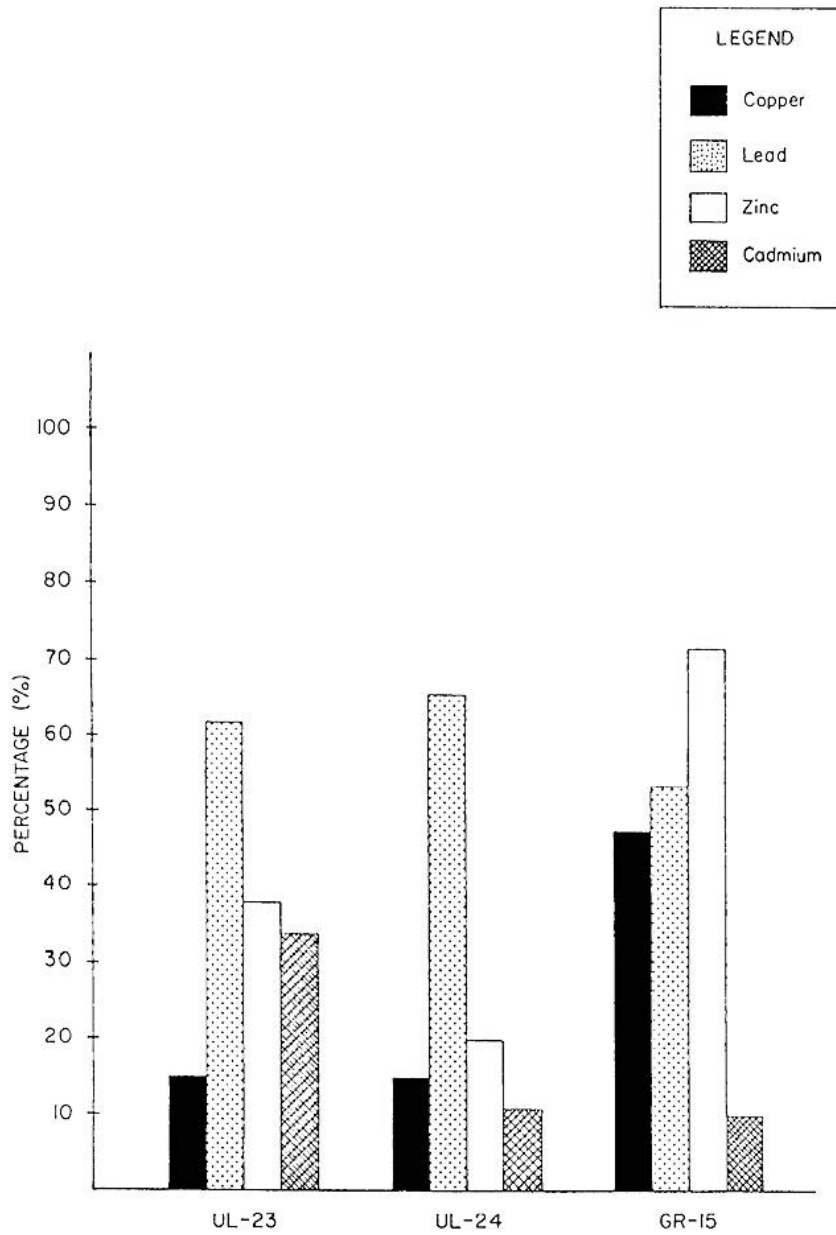
In terms of sediment (Table 2), agriculture and urban areas contributed thirteen to twenty-six times as much as undisturbed areas (i.e. approximately 500 to 1000 kg/ha/yr respectively). Urban land use in the Grand River basin is quite low (approximately 3% of the basin area) but contributes approximately 6% of the sediment load at the mouth of the river.

11.3.4 TOXIC MATERIALS (METALS, PESTICIDES AND ORGANIC CHEMICALS)

Toxic materials such as heavy metals, pesticides and organic chemicals have a strong affinity for the clay-size sediment fraction and as a result suspended sediment is a major transporter of these pollutants. Monitoring data indicate that the percent of the total load due to the particulate fraction varies from; 10-50% for copper, 50-70% for lead and 20-70% for zinc (Figure 6).

