TASK GROUP C (CANADIAN SECTION)

ACTIVITY 3

INTERNATIONAL REFERENCE GROUP

ON

GREAT LAKES

POLLUTION FROM LAND USE ACTIVITIES

THE EFFECT OF SOME WASTE DISPOSAL PRACTICES ON GREAT LAKES WATER QUALITY

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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. 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

As part of the Ontario Ministry of the Environment's input to the Pollution from Land Use Activities Reference Group (PLUARG) program, studies were conducted of some waste disposal practices consisting of sanitary landfilling, disposal of processed organic waste on agricultural land, private waste disposal, land irrigation from wastewater lagoons and point-source discharges (i.e. industrial and municipal effluents). Excluding point-source discharges, the other waste disposal practices studied appear to pose no serious environmental hazard, provided they are subject to proper site selection, design and operation. Contaminant attenuating mechanisms in the soil or the subsurface (i.e. bacterial decomposition, dilution with subsurface water, chemical and physical reactions in the wastewater and between the wastewater and the surrounding soils through which the wastewater passes) appear to be highly effective in restricting the migration of contaminants from waste disposal sites. The potential pollutants identified from existing waste disposal practices in Ontario are listed below:

Sanitary landfilling	- chloride
Disposal of processed organic waste on agricultural land -	- phosphorus, nitrogen and trace elements
Land irrigation from wastewater lagoons	- phosphorus and nitrogen
Private waste disposal	- phosphorus and nitrogen
Point sources	- phosphorus, nitrogen, chloride, trace elements and organic chemicals

Sites used for sanitary landfilling, processed organic waste disposal and land irrigation from wastewater lagoons are designed to minimize losses through surface runoff. Consequently, contaminated surface runoff from existing waste disposal sites was found to be of little importance but contamination of the unsaturated zone and ground-water system was observed locally.

However, where suitable and sufficient earth materials and acceptable ground-water flow conditions are present between the disposal site and where ground-water discharge occurs, most pollutants were attenuated below detectable limits. Based on these studies, loadings estimates suggest that less than 6% of the annual nitrogen, phosphorus and chloride loads at the mouths of the Grand River and Saugeen River pilot watersheds is contributed from sanitary landfilling, private waste disposal, processed organic waste disposal, and land irrigation from wastewater lagoons, inclusive.

With respect to point-source discharges, significant pollutant inputs were identified as contributing to water-quality impairment. For example, in terms of the total annual load monitored at the mouth of the Grand River basin, combined municipal and industrial point-source discharges accounted for 25% of the phosphorus, 20% of the nitrogen, 11% of the lead, 25% of the zinc and 21% of the copper loads. In contrast with the Grand River basin which has an urban population comprising 73% of the total basin population of 514,000, the Saugeen River Basin is essentially a rural watershed with an urban population of approximately 43% of the total basin population of 57,000. Consequently, on an annual basis, combined point-source inputs are estimated to contribute less than 7% of the phosphorus, 3% of the nitrogen and less than 2% of the trace elements loads at the mouth of the Saugeen River.

Where diffuse or non-point, waste disposal practices are a problem, obvious control strategies are the retention of contaminants, thus preventing them from reaching the receiving waters; proper design and management of waste disposal sites (including septic systems) to permit utilization of natural site characteristics for pollutant attenuation; and the treatment and recycling of waste materials.

9.0 INTRODUCTION

The Pollution From Land Use Activities Reference Group (PLUARG) was established by the International Joint Commission (IJC) as a result of the Great Lakes Water Quality Agreement of April 15, 1972. 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 program consisted of four major tasks as outlined in the Reference Group's February 1974 Detailed 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 a preparation of a land-use inventory, largely from existing data, and, second, the analysis of trends and 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 affect 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. Based on the climate, geology, soils and land uses, the Grand River and Saugeen River basins were chosen as pilot watersheds for intensive study under the Task 'C' program in Canada (Figure 1). The land uses not adequately represented in the pilot watersheds were incorporated into the PLUARG program as subwatershed studies conducted in different parts of the Great Lakes basin.

9.1 STUDY OBJECTIVES

This report deals with the impact of some waste disposal practices on Great Lakes water quality and is one of four technical reports prepared by the Ontario Ministry of the Environment as part of the Canadian Task 'C' pilot watershed studies. Sanitary landfilling, processed organic waste (sewage sludge) disposal on agricultural lands, land irrigation from wastewater lagoons and private waste disposal (septic-tank systems) were identified for investigation in the Reference Group's 1974 Detailed Study Plan. These studies were designed to provide information on the impairment of receiving waters, both surface and ground waters by any effluent/leachate generated as a result of these land-use practices and to provide an assessment of the impact on Great Lakes water quality. In addition, monitoring of wastewater discharges from point sources was undertaken to determine the magnitude and significance of pollutant contributions from direct municipal and industrial discharges with respect to those from diffuse or non point-source contributions in the Grand River and Saugeen River pilot watersheds.

9.2 STUDY APPROACH

Specific field studies, and/or the compilation of information from other existing studies, on the waste disposal practices listed in the Study Objectives were initiated as part of the Task 'C' program. Surface and ground-water monitoring networks were established to monitor the quantity and chemical composition of the effluent or leachate generated at each site. For those studies where

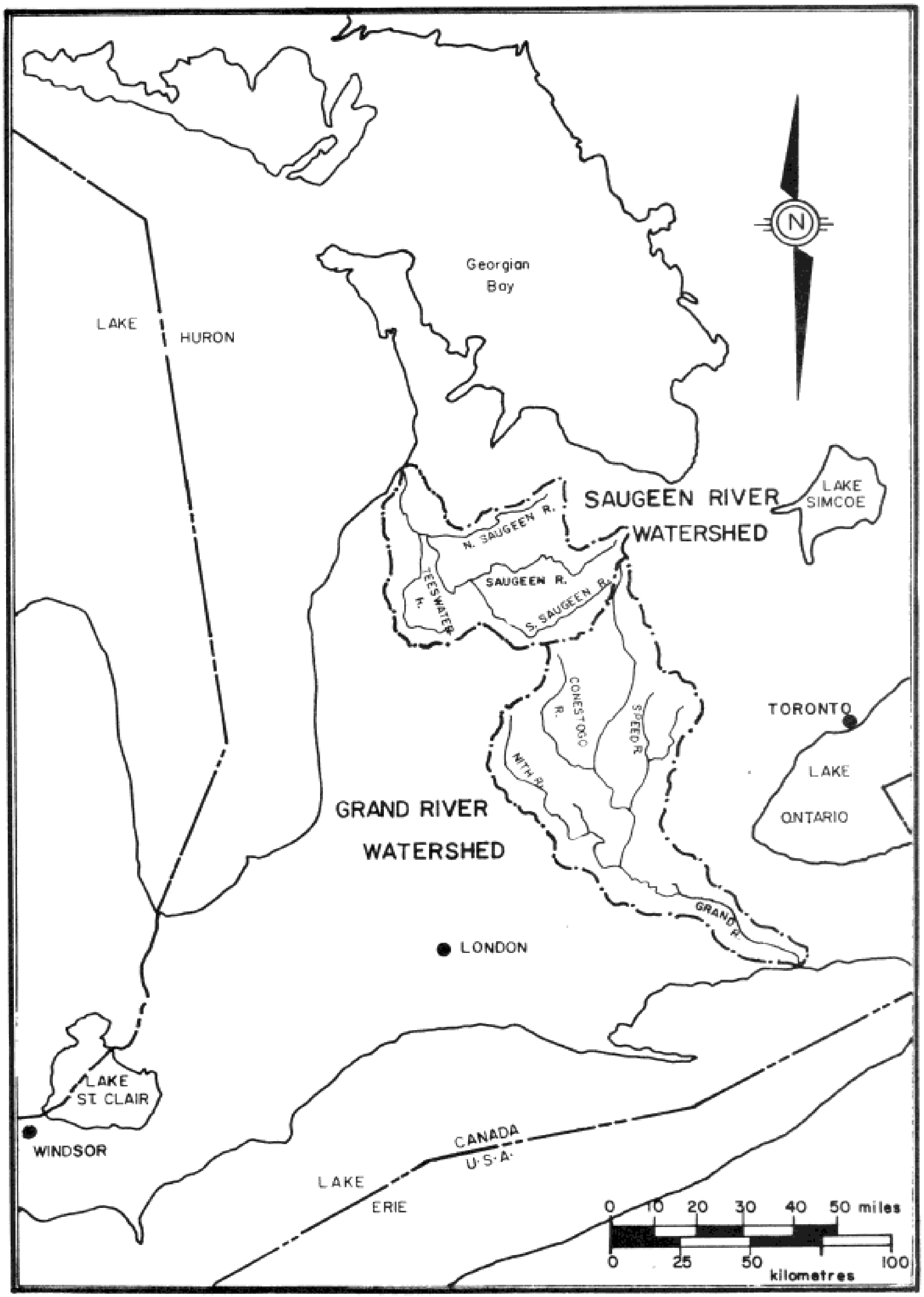

FIGURE # 1 LOCATION OF CANADIAN TASK C PILOT WATERSHEDS the pollutants were being discharged to the ground-water system, the pattern of migration and degree of attenuation were also monitored.

The detailed information derived from these specific studies was expressed as unit loads. These unit loads, in conjunction with basin-wide inventories, were used to estimate a total load attributable to each waste disposal practice in the Grand River and Saugeen River pilot watersheds. Using a simple mass balance approach, estimated loads derived from unit loads for all land uses and practices in the pilot watersheds were then summed. Comparison of the summed load with the monitored loads at the mouths of the pilot watersheds provided a gross error estimate on the reliability of the estimated loads.

9.3 DESCRIPTION AND LOCATION OF WASTE DISPOSAL STUDIES

9.3.1 Sanitary Landfill

In Ontario in 1974, there were approximately 1,016 active sanitary landfill sites occupying a total area of approximately 8,900 hectares and receiving approximately 30,000 metric tonnes of waste per day (Anon., 1977). This figure represents a solid-waste generation of approximately 2 kg/person/day from rural and urban areas within the Province (Anon., 1976a). Approximately 50% of all solid waste is comprised of commercial refuse and industrial wastes. The composition of municipal waste in 1974 (Middleton, 1975) averaged 35% paper, 22% food waste, 15% yard waste, 8% glass, 8% metal (ferrous 7%) and 12% miscellaneous (rubber, leather, cloth, plastic, wood, etc.).