Toxic metals associated with effluent discharges from point sources in the basin range from 10-25% of the total estimated load at the mouth. A significant proportion of the estimated metals load at the mouth (15 - 20%) is also contributed from diffuse urban runoff (tables 2h, i and j) which represents only 3% of the total land use in the basin.

Figure 6: PERCENTAGE OF METALS LOAD CARRIED
IN THE PARTICULATE PHASE
(Cu, Pb, Zn, & Cd)



Only limited information is available on organic chemicals at the present time; however, trace amounts have been detected in urban runoff and point-source discharges. Airborne transport of these materials from other source areas and subsequent fall out over relatively undisturbed land may also occur. Estimates of loadings for these parameters are not possible because of the limited data base. As indicated above, monitoring results suggest that a significant portion of the total load is sediment borne and as a result, further control measures for sediment-associated toxic materials may be necessary for urban areas. Toxic materials associated with other land uses are considered to be natural inputs from the chemical and physical weathering of earth materials.

11.3.5 CHLORIDE

Highway deicing salt is one of the most important practices contributing to increased chloride levels in the boundary waters. A complete inventory of salt usage as a deicing agent was solicited from the larger municipalities in Ontario and the Ministry of Transportation and Communications for the winter period of 1975-76. Based on these data, the amount of salt used as a deicing agent during the winter of 1975-1976 is approximately 50% of the chloride load that was measured at the mouth of the Grand River in 1976. It is not anticipated that all of the salt spread in 1975-76 will immediately appear in the Grand River system because of infiltration into the ground-water system. Background levels of chloride contribution were estimated conservatively to be about 20 kg/ha/yr for both agricultural and wooded/idle land use categories (Table 2g). A higher unit load input would be required if transportation corridor inputs were considered in these categories.

Discharge of ground water to receiving streams is slow with ground-water velocities ranging from two metres per day to two metres per year. As a consequence, levels of chloride in ground water adjacent to highway have been increasing as the use of salt as a deicing agent has increased. Salt usage on provincial highways has doubled from 1960 to 1975. As a result of governmental concern, a review of salting practices is being undertaken. In the Ontario portion of the lower Great Lakes basin, it is estimated that 770,000 metric tonnes of salt (470,000 metric tonnes of chloride) were used for highway deicing during the winter of 1975-76. Highway salting ranges from 20 metric tonnes of salt (13 metric tonnes of chloride) per kilometre of two-lane highway to 67 metric tonnes of salt (40 metric tonnes of chloride) per kilometre of four-lane highway.

Point-source discharges contribute approximately 30% of the chloride load at the mouth of the Grand River (Table 2). Sanitary landfills are estimated to contribute a large unit-area load (2,600 kg/ha/yr) but the significance tends to be diminished by the small area in use (only 530 ha) in the Grand River basin. Other sources of chlorides are private-waste disposal systems and spray-irrigation operations, both of which are not considered to be significant basin-wide contributors (Table 2). Natural inputs of chlorides are estimated to be in the order of 20 kg/ha/yr amounting to about 15% of the total load measured in 1976 at the watershed outlet.

11.3.6 BACTERIA

Agricultural and urban areas that are contaminated by animal (wild and domestic) wastes, are responsible for most of the microbial pollution. Bacterial populations derived from these land-use areas are principally of local concern, since die-off rates limit actual in-stream transport. Microbial contamination is considered significant to Great Lakes water quality only where runoff is discharged directly to the lakes and in areas where the lakes are used for body-contact recreation.

11.4 TRANSMISSION OF POLLUTANTS FROM SOURCE AREAS TO BOUNDARY WATERS

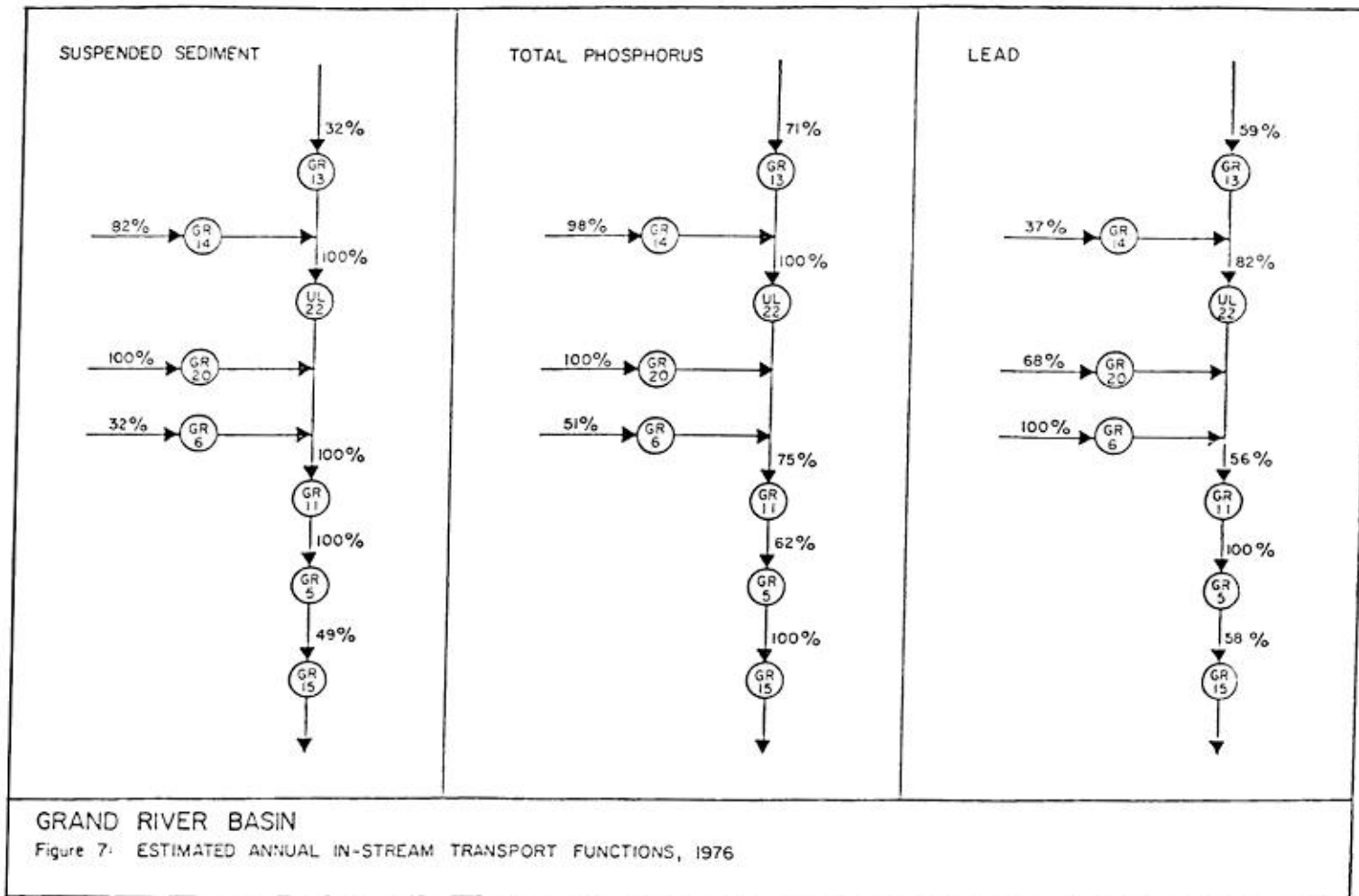
An understanding of the in-stream transport of pollutants is essential if the importance of source areas to the degradation of boundary waters is to be assessed. Several PLUARG Technical committees have recognized that deficiencies in existing land-use loading models and process-response studies exist 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 pollutant transport phenomena. As an example, phytoplankton growth converts nutrients from soluble to organic sediment forms which may be released 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 (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 transport for dissolved and clay-sized particles seems reasonable both on 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. $10 \text{ m}^3/\text{s}$ at the mouth).

The coarser particulates (silt and sand) are transported intermittently by suspension and bed-load movement. Flow-regulation structures and stream reaches with low stream velocities may temporarily trap coarser sediment. Subsequent high flows often result in remobilization of 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 land-use activities regardless of their distance from the Great Lakes will have an impact on the Great Lakes. On an annual basis, however, monitoring data in the Grand River watershed demonstrate that the in-stream transport



of contaminants can be extremely variable and substantially less than 100% in some areas, especially for sediment-associated contaminants.