One site, the Violet Sanitary Landfill in the Wilton Creek drainage basin (Figure 2) serving a population of 10,000, was selected for intensive study by the Ontario Ministry of the Environment

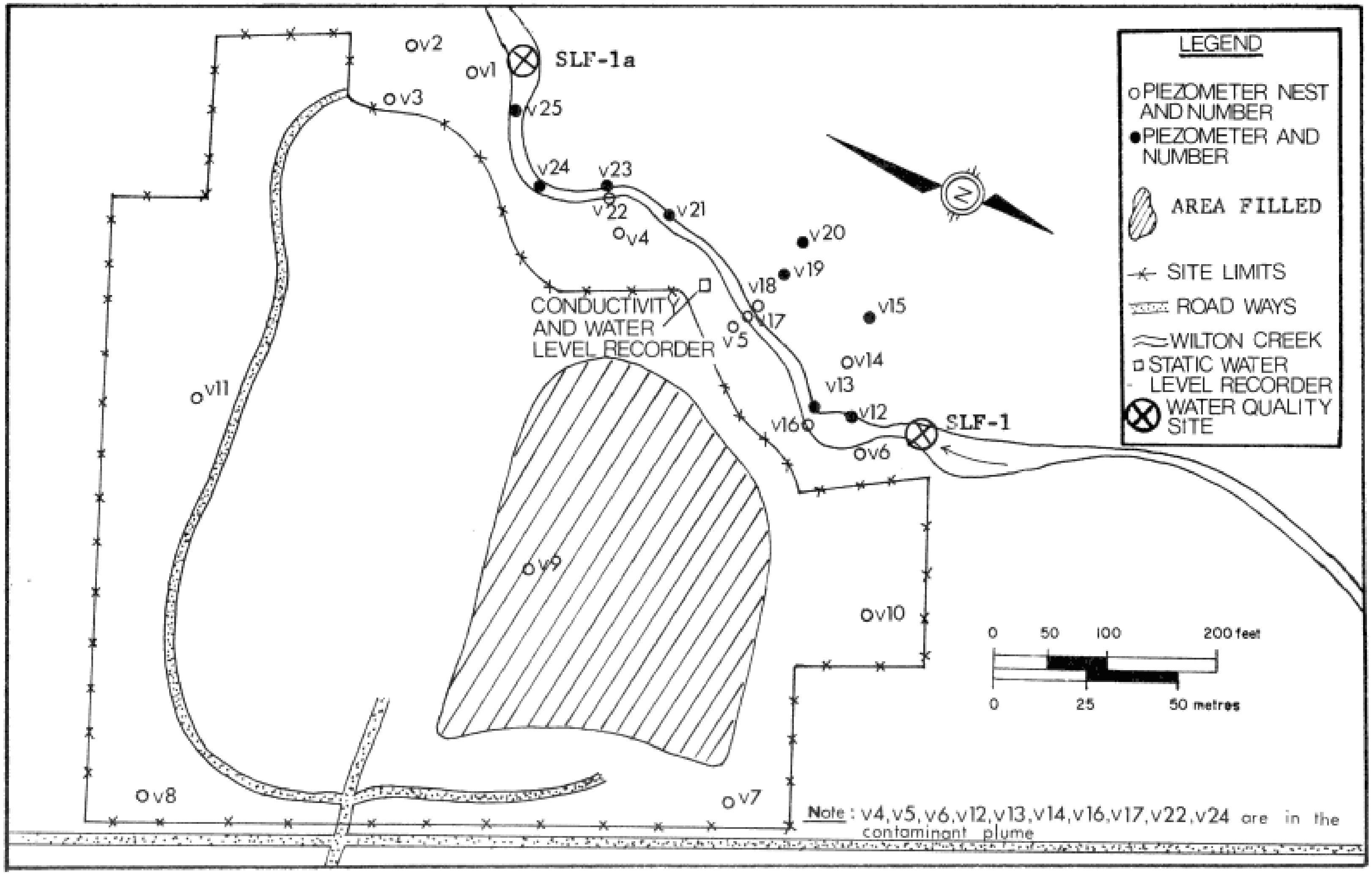

FIGURE # 2 VIOLET SANITARY LANDFILL SITE as part of the PLUARG Task 'C' program. The site occupies a total area of 11 hectares in an abandoned sand and gravel pit and has been in operation since 1971. Approximately 68,000 metric tonnes of domestic refuse and polyester fibre (50,000 and 18,000 tonnes, respectively) have been deposited in approximately 3 hectares of the site to an average refuse depth of 6 metres. At the present rate of filling, the life expectancy of the site is 6 years (1979-1985).

9.3.2 Processed Organic Waste Disposal on Agricultural Lands

Treatment of wastewater at a municipal sewage treatment plant has developed into a highly efficient chemical, physical and biological process providing for phosphorus, biochemical oxygen demand (BOD) and solids removal prior to discharging effluents into receiving waters. With the continual upgrading of effluent quality, the sludge or solid waste generated may contain significant quantities of undesirable contaminants, as well as nutrients and trace elements that can be utilized by field crops and plants for their growth. According to the USA Council for Agricultural Science and Technology (CAST), a report (Anon., 1976b) stated:

> "Long-term soil contamination, toxicity to plants, and accumulation of toxic elements in the food supply are thought to be the most serious potential problems resulting from application of sludge to crop lands."

Data extrapolated from a 1975 sludge disposal practices survey indicated that in Ontario, 210 sewage treatment plants produced 176,000 dry tonnes of sludge of which 34% or approximately 60,000 dry tonnes were applied to agricultural lands. The remaining sludge was disposed of by incineration (40%), landfilling (23%) and composting, etc. (4%). The disposal of processed organic waste on agricultural lands was studied by the Ontario Ministry of the Environment as part of the PLUARG Task 'C' program at two sites in the vicinity of Newmarket (Figure 3) and Brantford

(Figure 4).

9.3.2.1 Newmarket Site: The Newmarket study site (Figure 3) is in the Black River drainage basin in the Regional Municipality of York, approximately 11 kilometres northeast of the Town of Newmarket. The site covers an area of 3.2 hectares which has been in continuous crop production for at least the past 10 years. Crops grown during this period include corn, barley and, during the past 3 years, grass-hay. The land surface is undulating to rolling, sloping in the direction of York Regional Road 13 at an average gradient of approximately 6%. The surface soil is classified as silty-clay loam (Anon., 1962; USDA-SCS, soil textural classification).

9.3.2.2 Brantford Site: The Brantford study site (Figure 4) is located on the flood plain of the Grand River on the outskirts of the City of Brantford, adjacent to the Brantford Water Pollution Control Plant and Sanitary Landfill site. The study site covers an area of 16 hectares and has been in continuous corn production for at least the past 10 years. The land surface is relatively flat and slopes gently (1 to 2%) towards the Grand River. The surface soil is a silt loam (Anon., 1962; USDA-SCS, soil textural classification).

9.3.3. Land Irrigation from Wastewater Lagoons

Wastewater from municipal and industrial sources can be effectively treated by storing the wastewater in stabilization ponds or lagoons for a suitable period of time. During this retention period, biological processes breakdown and stabilize the organic material present in the wastewater. The efficiency of waste-stabilization ponds to improve wastewater quality is highly variable and is dependent on such factors as the depth of wastewater, temperature, biological growth, wastewater characteristics, and retention time.