Estimated annual, in-stream transport functions for suspended sediments, total phosphorus and lead along stream reaches in the Grand River watershed for 1976 are shown in Figure 7. The transport functions are expressed as percentages which were calculated as described previously (in Section 9.3.7). These values should be viewed with extreme caution at this stage because the assumption that stream-bank erosion does not contribute any material is likely in error, and therefore, the total load estimate (using the method described in Section 9.3.7) is probably too low. Inaccuracies in estimating point and diffuse source loads and calculating monitored loads also contribute to the poor reliability of the derived transport-function values. Further study will be required to refine the loading estimates used in the mass balance equation (Section 9.3.7).

A transport value of less than 100% probably represents in-stream "deposition" conditions; however, a value of 100% or more does not necessarily mean that all sediment entering this stream reach passes the outlet station. Although streambank and channel erosion have been assumed to be non-existent for the purpose of simplifying the analysis, it is possible that both in-stream deposition and scour are occurring in different reaches of a catchment and the resultant load at the outlet is a combination of stream erosion and overland-transported material. Estimates of less than 100% in-stream transport of suspended sediment were obtained from the 1976 monitoring data for the stream reaches (figures 4 and 7) above sites GR-14 (32%), GR-13 (32%), GR-6 (32%) and between GR-5 and GR-15 (49%). These data suggest that sediment deposition occurred along the above-mentioned reaches during 1976. The low transport values for the reaches above GR-13 and GR-14 are probably due to sedimentation in the reservoirs associated with the flow-regulation structures in these reaches. The low transport value between GR-5 and GR-15 is probably due to the reduced, longitudinal stream profile of 0.00038 metres per metre over this river reach.

11.4.2 BIOCHEMICAL PROCESSES

Aquatic plants can cause a significant retention of nutrients due to biological uptake during growth periods and subsequent rapid release of nutrients during times of stress. Various attached algae and rooted macrophytes (Cladophora, Potamogeton, etc.) inhabit shallow, fast-flowing river reaches in the Great Lakes basin during the late spring and summer months. These plants grow attached to or rooted to the rubble substrate and carry on their life process "in-situ" (photosynthesis and respiration) until some external environmental factor (i.e. temperature change) stresses the plants. When the plants are stressed some die and are transported downstream.

Both respiration and photosynthesis are in part dependent on temperature which can inhibit plant growth. In addition to light, phosphorus, nitrogen and carbon can also be limiting to aquatic plant growth. Tolerance limits for nutrient concentrations vary widely with plant species.

The aquatic weed growth in a 3.75 km stretch of the middle Grand River above the confluence of the Conestogo River (Figure 1) has been studied since 1974 by the Ontario Ministry of the Environment as part of an ongoing Ministry program on the "Grand River Basin Water Management Study". A mass-balance approach was utilized in assessing the data collected for this study during the summer period (May 4-August 26) of 1976. Significant differences between incoming and outgoing phosphorus loads in May and early June were estimated to be due to the growth processes of *Cladophora*, and in mid-July to August to *Potamogeton*, in this river reach. Assimilation by the biomass was estimated to have reduced the soluble phosphorus flux (outflow minus inflow) on this river reach by up to 55% on a daily basis. Total cumulative, assimilated soluble phosphorus for this 3.75 km stretch of river was estimated to be approximately 400 kg for the full growing season from April to September.

This study suggests that aquatic weed growth can affect nutrient transport on a daily basis. In addition, the significant reduction in phosphorus over this small river reach suggests that the entire attached plant community within the Grand River basin can assimilate considerable quantities of nutrients daily throughout the late spring and summer. As biomass surveys have not been attempted for the PLUARG study, it is impossible to estimate the total effect on the Grand River watershed.

The release of the aquatic biomass is also of concern, in that, over a relatively short period of time much of the phosphorus held in the plant material can be washed downstream following a period of stress.

11.5 DATA TRANSFERABILITY

Extrapolation of the pilot watershed data to unmonitored areas outside the PLUARG pilot watersheds is possible provided the characteristics of the unmonitored areas are similar to those in the pilot watersheds. In terms of extrapolation to other parts of the Great Lakes basin, the critical sources of pollutant contribution have been identified as being runoff from urban and agricultural land and point-source inputs. Waste disposal (sanitary landfills, processed-organic waste disposal, spray irrigation and private-waste disposal) constitute a potential environmental pollution threat to ground water and soil in the vicinity of each site. Depending on the nature, design, regulation and management practices of the different waste disposal systems used in the Great Lakes basin, the data from the Grand River pilot watershed studies (waste disposal) can be used for gross extrapolation on a Great Lakes basin basis.

The inherent variability of hydrological characteristics (streamflow and precipitation) and the lack of an efficient technique to partition the diffuse-source pollutant loads from a multiple land-use watershed into homogeneous land-use loads cause problems for extrapolation. The PLUARG monitored data, which were derived at the multiple land use, subwatershed outlets in the Grand River basin, suggest that extrapolation of these data outside the pilot watersheds may only be grossly applicable (within an order of magnitude).

Unit-area load estimates for urban, agricultural and undisturbed (wooded idle) land-uses were calculated (Table 4) using the monitoring data at special study sites in the Grand River basin. Using these unit-area load values, loads were estimated for the land uses in each of the eight major subwatersheds in the Grand River watershed (Figure 3). The estimated loads for these subwatersheds varied significantly from the monitored load at each subwatershed outlet, but for the most part were usually higher than the monitored load. The monitored load at each subwatershed outlet was corrected for point-source inputs as well as tributary inputs to each of the subwatersheds, prior to comparison with the estimated load. Ratios of the monitored loads (in 1976) to the estimated loads, using these unit-area load values for the land uses in each subwatershed, varied widely with the parameter (in kg/ha/yr) and within each subwatershed as shown below:

	km ²	Outlet	TP	FRP	SS	NO ₃ + NO ₂	+Pb	Zn
Upper Grand R.	795	(GR-13)	.72	.22	.33	.64	.59	.75
Conestoga R.	775	(GR-14)	.98	1.4	.83	1.2	.37	.86
Middle Grand R	1,940	(UL-22)	1.6	.78	1.7	1.1	.82	1.5
Nith R.	1,035	(GR-20)	1.2	.84	1.5	1.2	.68	1.2
Horner Cr.	384	(GR-6)	.52	.42	.32	2.4	1.1	.4
Brantford	293	(GR-11)	.75	.85	1.0	1.0	.56	.82
Caledonia	770	(GR-5)	.62	1.0	1.1	.93	1.1	1.1
Dunnville	637	(GR-15)	1.1	.75	.49	1.1	.59	.7
Total Grand R.	6,670		.83	.58	.89	1.3	.33	.88

where: TP = total phosphorus; NO₃ + NO₂ - nitrate + nitrite-nitrogen
 FRP = filtered reactive phosphate; Pb = lead
 SS = suspended sediment; Zn = zinc

The monitored/estimated ratios were less than one for the upper Grand River subwatershed (GR-13), which represents the headwater area of the Grand River basin. In contrast to this, the estimated loads for the middle Grand River (UL-22), Nith River (GR-20) and the Caledonia (GR-5) were lower than the monitored loads for most parameters as shown above. Extrapolation of the unit-area loads for all the land uses totalled in the Grand River watershed resulted in the monitored/estimated ratio being less than one for all parameters except for nitrate + nitrite (as shown above).

The transferability or extrapolation of the unit-area loadings data outside the pilot watershed cannot be done with high accuracy because of the data limitations. These limitations consist of a paucity of information on the in-stream transport of materials and biochemical transformations, and inadequacies of the monitoring program and the resulting loadings estimate biases. However, subjective selection of unit-area loads within the ranges shown in Table 4 for similar land-use situations in unmonitored areas of the Great Lakes basin may provide a reasonable initial estimate of loadings.

12.0 RECOMMENDATIONS

In addition to determining the impact of land-use activities on the water quality of the Great Lakes, the Reference Group was requested to recommend remedial measures or alternative strategies for maintaining or improving Great Lakes water quality. Sound water-management strategies require consideration of the environment as a whole including land, air and water aspects as well as the consequence on the social fabric of the basin. The implementation of any water-management practice also has the potential for creating secondary problems, some of which could be as serious as those being solved by the recommended control strategy. Public acceptability, costs, benefits, maintenance and adverse effects require evaluation and study prior to implementing any control strategy in the Great Lakes basin.