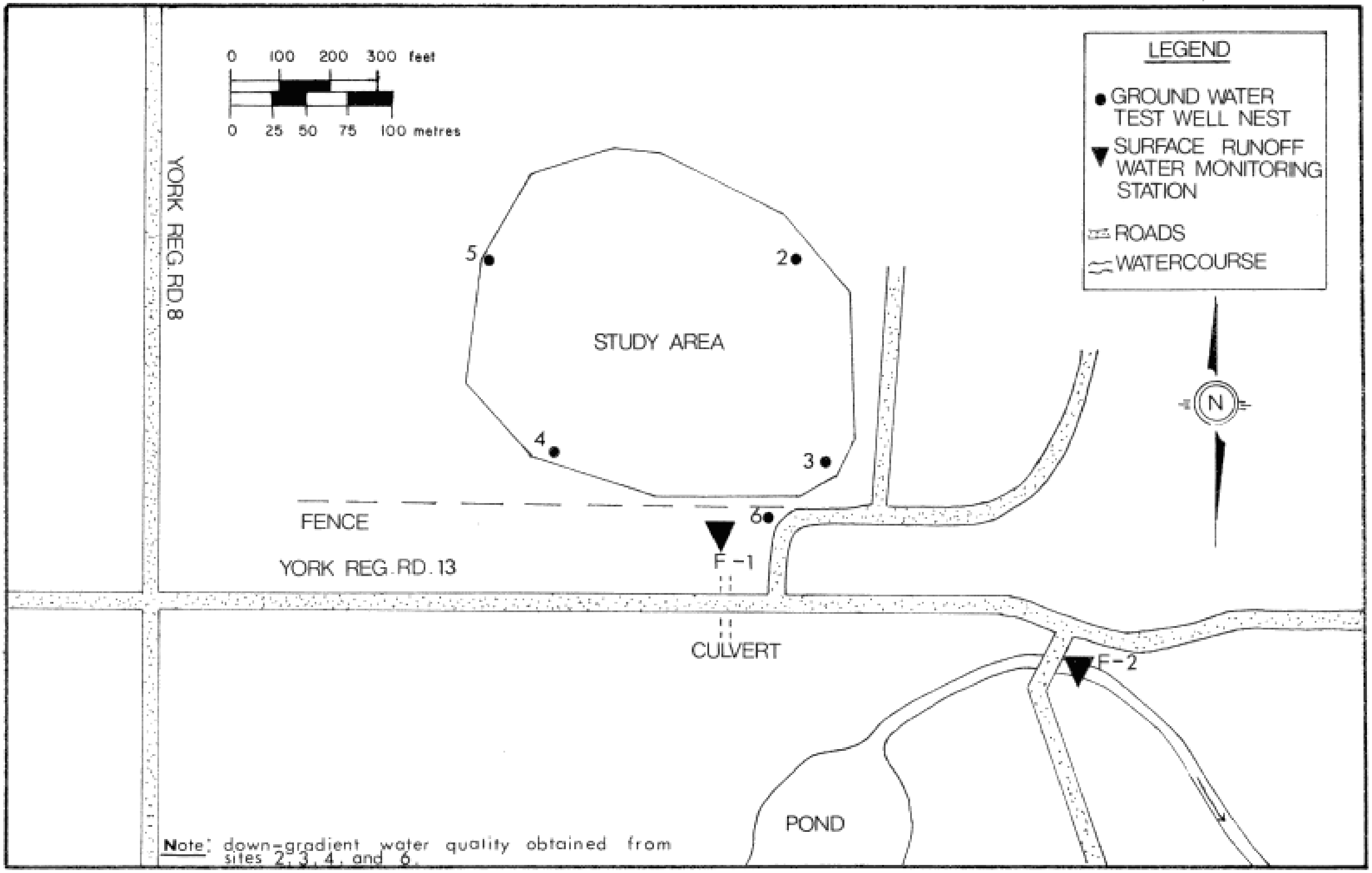

FIGURE #3 NEWMARKET PROCESSED ORGANIC WASTE DISPOSAL SITE

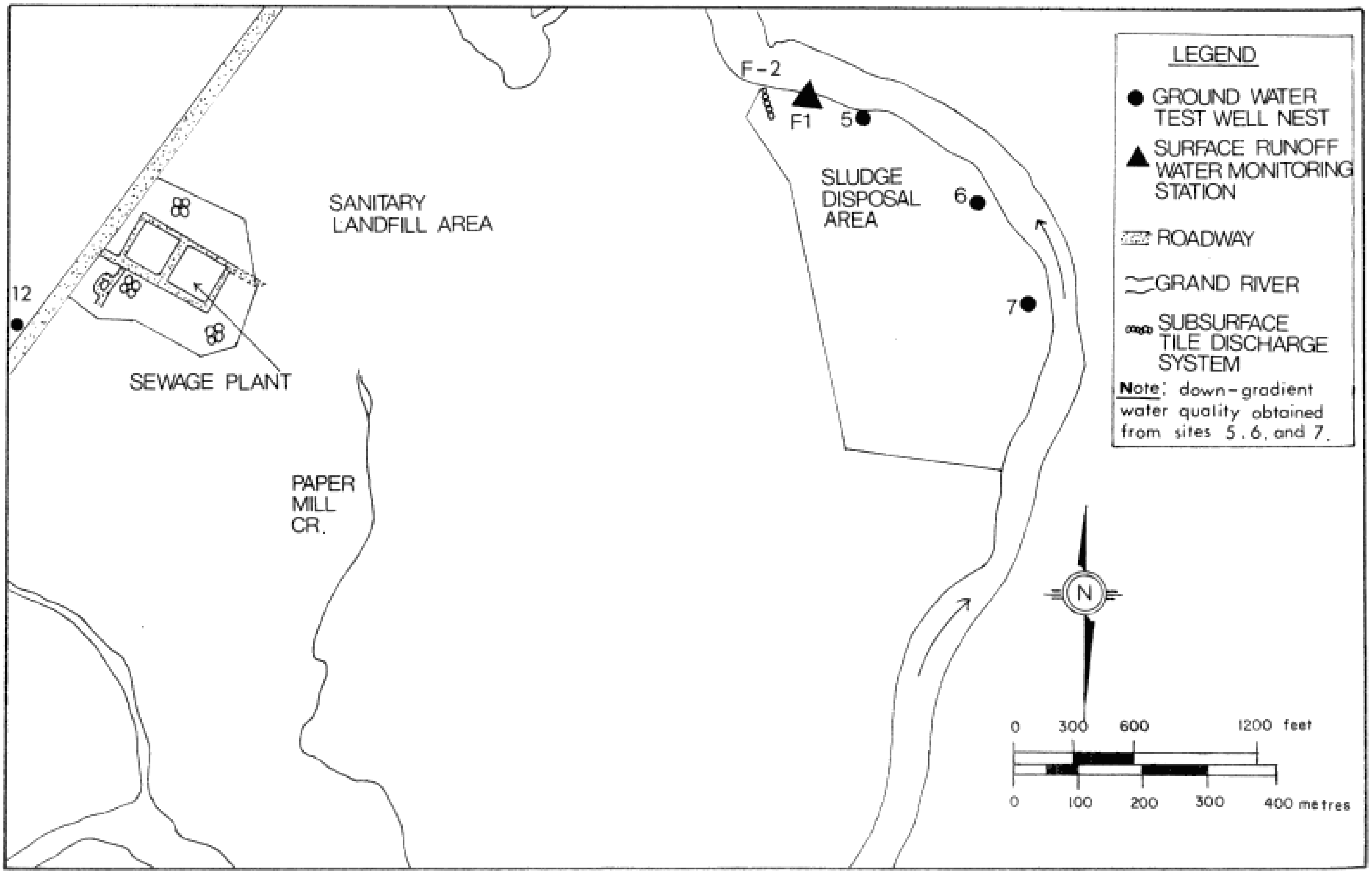

FIGURE #4 BRANTFORD PROCESSED ORGANIC WASTE DISPOSAL SITE

The wastewater from waste-stabilization ponds can be further treated by land irrigation. Land treatment schemes take advantage of the combined capacities of the soil and vegetation to renovate the wastewater effluent by filtration, soil adsorption, chemical precipitation, ion exchange, biochemical transformation and/or biological absorption. The method of liquid application of wastewater depends on climatic and site conditions as well as the degree of wastewater renovation required. Land irrigation techniques in Ontario have had the greatest application in the treatment of industrial wastewater effluents.

At the present time, there are approximately 58 industrial wastewater irrigation systems in operation consisting primarily of food processing and dairy wastes (Figure 5), treating approximately 4.3 million cubic metres per year (958 million gallons per year) of wastewater (Anon., 1973). In Ontario, there are approximately 100 municipal wastewater lagoons with a total combined capacity of 43.9 million cubic metres per year or 9.7 billion gallons per year (Anon., 1973). The bulk of these lagoon operations (98) utilize direct discharges to receiving streams after an appropriate period of wastewater retention. The remaining two municipal wastewater stabilization pond operations, at Shelburne and Smithville, have experimental irrigation systems treating 75,000 cubic metres per year (16.5 million gallons per year) of municipal wastewater effluent (Figure 5).

Under the PLUARG program additional specific field investigations were not conducted because of the considerable amount of information available in Ontario with respect to wastewater lagoons and land irrigation systems. The data discussed in this report are primarily based on published information (Sullivan et al, 1973), including an inventory of irrigation systems in the Great Lakes basin (Anon., 1973) and two pilot studies undertaken from 1971 to 1973 by the Ontario Ministry of the Environment (Ehlert, 1973 and 1975).

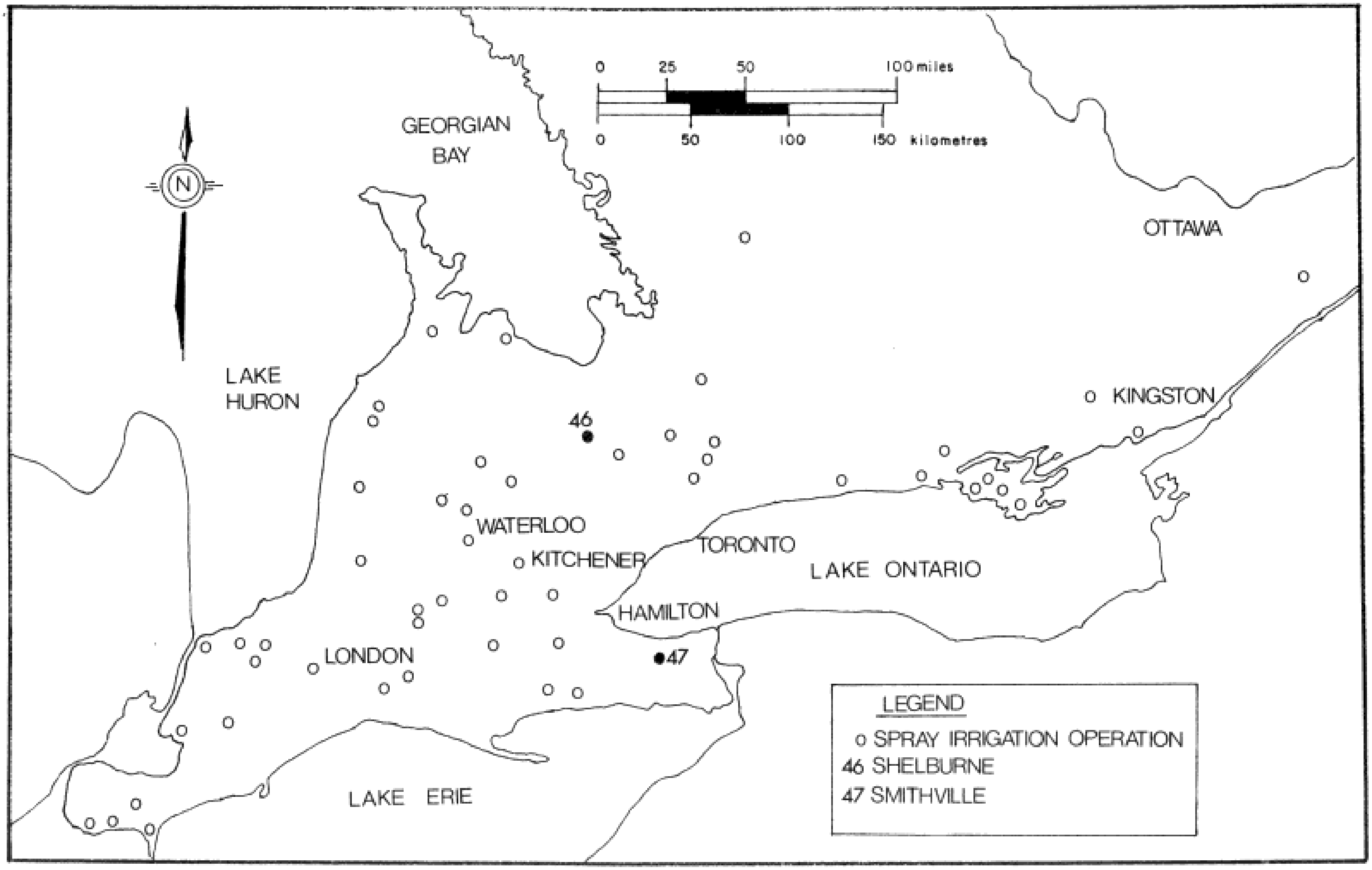

FIGURE #5 LOCATION OF SPRAY IRRIGATION SYSTEMS IN SOUTHERN ONTARIO

9.3.3.1 Spray Irrigation (from Ehlert, 1973): Land irrigation using "spray irrigation-infiltration" was monitored for a total of 28 weeks during the summer-fall periods of 1971 and 1972 at the sewage treatment facilities in the Village of Shelburne (Figure 6). Sewage treatment is provided by a 5.3 hectare continuous overflow waste-stabilization pond consisting of two, 2.7 hectare cells operated in parallel and designed to serve 1,350 people. Average flow to both cells during the study period was 835 cubic metres per day. A four-hectare parcel of land located adjacent to the waste stabilization pond was utilized for irrigation and consisted of 2 sections. One section of 3.2 hectares had a twitch grass cover and the soil consisted of a well-drained sandy loam with a permeability of approximately 10^{-3} cm/sec. The other section was a poorly-drained treed area with heavy ground cover.

9.3.3.2 Overland Runoff (from Ehlert, 1975): Land irrigation using "overland runoff" was monitored for a total of 43 weeks during the summer-fall periods of 1972 and 1973 at the sewage treatment facilities in the Community of Smithville (Figure 7). A single 3.5 hectare waste stabilization pond with a capacity to treat 1,540 cubic metres of municipal waste was monitored. The overland runoff irrigation area consisted of a section of land, approximately 21 hectares in size, having an average slope of about 5%. The cover vegetation consisted of thick grass with large quantities of weeds on clay loam soil with a permeability of approximately 10^{-4} to 10^{-5} cm/sec.

9.3.4 Private Waste Disposal Systems

Based on 1971 census data, approximately 408,000 private waste disposal systems (septic tanks) are being used by one and one-half million people in the Ontario portion of the Great Lakes watershed (i.e. 3.7 people per system). An additional 136,000 systems are used for waste disposal purposes in seasonal dwellings. The pollutant input from these systems to the Great Lakes was estimated (Chan, 1978), based on monitoring data from nine systems (Figure 8) constructed in soils

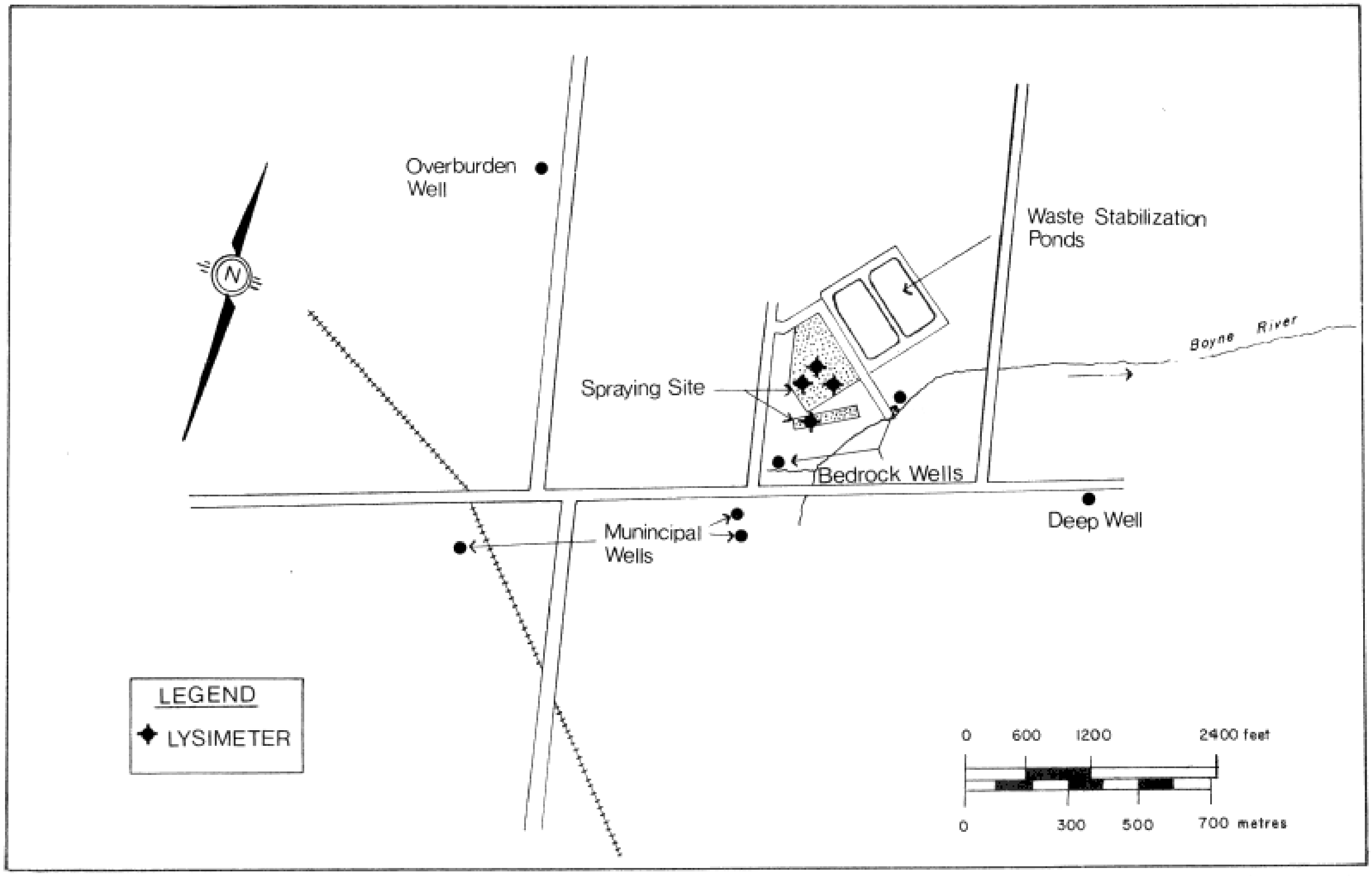

FIGURE # 6 SPRAY IRRIGATION SITE AT SHELBURNE

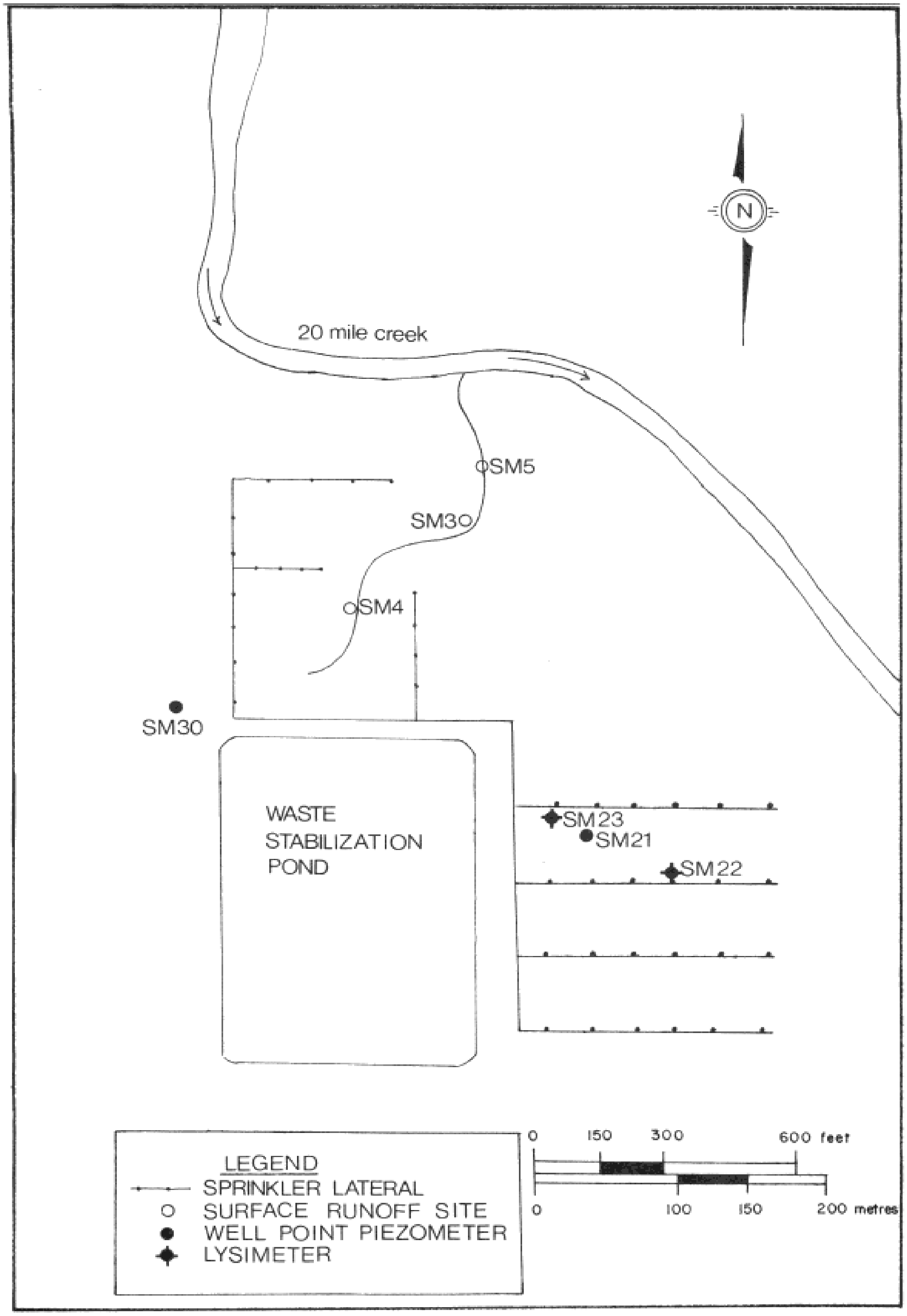

FIGURE # 7 DISPOSAL SYSTEM AT SMITHVILLE ranging from beach sands to clay silts. The systems were chosen to represent different combinations of site and hydrogeological conditions present in the Ontario portion of the Great Lakes basin.

In most cases, a two-year study was conducted at each site. Usually in the first year, a preliminary study of the ground water and soil conditions was undertaken. After analyzing the preliminary results, a more detailed program was designed and carried out in the second year with the emphasis on the study of the contamination of the ground water on the downgradient sides of the private waste disposal systems. The study included periodic sampling of ten septic-tank effluents to determine their chemical composition and potential pollutant impacts. These samples were composited on an hourly basis, ranging from 6 to 11 composite samples for each system, for a period of several days to ensure collection of representative samples.

9.3.5 Point Sources

Monitoring of municipal and industrial point sources was initiated during the course of the Task 'C', PLUARG study, to provide information on liquid wastes from outfalls (pipe sources) discharging directly to receiving waters in the Grand River and Saugeen River pilot watersheds. The combined municipal and industrial point-source discharges constitute approximately 40% and less than 5% of the low flow in the Grand and Saugeen rivers, respectively.

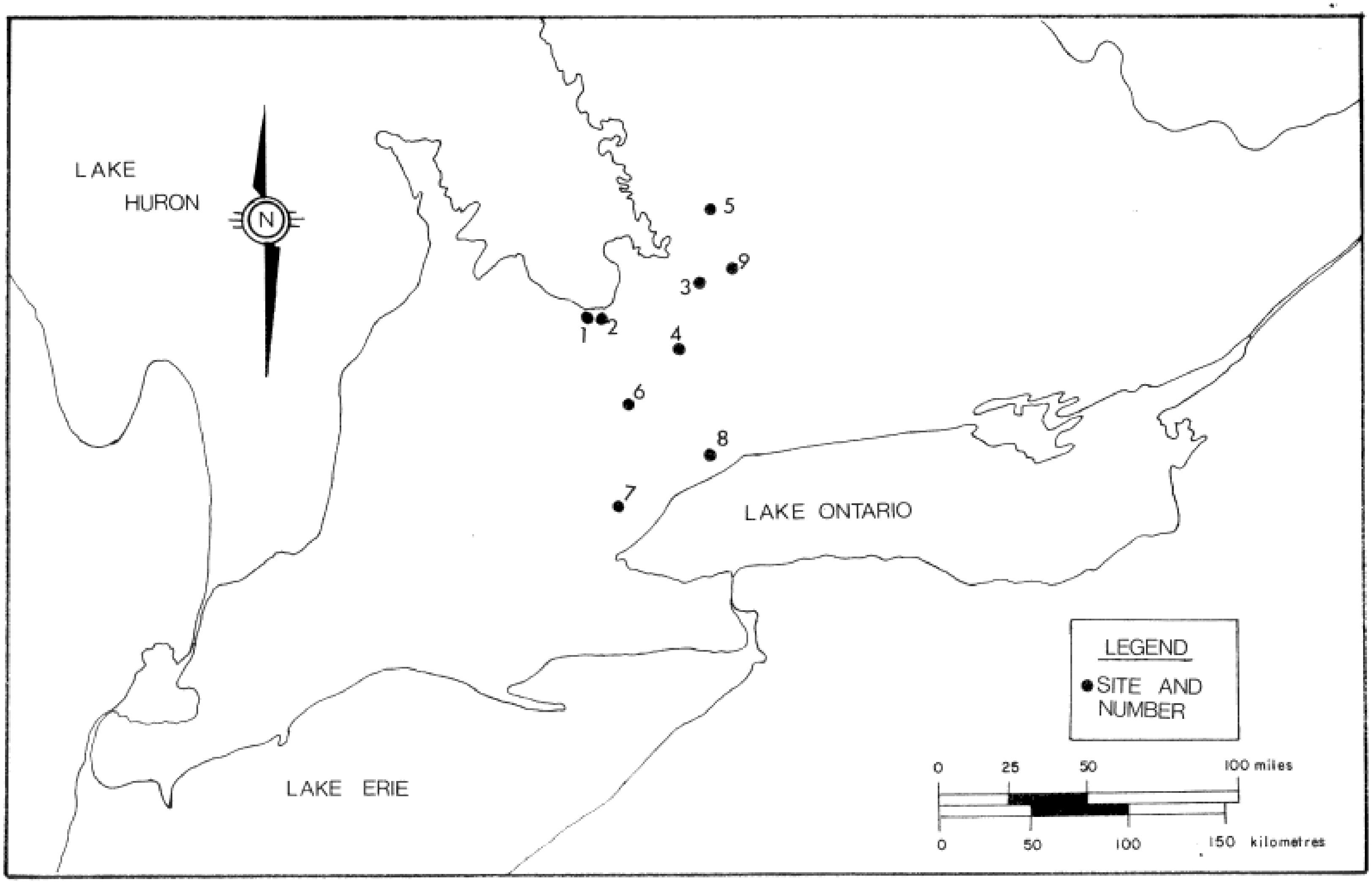

FIGURE # 8 LOCATION OF PLUARG PRIVATE WASTE DISPOSAL SITES IN SOUTHERN ONTARIO

9.3.5.1 Municipal: Municipal point-source information was derived from existing effluent quality data on file with the Ontario Ministry of the Environment for municipal sewage treatment plants (Anon., 1975 and 1976c) and from supplementary PLUARG monitoring in the two pilot watersheds. Municipal effluents were sampled under the PLUARG program at the 15 major sewage treatment plants (figures 9 and 10) representing about 94% and 84% of the municipal sewage treated in the Grand River and Saugeen River basins, respectively. The population served by the municipal sewage treatment systems in the Grand River basin (i.e. sewered) is approximately 374,000 or 74% of the basin population and approximately 24,500 or 43% of the basin population in the Saugeen River basin. The effluent discharges were sampled after a prolonged dry spell to ensure that sewage quality and quantity were not influenced by significant infiltration into the sanitary sewage system. Sampling was also undertaken during a basin-wide rainfall event in the Grand River basin to examine changes in sewage effluent quality as a result of inputs from combined sewers, infiltration, etc.