The two major in-lake problems have been identified as the acceleration of the natural aging process in the lakes (eutrophication) and those toxic materials which constitute an environmental health hazard (human and/or biological). Eutrophication is principally controlled by phosphorus and to a lesser extent by nitrogen. The hazardous lake problems are attributable to pesticides, organic chemicals, heavy metals and bacterial contamination. Sediment is an important aspect of both eutrophication and toxicity problems as a result of the sediment's capacity to adsorb phosphorus and other contaminants.

Control strategies for sediment may be at least partially effective in controlling other contaminants such as pesticides, organic toxicants and trace elements which are adsorbed to the sediment. Alternatively, the presence of sediment, finer-grained materials in particular, may concentrate significant quantities of these materials which may then be removed from the aquatic system by sediment transport and deposition. However, accumulation and later release of these materials may also occur under changing equilibrium conditions creating other problems requiring further control.

Remedial or preventative strategies would be most cost effective if the pollutant is controlled where it is found at its highest concentration. Generally, this is usually the source area of the pollutant discharge or emission. Treatment costs will probably increase as the pollutant becomes dispersed as a result of the larger area requiring control; however, the degree of treatment that is required may vary if concentration levels decrease (with dispersion) away from the source.

The nature of the pollutant requiring control will also be an important factor in dictating the required degree of treatment. Small amounts and/or infrequent inputs of toxic and persistent materials, such as some pesticides, organic toxicants and trace elements can create long-term

problems. Residues of these materials or their degradation products may not decline below acceptable limits for a long period of time because of their persistent nature. Bioaccumulation in the food chain may further aggravate the problem of controlling these kinds of materials.

Loading distributions suggest that seasonal application of remedial measures will be most cost effective, particularly during high-flow periods such as the spring melt when the bulk of the contaminant load is transported to the Great Lakes. Ranking of source areas in terms of relative concern may also be appropriate as a control strategy in that contaminants from some urban areas, for example, may be more varied and at higher levels than those from rural or forested lands. Furthermore, some source areas may also only represent a small portion of the total land area in the watershed and consequently, remedial measures may not be required for large areas of land.

Obvious control strategies are the retention of contaminants and their prevention from reaching the receiving waters. For sediment, this can be accomplished by reducing soil erosion rates and eliminating transport of the eroded soil. Strict regulation of pesticides and organic chemicals to avoid careless handling, misuse and spillage would also eliminate many of the potentially hazardous problems created by these materials reaching the receiving waters.

12.1 FEASIBLE REMEDIAL MEASURES

The effectiveness of remedial measures and alternative strategies to control non-point sources of water pollution were not assessed under the PLUARG studies; however, a catalogue of remedial measures was prepared under the Task A program. On the basis of this catalogue and the findings contained in this pilot watershed report, possible alternative strategies for pollutant control are presented in the following sections. Prior to the implementation of any recommended strategy, demonstration projects should be undertaken to determine their cost effectiveness, public acceptability, maintenance requirements and potential adverse effects.

12.1.1 URBAN

Sediment and sediment-associated contaminants are the most serious problems requiring control in urban runoff. The following measures should be assessed to determine their effectiveness in controlling pollution from urban runoff:

- a. The use of mulches, sedimentation ponds, etc. to reduce sediment loads due to erosion from urban construction sites,
- b. The use of bank stabilization techniques to reduce sediment loads due to streambank erosion,

- c. The reduction of atmospheric emissions which subsequently accumulate on impervious surfaces and are washed off during rainstorm or melt periods,
- d. Reduction or replacement of salt as a deicing agent on highways to reduce chloride loads from urban areas,
- e. The initiation of public-education programs designed to reduce the accumulation of litter and animal waste on streets, and to promote the proper use of pesticides and fertilizers on residential property, would reduce the pollutant inputs of phosphorus, bacteria and pesticides from urban areas,
- f. The implementation of street sweeping practices to remove accumulated contaminants from streets,
- g. Improve collection and treatment systems and promote new storage and infiltration systems for urban storm runoff such as on-site storage of contaminants, porous pavement to promote infiltration, separation and recovery basins, traps, etc.
- h. Control of atmospheric fallout of PCBs from waste incineration at low temperatures and leakage from disposal sites is required.
- i. Reduce pesticides washoff from utility corridors and residential, recreation and agricultural lands.
- j. Reduce washoff of accumulated bacterial contaminants (i.e. organic debris, animal excreta) from pervious surfaces and industrial point sources (i.e. food processing plants).