9.3.5.2 Industrial: In the Grand River watershed, as part of the industrial sampling program, cooling, process and general purpose waters were collected from 95 commercial, institutional and industrial sources (Figure 11). Most of the industrial waste volume produced in the Saugeen River watershed is processed by the sewage treatment plants and consequently, only one industrial source was required to be sampled.

9.4 METHODOLOGY

9.4.1 Data Collection

The details of water quality and quantity sample collection and instrumentation for surface and ground waters monitored under the PLUARG program are described in a companion technical report on data collection methodology (Onn, in press). Methodology and instrumentation techniques

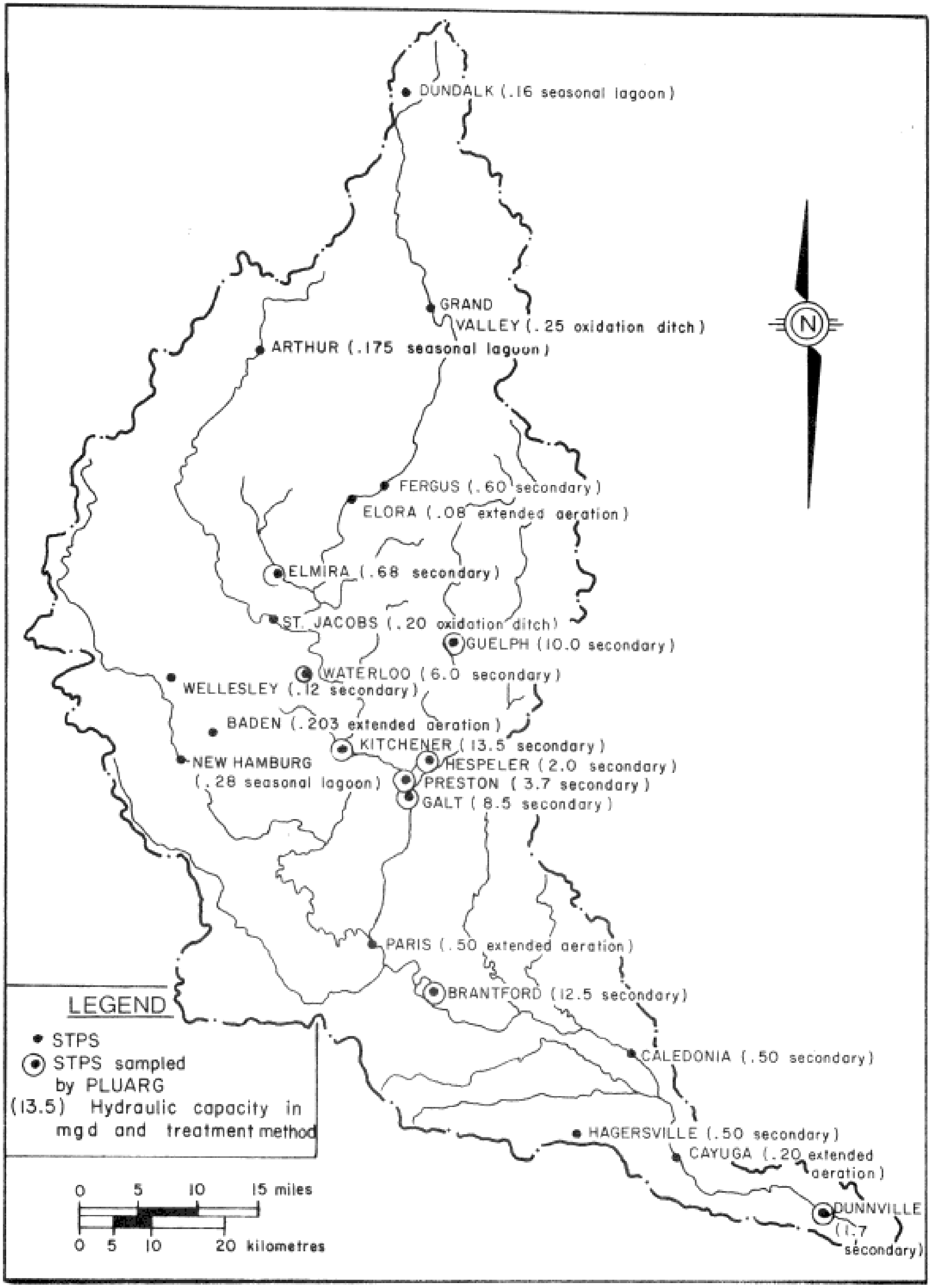

FIGURE #9 LOCATION OF SEWAGE TREATMENT PLANTS (STPs) IN THE GRAND RIVER PILOT WATERSHED

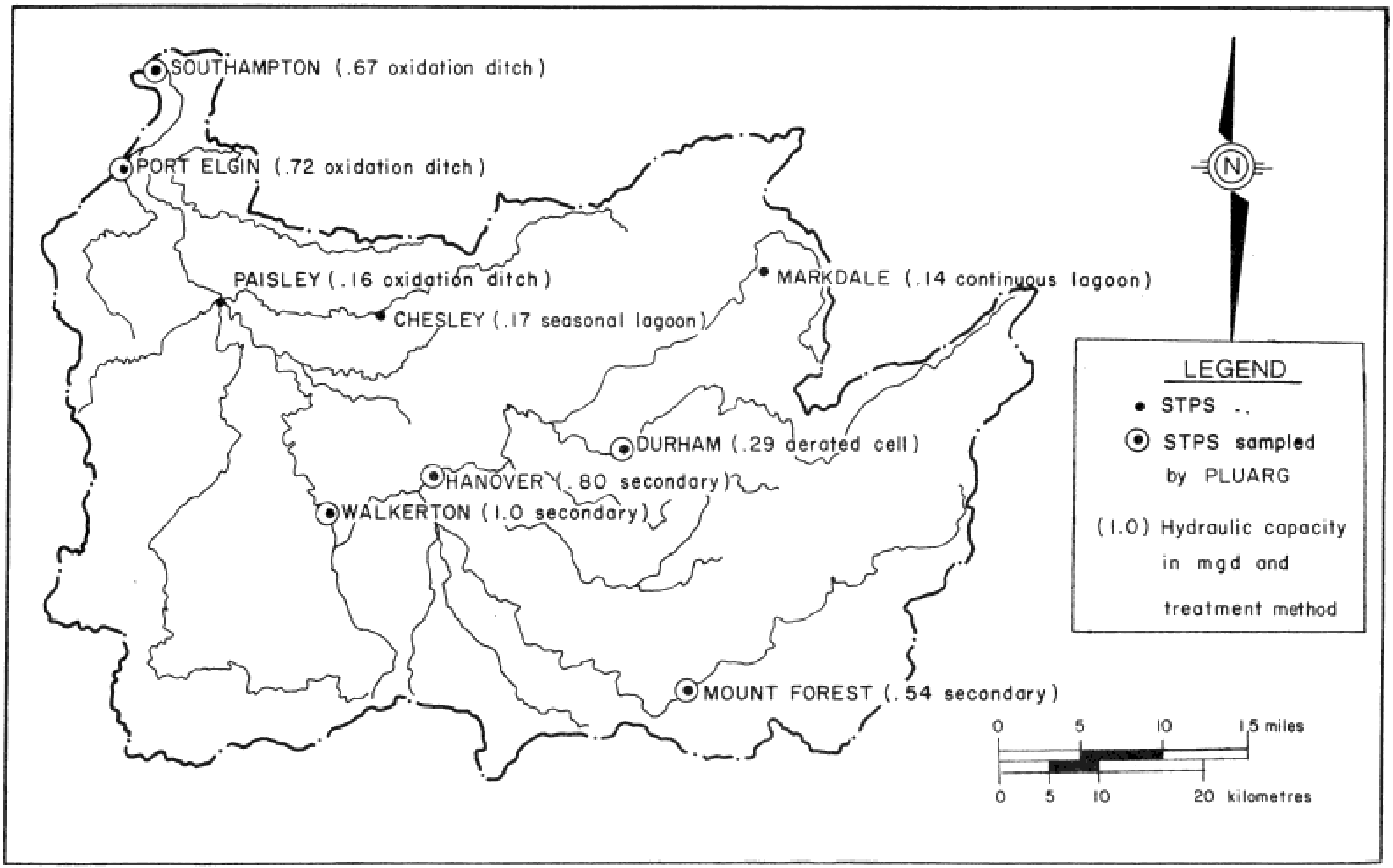

FIGURE # 10 LOCATION OF SEWAGE TREATMENT PLANTS (STP s) IN THE SAUGEEN RIVER PILOT WATERSHED

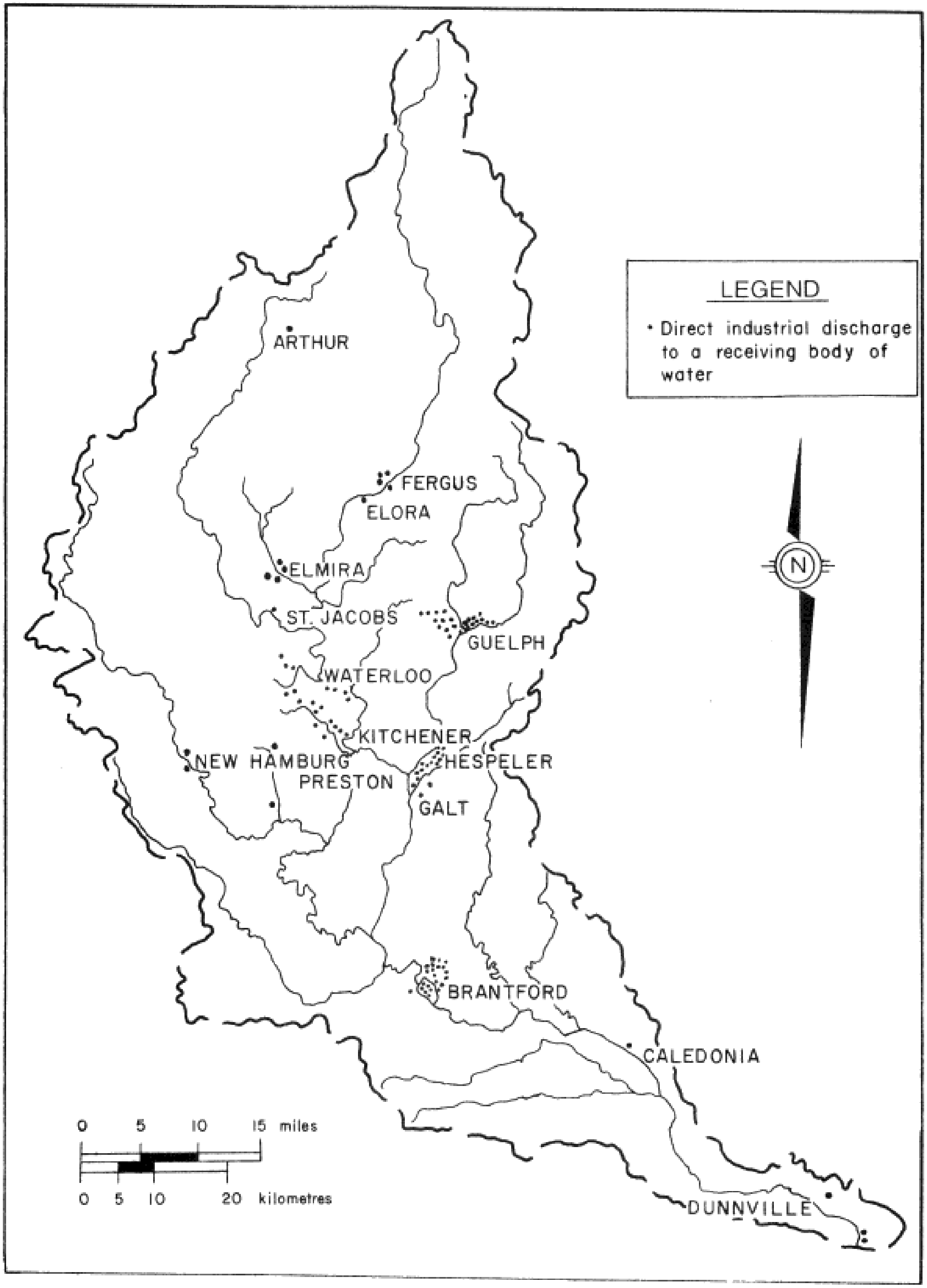

FIGURE # 11 LOCATION OF DIRECT INDUSTRIAL DISCHARGES IN THE GRAND RIVER PILOT WATERSHED used to monitor the wastewater lagoon and land irrigation systems are described by Ehlert (1973 and 1975).

9.4.2 Load Estimates

As part of the mass-balance approach to evaluate the impact and significance of land drainage on the boundary waters of the Great Lakes, water quality and quantity data from the PLUARG monitoring were translated into quantitative estimates of pollutant mass transport (i.e. loadings). In some of the wastes disposal studies, pollutant impact on a receiving stream was not measurable because of factors such as the size of the receiving stream in relation to the volume discharged from a source, the distance from a source to the receiving water and attenuating mechanisms within the ground-water flow system.

For pollutants reaching the ground water, attenuating mechanisms consist of bacterial decomposition, dilution, chemical and physical reactions in the wastewater and between the wastewater and the surrounding soils through which the wastewater passes. Since land uses and practices involving sanitary landfilling, processed organic waste disposal, land irrigation from wastewater lagoons and private waste disposal impact initially on ground-water systems, loads to the ground-water systems were computed. Nominal rates of pollutant loadings to receiving waters were then assigned. Pollutant loads were then coupled with land-use inventories in the Grand River and Saugeen River pilot watersheds to provide basin loading estimates for different waste disposal sources in the watersheds.

9.4.2.1 Sanitary Landfill: In the sanitary landfill study, paired samples taken weekly in the receiving stream above and below the contaminant discharge zone showed measurable downstream concentration differences during the low flow period from July 15 to October 15, 1976. It was assumed that during this period of time, flow in the stream was solely supported by ground-water discharge. An average daily contaminant load was computed for this period using concentration and streamflow data and adjusted to a mean daily load. This estimate was weighted to account for the variations in the ground-water gradient during the year. Pollutant loads in the pilot watersheds were then estimated based on these data.

9.4.2.2 Processed Organic Waste Disposal and Wastewater Land Irrigation: In the processed organic waste disposal and land irrigation from wastewater lagoon studies, pollutant contributions in the receiving waters were not measurable in receiving streams. However, the impact on the ground-water system was monitored and unit-area loads were computed. Based on these data, and assuming a nominal rate of attenuation in the ground-water system, pollutant loads to the receiving waters of the pilot watersheds were estimated.

9.4.2.3 Private Waste Disposal: Monitoring data from private waste disposal sites under the PLUARG study (Chan, 1978) were used to compute a net load to the Great Lakes boundary waters from septic-tank systems. Pollutant attenuation rates in the ground-water system were estimated and a unit load per system computed (Chan, 1978). Using 1971 census data, net pollutant loads to the pilot watershed mouths were then estimated, assuming that 30% of the septic-tank systems in Ontario are faulty and will eventually discharge to receiving streams.

9.4.2.4 Point Sources: Loads for municipal sources in the pilot watersheds were derived using both the PLUARG monitoring data and water-quality information obtained from the Ontario Ministry of the Environment's routine monitoring of municipal, sewage treatment plant effluents (Anon., 1975 and 1976c). The Ministry analyzes effluent discharges from all sewage treatment plants routinely, for total phosphorus, suspended solids and biochemical oxygen demand. Some of the treatment plants also have the effluent analysed for total Kjeldahl nitrogen, (nitrite + nitrate)-nitrogen and ammonia nitrogen. Effluent data were compiled for 1975 and 1976, and the loads were calculated for each of the measured parameters in tonnes per year. Total annual flow, in cubic metres per year, and average concentrations in milligrams per litre, of the effluent for each sewage treatment plant were used in calculating the annual loads.

Loading estimates for industrial sources were calculated by obtaining a product of total annual discharge and average pollutant concentrations obtained from routine Ministry and supplementary PLUARG monitoring undertaken in 1976. The quality and quantity of these industrial effluents are extremely variable with time and some parameters were analyzed 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 the waste volumes were high. As a result, these loading estimates may be significantly higher than the actual long-term loads.

9.5 PARAMETERS

The parameters identified by the PLUARG for the Task 'C' studies were as follows:

- total phosphorus, (TP)
- filtered reactive phosphorus, (FRP)
- filtered (nitrite + nitrate)-nitrogen, (NO_2 + NO_3 -N)
- 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 from the Ontario Ministry of the Environment (Anon., 1979a) on the major cations and anions, phenols and carbon. Stream-flow data for the PLUARG period are also available in a separate document (Anon., 1979b).

10.0 TABULATED RESULTS OF DATA COLLECTION

10.1 POLLUTANT CONCENTRATIONS

Concentration data from the various waste disposal practices are listed in tables 1 to 6 inclusive. Table 1 presents average concentrations of leachate and, ground- and surface-water parameters monitored in the vicinity of the Violet sanitary landfill site. Tables 2 and 3 present average concentrations of the sewage sludge, soil and ground- and surface-water parameters monitored at the processed organic waste disposal sites in the vicinity of Brantford and Newmarket. Table 4 presents concentration data for biomass samples from the Newmarket and Brantford sites.

Table 5 presents average concentration data for sewage, sewage effluent and ground- and surface-water parameters as part of land irrigation studies undertaken prior to the PLUARG program by the Ontario Ministry of the Environment in the vicinity of Smithville and Shelburne. Table 6 presents average concentration data for septic-tank effluent and ground water monitored in the vicinity of nine private waste disposal sites chosen for detailed study under the PLUARG program. Table 7 presents ranges of concentrations monitored from municipal and industrial point sources in the Grand River and Saugeen River pilot watersheds.

Table 1. Average concentrations, sanitary landfill study, Violet Landfill site.

PARAMETERS (in mg/L or otherwise stated)	Water* Quality Criteria	1975/76/77 Leachate Quality (Well V9)	1975/76 Down gradient GroundWater Quality (13 Wells)	1975/76 Background Ground-Water Quality (11 Wells)	1975 Upstream Surface-Water Quality (SLF-1)	1976 Upstream Surface-Water Quality July 15- Oct 15 (SLF-1)	1976 Downstream Surface-Water Quality July 15- Oct 15 (SLF-1a)
Conductivity (micromhos/cm^3)	-	7.700.	1,400.	533.	529.	562.	596.
Alkalinity	-	2.750.	368.	232.	171.	181.	190.
Chloride	250.	740.	240.	18.	54.	59.	64.
Sodium	-	576.	136.	10.	23.	25.	28.
Calcium	-	159.	126.	78.	65.	68.	70.
Magnesium	-	157.	29.	17.	15.	17.	18.
Potassium	-	338.	3.	2.	3.	3.	3.
Sulphate	250.	25.	23.	31.	24.	23.	23.
pH (units)	6.5 to 8.5	7.2	7.4	7.8	8.1	8.4	8.1
Total Carbon	-	1,000.	117.	119.	50.	54.	56.
Inorganic Carbon	-	770.	97.	76.	41.	43.	46.
Organic Carbon	-	230.	20.	43.	9.	11.	10.
COD	-	8,300.	50.	23.	-	23.	20.
Ammonia Nitrogen	0.02**	318.	0.36	0.19	0.01	0.014	0.012
Nitrate + NitriteNitrogen	10.	0.02	0.24	2.1	0.36	0.026	0.018
Total Kjeldahl Nitrogen	-	330.	2.4	1.9	0.61	0.61	0.55
Total Nitrogen	-	330.	2.6	4.0	0.97	0.64	0.57
Total Phosphorus	0.03	2.5	0.46	1.1	0.074	0.073	0.063
Filtered Reactive Phosphorus	-	0.25	0.0019	0.0064	0.018	0.040	0.029
Suspended Solids	-	-	-	-	7.	-	-
Nickel	0.025	0.11	0.01	0.029	0.003	-	-
Zinc	0.03	+	+	+	0.004	-	-
Copper	0.005	0.033	0.037	0.060	0.008	-	-
Lead	0.005***	0.022	0.088	0.15	0.005	-	-
Cadmium	0.0002	0.006	0.002	0.0025	0.001	-	-
Chromium	0.1	0.049	0.010	0.025	0.003	-	-
Mercury (ppb)	0.2****	+	+	+	0.078	-	-
Manganese	0.05	+	+	+	-	-	-
Arsenic	0.1	0.003	0.003	0.002	0.009	-	-
Iron	0.3	+	+	+	0.24	0.18	0.28
Number of Samples	-	5	117	88	39	15	15

+ Unrepresentative values as a result of well screen contamination and sample collection techniques.

* Provincial Water Quality Objectives (Water Management; Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment, 1978).