12.1.2. RURAL

Erosion of agricultural land is a major contributor of sediment to streams. The major controlling factors in the rate of erosion are soil type, slope, cover, climate and cropping practices. The reduction of erosion rates can be realized by various control strategies to maintain soil structure (i.e. minimum tillage methods) and the use of cover crops to lessen the erodibility of soil from the impact of rain. Other alternative strategies such as contour cropping, diversion terraces, etc., will reduce the transport of eroded soil into the drainage channel. Field borders (i.e. buffer strips of vegetation on the drainage way) will reduce the velocity of runoff water and the amount of material that can be held in suspension. Restriction of livestock access to streams during periods of high soil moisture will reduce the incidence of stream-bank instability and subsequent slumping of materials into the stream.

Excessive fertilizer and manure applications can elevate natural nutrient levels in the streams which drain areas of active fertilization. Proper use of fertilizer and manure for optimum crop production and plant growth should be encouraged (i.e. immediate plow down). Runoff or seepage from manure sewage or livestock feeding areas should be discouraged. Restriction of livestock access and defecation in the streams may be necessary in some areas to reduce both nutrient and bacterial contamination from livestock.

12.1.3 PRIVATE WASTE DISPOSAL

Properly designed and constructed septic systems utilize the natural sorption characteristics of the soil to minimize pollution. System failures can result in the impairment of receiving-stream water quality with respect to phosphorus inputs. Although attenuation of phosphorus by soil adsorption is a natural control, abatement at the source in private-waste disposal systems (i.e. alum additives in the septic tank or holding tanks) may be an environmentally satisfactory solution where insufficient soil is available for natural attenuation. An alternative strategy is the use of other suitable soils with high exchange capacities; however, the cost of this alternative will be directly related to the cost of transporting these materials to the site.

Human waste also contains naturally high levels of organic nitrogen forms and significant amounts of organic nitrogen will accumulate in the septic system. The attenuation of most organic nitrogen forms by soil mineral particles is reasonably good (up to 81%); however, the septic system leachate may contain large amounts of the highly soluble nitrate ion. Nitrate is formed as a result of mineralization and nitrogen transformations (i.e. nitrification) of organic nitrogen. Consequently, localized ground-water problems can occur as a result of nitrate leaching from the septic system.

Bacterial contamination may occur as a result of runoff from faulty private-waste disposal systems (seepage of septic tank effluent) and create localized problems in the receiving waters.

Providing the septic-tank/tile field system is designed and constructed according to current regulations, the proposed minimum distances between tile fields, wells and surface waters are considered adequate to avoid contamination of drinking water and to protect the surface waters.

12.1.4. SOLID AND LIQUID WASTE DISPOSAL

If waste is enriched with heavy metals and organic chemicals, accumulations in the soil from land disposal of the wastes could ultimately create an environmental health hazard. Proper design and management of solid waste-disposal sites (utilizing the natural attenuating capacity of soil for removing pollutants from the leachates generated by the solid waste) will minimize pollutant transmission to receiving waters. However, local impairment of ground water may occur and as a result stringent site-specific controls may be required.

Guidelines for sewage sludge utilization on agricultural lands have been developed for use in the Province. Providing implementation of the guidelines is strictly enforced with respect to application rates, site selection and sludge content, environmental hazards will be minimized as a result of spreading sewage sludge on agricultural lands.

Treatment and recycling of waste materials is the ultimate solution to waste disposal rather than storage and concentration as presently exists (i.e. sanitary landfills, etc.). Schemes should be encouraged which renovate the natural environment (i.e. infiltration and recharge to ground water systems, etc.).

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