** Un-ionized ammonia nitrogen; amount dependent on temperature and pH of the aqueous ammonia solution.

*** Criterion dependent on alkalinity; ranges from 0.005 to 0.025 mg/L.

**** Criterion based on filtered water sample.

Table 2. Average Concentrations, processed organic waste disposal study, Newmarket # Site

PARAMETERS (in mg/L or ug/g or otherwise stated)	Water* Quality Criteria	1976 Sludge Quality	1976 Sludge Amended Soil	Average Ontario Soil (Frank et al, 1976)	1976/77 Downgradient Ground-Water Quality (6 Wells)	1976/77 Background Ground-Water Quality (1Well)	1976 Surface-Runoff Water Quality (F-1)	1976 Black River Water Quality (F-2)
Conductivity (micromhos/cm^3)	-	-	-	-	472.	427.	330.	430.
Alkalinity	-	6,407.	-	-	194.	175.	138.	174.
Chloride	250.	341.	-	-	7.	7.	5.	18.
Sodium	-	144.	168.	-	8.	9.	4.	8.
Calcium	-	7,314.	8,100.	-	61.	57.	59.	70.
Magnesium	-	259.	1,400.	-	20.	15.	4.	9.
Potassium	-	40.	570.	-	1.	2.	2.	2.
Sulphate	250.	-	-	-	47.	38.	25.	27.
pH(units)	6.5 to 8.5	7.2	8.1	-	8.2	8.0	7.8	7.9
Total Carbon	-	-	-	-	102.	91.	51.	53.
Inorganic Carbon	-	-	-	-	63.	58.	36.	44.
Organic Carbon	-	-	-	-	39.	33.	15.	9.
COD	-		38,300.	-	123.	122.	-	21.
Ammonia Nitrogen	0.02**	332.	-	-	-	-	0.20	0.04
Nitrate + Nitrite Nitrogen	10.	-	-	-	0.48	0.09	1.3	0.46
Total Kjeldahl Nitrogen	-	1.566.	-	-	0.92	0.86	1.8	0.54
Total Nitrogen	-	-	1,400.	-	1.4	0.95	3.1	1.0
Total Phosphorus	0.03	880.	910.	-	0.73	0.25	0.62	0.05
Filtered Reactive Phosphorus	-	-	-	-	-	-	0.18	0.02
Suspended Solids	-	51,558.	-	-	-	-	194.	17.
Nickel	0.025	0.6	3.8	15.0	0.008	0.010	0.007	0.01
Zinc	0.03	107.	42.	53.5	+	+	0.047	0.008
Copper	0.005	24.	9.	25.4	0.012	0.009	0.033	0.008
Lead	0.005***	21.9	7.	14.1	0.015	0.009	0.012	0.007
Cadmium	0.0002	0.27	0.3	0.56	0.017	0.006	0.007	0.007
Chromium	0.1	4.4	10.	14.3	0.010	0.020	0.025	0.007
Mercury(ppb)	0.2****	-	60.	80.	+	+	0.05	0.04
Manganese	0.05	26.	230.	-	+	+	-	-
Arsenic	0.1	0.18	2.3	6.3	0.001	0.001	0.002	0.001
Iron	0.3	1,467.	11,700.	14,470.	+	+	2.3	0.6
Total Coliform (# per 100 mL)	1,000.	-	-	-	L10	-	172.	1,500.
Fecal Coliform (# per 100 mL)	100	-	-	-	1	-	1.	500.
Fecal Streptococcus (# per 100 mL)	-	-	-	-	1	-	10.	300.
Number of Sample	-	10	1	296	101	12	9	5

+ Unrepresentative values as a result of well screen contamination and sample collection techniques.
* Provincial Water Quality Objectives (Water Management; Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment, 1978).
# Sludge Application Rate 9.6 metric tons per hectare.
** Un-ionized ammonia nitrogen; amount dependent on temperature and pH of the aqueous ammonia solution.
*** Criterion dependent on alkalinity; ranges from .005 to .025 mg/L.
**** Criterion based on filtered water sample.
L Less than

Table 3. Average concentrations, processed organic waste disposal study, Brantford # site

PARAMETERS (in mg/L or µg/g or otherwise stated)	Water* Quality Criteria	1975 Sludge Quality	1976 Sludge Amended Soil	Average Ontario Soil (Frank *et al.* 1976)	1975/76 Tile Drain Quality (F-2)	1975/76 Downgradient Ground-Water Quality (3 Wells)	1975/76 Background Ground-Water Quality (1 Well)	1976 Flood Water Quality (F-1)
Conductivity (micromhos/cm^3)	-	-	-	-	1,009.	837.	349.	335.
Alkalinity	-	5,920.	-	-	274.	257.	154.	125.
Chloride	250.	545.	-	-	20.	20.	11.	12.
Sodium	-	117.	220.	-	8.	12.	9.	6.
Calcium	-	1,376.	79,000.	-	156.	130.	64.	46.
Magnesium	-	202.	24,000.	-	27.	23.	25.	10.
Potassium	-	67.	2,000.	-	2.	1.	3.	2.
Sulphate	250.	-	-	-	95.	162.	75.	22.
pH (units)	6.5 to 8.5	7.3	-	-	7.5	7.9	7.8	7.9
Total Carbon	-	-	-	-	69.	158.	107.	41.
Inorganic Carbon	-	-	-	-	65.	85.	54.	31.
Organic Carbon	-	-	-	-	4.	73.	53.	10.
COD	-	-	50,000.	-	18.	139.	95.	22.
Ammonia Nitrogen	0.02**	767.	-	-	-	-	-	0.3
Nitrate + Nitrite Nitrogen	10	-	-	-	37.9	0.9	0.1	2.7
Total Kjeldahl Nitrogen	-	2,117.	-	-	0.2	3.4	2.8	1.3
Total Nitrogen	-	-	2,000.	-	38.1	4.3	2.9	4.0
Total Phosphorus	0.03	947.	990	-	0.05	1.0	0.5	0.26
Filtered Reactive Phosphorus	-	-	-	-	-	-	-	0.07
Suspended Solids	-	45,214.	-	-	-	-	-	139.
Nickel	0.025	3.5	18.	15.9	0.007	0.009	0.001	0.003
Zinc	0.03	67.4	110.	53.5	+	+	+	0.19
Copper	0.005	52.9	19.	25.4	0.005	0.013	0.009	0.016
Lead	0.005***	47.2	20.	14.1	0.025	0.012	0.013	0.01
Cadmium	0.0002	0.7	0.9	0.56	0.004	0.008	0.006	0.008
Chromium	0.1	35.2	42.	14.3	0.033	0.016	0.011	0.025
Mercury(ppb)	0.2****	23.	110.	80.	+	+	+	0.037
Manganese	0.05	10.	640	-	+	+	+	-
Arsenic	0.1	-	4.8	6.3	0.0023	0.0011	0.00063	0.002
Iron	0.3	2,049.	18,000.	14,470.	+	+	+	4.8
Total Coliform (# per 100 mL)	1,000.	-	-	-	L10	L10	-	1,200.
Fecal Coliform (# per 100 mL)	100.	-	-	-	L10	1	-	87.
Fecal Streptococcus(# per 100 mL)	-	-	-	-	L10	20	-	495.
Number of Samples	-	14	1	296	12	45	6	6

+ Unrepresentative values as a result of well screen contamination and sample collection techniques.
* Provincial Water Quality 0bjectives (Water Management; Goals, Policies, 0bjectives and Implementation Procedures of the M0E, 1978).
\# Sludge Application Rate 15.2 metric tons per hectare.
** Un-ionized ammonia nitrogen; amount dependent on temperature and pH of the aqueous ammonia solution.
*** Criterion dependent on alkalinity; ranges from 0.005 to 0.025 mg/L.
**** Criterion based on filtered water sample.
L = Less than

Table 4. BIOMASS CONCENTRATIONS, PROCESSED ORGANIC WASTE DISPOSAL STUDY, NEWMARKET AND BRANTFORD SITE

PARAMETERS (in µg/g)	ACCEPTABLE LEVELS* Corn Leaf		BRANTFORD		ACCEPTABLE LEVELS* Alfalfa		NEWMARKET Grass-Hay
	Lower	Upper	Corn Leaf	Corn Grain	Lower	Upper	
Calcium	-	-	-	-	-	-	6,900.
Magnesium	1,000.	3,900.	-	-	2,000.	10,000.	2,150.
Potassium	12,500.	22,400.	5,700.	-	17,500.	35,000.	-
Total Nitrogen	25,000.	35,000.	17,000.	16,000.	-	-	-
Total Phosphorus	1,500.	3,900.	1,700.	3,200.	2,000.	7,000.	4,750.
Nickel	-	-	-	L 2.	-	-	L 3.
Zinc	10.	70	-	18.	10.	70.	45.
Copper	2.	20	-	1.4	5.	30.	12.4
Lead	-	-	-	L 2.	-	-	6.
Cadmium	-	-	-	L 0. 2	-	-	0.3
Chromium	-	-	-	L 0. 2	-	-	6.
Mercury	-	-	-	L 0 .01	-	-	0.085
Manganese	15.	150	-	L 25.	20.	100.	-
Arsenic	-	-	-	L 0.2	-	-	0.13
Iron	-	-	-	L 1,000.	-	-	200.

* BATES, T., 1969. Progress Report, Department of Soil Science, University of Guelph. (Note: 'Lower Level' indicates plant deficiency below this value.)

L = Less than

Table 5. AVERAGE CONCENTRATIONS, LAND IRRIGATION STUDY, SMITHVILLE (Overland Runoff) AND SHELBURNE (Spray Irrigation) SITES

PARAMETERS (in mg/L or otherwise stated)	Water* Quality Criteria	SMITHVILLE							SHELBURNE	
		Raw Sewage Quality 1972 (1973)	Sewage Effluent Quality 1972 (1973)	Ground-Water Quality at 1 ft. (SM 22,23) 1972 (1973)	Ground-Water Quality at 10 ft. (SM 21) 1972 (1973)	Background Ground-Water Quality (SM 30) 1973	Surface Runoff Quality (SM 3,4,5) 1972 (1973)	Twenty Mile + Creek Quality 1972 (1973)	Sewage Effluent Quality 1971 (1972)	GroundWater Quality from Lysimeters (0.5 to 3' depth) 1971 (1972)
Alkalinity	-	-	-	-	-	-	-	-	287. (258.)	-
Chloride	250.	-	-	-	-	-	-	-	75. (79.)	-
Sodium	-	-	-	-	-	-	-	-	67. (53.)	-
Calcium	-	-	-	-	-	-	-	-	81. (57.)	-
Magnesium	-	-	-	-	-	-	-	-	30. (28.)	-
Potassium	-	-	-	-	-	-	-	-	11. (11.)	5. (-)
Sulphate	250.	-	-	-	-	-	-	-	57. (81.)	-
pH (units)	6.5 to 8.5	-	8.3 (7.9)	7.2 (7.1)	7.5 (7.4)	(7.4)	-	-	8.2 (8.7)	-
Ammonia Nitrogen	0.02**	-	6.4 (11.9)	0.6 (2.3)	0.2 (1.0)	(0.3)	1.1 (1.5)	0.1 (.2)	3.0 (2.2)	0.01 (0.4)
Nitrate + Nitrite Nitrogen	10.	-	0.3 (.1)	0.1 (.2)	0.1 (.2)	(0.1)	-	-	0.3 (.1)	2.1 (0.2)
Total Kjeldahl Nitrogen	-	-	14.6 (27.3)	3.2 (10.6)	2.0 (4.3)	(1.5)	5.3 (7.1)	1.0 (1.1)	9.2 (10.7)	2.0 (3.9)
Total Nitrogen	-	-	14.9 (27.4)	3.3 (10.8)	2.1 (4.5)	(1.6)	-	-	9.5 (10.8)	4.1 (4.1)
Total Phosphorus	0.03	11.8(10.6)	6.4 (8.1)	0.5 (1.8)	0.4 (.5)	(0.2)	2.4 (2.6)	0.2 (.2)	4.1 (3.8)	0.2 (0.6)
Filtered Reactive Phosphorus	-	-	-	-	-	-	-	-	2.9 (1.8)	0.04 (0.1)
Suspended Solids	-	256.(329.)	65.(86.)	-	-	-	108. (78.)	11. (40.)	60. (70.)	-
Manganese	0.05	-	-	-	-	-	-	-	0.2 (0.04)	-
Iron	0.3	-	-	-	-	-	-	-	0.3 (0.3)	-

* Provincial Water Quality 0bjectives (Water Management; Goals, Policies, 0bjectives and Implementation Procedures of the Ministry of the Environment, 1978).

** Un-ionized ammonia nitrogen; amount dependent on temperature and pH of the aqueous ammonia solution.

\+ Water-quality station 06-0024-002-02; from Volume VII (1972) and Volume VIII (1973), "Water Quality Data, 0ntario Lakes and Streams", Water Resources Branch, Ontario Ministry of the Environment.

Table 6. AVERAGE CONCENTRATIONS, PRIVATE WASTE DISPOSAL STUDY

PARAMETERS (in mg/L or otherwise stated)	Water* Quality Criteria	SITE 1 1974 Distance from site (metres)		SITE 2 1975 Distance from site (metres)		SITE 3 1975 Distance from site (metres)		SITE 4 1976 Distance from site (metres)		SITE 5 1976 75/76 Distance from site (metres)		SITE 6 1976 Distance from site (metres)		SITE 7 1976 Distance from site (metres)		SITE 8 1976 Distance from site (metres)		SITE 9 1976 Distance from site (metres		Average Septic Tank Effluent Quality
		.1m	9m	6m	26m	Septic Tank	7m	Septic Tank	6m	Septic Tank	12m	Septic Tank	7m	Septic Tank	10m	Septic Tank	4m	Septic Tank	6m	Sites 3 to 9 and 3 others
Alkalinity	-	-	-	-	-	433.	-	687.	-	224.	-	599.	-	541.	-	992.	-	384.	-	508.
Chloride	250.	36.	4.	37.	8.	78.	41.	95.	46.	49.	32.	124.	86.	322.	574.	112.	195.	84.	43.	79.
Sodium	-	-	-	21.	7.	68.	15.	67.	11.	53.	34.	172.	32.	241.	153.	142.	27.	68.	30.	91.
Calcium	-	-	-	121.	87.	75.	85.	44.	126.	14.	9.	48.	197 .	74.	810.	117.	184.	33.	27.	-
Magnesium	-	-	-	6.	9.	20.	12.	19.	18.	5.	2.	26.	20.	45.	203.	38.	42.	15.	11.	25.
Potassium	-	-	-	3.	2.	25.	12.	48.	3.	16.	6.	21.	2.	17.	2.	32.	1.	24.	5.	23.
Sulphate	250.	-	-	28.	24.	32.	21.	28.	28.	28.	22.	37.	92.	45.	108.	32.	100.	43.	38.	41.
Total Carbon	-	-	-	-	-	204.	-	253.	-	150 .	-	243.	-	199.	-	351.	-	218.	-	205.
Inorganic Carbon	-	-	-	-	-	111.	-	152.	-	67.	-	143.	-	124.	-	171.	-	113.	-	115.
Organic Carbon	-	-	-	11.	12.	93.	36.	101.	10.	83.	20.	100.	93.	75.	18.	180.	10.	105.	4.	90.
Ammonia Nitrogen	0.02**	L 0.1	L.1	0.28	.22	0.38	0.10	141.7	0.09	40.8	1.62	59.	0.08	39.	0.02	104.	0.03	68.	0.02	63.
Nitrate+Nitrite -Nitrogen	10.	0.44	.24	0.22	.09	0.14	0.76	0.32	0.10	0.12	0.07	0.16	0.12	0.11	5.93	0.22	1.40	0.3	15.7	0.11
Total Kjeldahl Nitrogen	-	0.50	.42	0.68	.57	55.	0.47	158.3	0.57	55.5	2.37	71.	0.75	57.	0.17	117.	0.15	83.	.50	75.
Total Nitrogen	-	0.94	.66	0.90	.66	55.1	1.23	158.6	0.68	55.6	2.44	71.2	0.87	57.1	6.10	117.2	1.55	83.3	16.2	75.1
Total Phosphorus	0.03	0.57	.16	0.22	.01	7.7	0.01	20.5	0.01	9.1	0.04	8.8	0.05	20.	0.03	18.1	L 0.01	10.6	L0.01	12.1
Filtered Reactive Phosphorus	-	0.45	.13	0.21	L.02	4.6	0.01	17.5	L 0.01	7.2	0.02	7.1	0.02	16.	L 0.01	12.8	L 0.01	8.7	L0.01	9.6
Nickel	0.025	-	-	-	-	0.01	-	L 0.01	-	-	-	-	-	0.02	-	-	-	-	-	-
Zinc	0.03	-	-	-	-	0.08	-	0.14	-	-	-	-	-	0.05	-	-	-	-	-	-
Copper	0.005	-	-	-	-	0.18	-	0.02	-	-	-	-	-	0.03	-	-	-	-	-	-
Lead	0.005***	-	-	-	-	0.03	-	L 0.02	-	-	-	-	-	L 0.02	-	-	-	-	-	-
Cadmium	0.0002	-	-	-	-	L 0.01	-	L 0.01	-	-	-	-	-	L 0.01	-	-	-	-	-	-
Chromium	0.1	-	-	-	-	0.02	-	0.01	-	-	-	-	-	0.02	-	-	-	-	-	-
Manganese	0.05	-	-	-	-	0.04	-	0.04	-	-	-	-	-	0.03	-	-	-	-	-	-
Arsenic	0.1	-	-	-	-	0.002	-	0.002	-	-	-	-	-	0.003	-	-	-	-	-	-
Iron	0.03	-	-	0.18	.17	0.51	0.05	0.8	-	1.6	18.5	1.2	0.69	0.34	0.09	2.1	0.18	1.1	0.32	0.8
Total Coliforms (# per 100 m/L)	1000.	1800.	200.	L 10.	L10.	-	170.	-	2800.	-	900.	-	1700.	-	760.	-	1800.	-	90.	-
Fecal Coliforms (# per 100 m/L)	100.	L 10.	L40.	L 10.	L10.	-	L 10.	-	110.	-	30.	-	20.	-	138	-	80.	-	40.	-
Fecal Streptococci (# per 100 m/L)	-	-	-	L 10.	110.	-	50.	-	L10.	-	40.	-	L 10.	-	220.	-	30.	-	100.	-
Number of Samples	-	6	6	5	6	9	6	7	6	11	7	6	3	7	3	8	3	8	2	76

* Provincial Water Quality Objectives (Water Management; Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment, 1978).

** Un-ionized ammonia nitrogen; amount dependent on temperature and pH of the aqueous ammonia solution.

*** Criterion dependent on alkalinity; ranges from 0.005 to 0.025 mg/L.

L = Less than

Table 7. RANGE OF CONCENTRATIONS, POINT SOURCE STUDY, GRAND RIVER AND SAUGEEN RIVER PILOT WATERSHEDS

PARAMETER	CRITERIA*	SAUGEEN RIVER	GRAND RIVER	
		MUNICIPAL (6STPs)	MUNICIPAL (9STPs)	95INDUSTRIAL OUTFALLS
mg/L				
Total Phosphorus	0.03	1.73- 6.59	0.45 - 4.45	L 0.001 - 180.
Nitrate+Nitrite-Nitrogen	10.	0.05-18.9	0.01 - 18.1	L.005 - 5.7
Ammonia Nitrogen	0.02**	0.02-19.5	0.01 - 18.9	L .002 - 20.
Chloride	250.	038.- 92.	142 - 945.	11 - 2000.
Zinc	0.03	0.019 -0.09	0.03 - 0.79	0.002 -65.
Lead	0.005***	L.002- 0.029	L 0.002 - 0.04	L 0.001 - 46.
Cadmium	0.0002	L.001- 0.002	L 0.001 - 0.008	L 0.001 - 0.33
Copper	0.005	.008- 0.076	0.007 - 0.119	0.002 - 59.
Iron	0.3	0.09- 0.93	0.25 - 5.01	L 0.03 - 24.
Nickel	0.025	L 0.002- 0.0048	L 0.001 - 0.35	L 0.001 - 73.
Chromium	0.10	L 0.002- 0.023	L 0.002 - 0.31	L 0.001 - 7.2
Arsenic	0.10	0.001- 0.003	L 0.001- 0.002	L 0.001 - 0.038
ug/L				
Mercury	0.2****	L. 0.03 - 0.38	0.02 - 0.43	0.04 - 21.
PCB	0.001	ND- 0.05	ND- 0.34	ND-1.2
HC	-	ND	ND- 0.025	ND- 0.02
Lindane	0.01	ND	ND- 0.111	ND- 0.003
Heptachlor Epoxide	0.001	ND- 0.025	ND- 0.003	ND- 0.010
p,p'DDE	0.003	ND	ND- 0.009	ND- 0.010
Dieldrin	0.001	ND- 0.005	ND- 0.05	ND- 0.010
Endrin	0.002	ND	ND- 0.01	ND- 0.010
o,p'DDT	0.003	ND	ND- 0.007	ND- 0.008
p,p'DDD	0.003	ND	ND- 0.04	ND- 0.008
p,p'DDT	0.003	ND	ND- 0.05	ND- 0.008
α Chlordane	0.06	ND	ND- 0.12	ND- 0.003
γ Chlordane	0.06	ND	ND- 0.15	ND- 0.004
Mirex	0.001	ND	ND- 0.002	ND
BHC	-	ND	ND- 0.01	ND- 0.010

* Provincial Water Quality 0bjectives (Water Management; Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment, 1978).

** Un-ionized ammonia nitrogen; amount dependent on temperature and pH of the aqueous ammonia solution.

*** Criterion dependent on alkalinity; ranges from 0.005 to 0.025 mg/L.

**** Criterion based on filtered water sample.

L = Less than

ND = Not Detected

10.2 UNIT LOADS

Unit load estimates are presented in tables 8 to 10, inclusive. Table 8 presents unit-area load estimates for surface runoff from lands used for processed organic waste disposal. Runoff from agricultural land is included for comparative purposes. Table 9 presents unit-area load estimates to ground-water systems from sanitary landfilling, processed organic waste disposal and land irrigation from wastewater lagoons. The details of unit-area load calculations are also given in Table 9. Table 10 presents unit loads per capita for private waste disposal systems and municipal and industrial point sources in the Grand River and Saugeen River pilot watersheds. The details of unit loads per capita calculations are also given in Table 10.

Table 8. SURFACE RUNOFF, UNIT–AREA LOAD ESTIMATES

LAND USE		TOTAL PHOSPHORUS (kg/ha/yr)	TOTAL NITROGEN (kg/ha/yr)	CHLORIDE (kg/ha/yr)	COPPER (kg/ha/yr)	LEAD (kg/ha/yr)	ZINC (kg/ha/yr)
Processed Organic Waste Disposal		0.32	1.6	2.4	0.02	0.006	0.02
Agricultural Land*	(mean)	0.89	11.7	47.2	0.04	0.015	0.11
	(range)	0.05-2.30	0.62-23.5	5.0-124	0.002-0.093	0.004-0.037	0.005-0.28

* From Avadhanula, 1979

Table 9. GROUND WATER, UNIT-AREA LOAD ESTIMATES

Land Use	Area In Ontario (hectares)	Gross Waste-Application Rate (m^3/ha/yr)	Total Phosphorus (kg/ha/yr)	Total Nitrogen (kg/ha/yr)	Chloride (kg/ha/yr)	Copper (Kg/ha/yr)	Lead (kg/ha/yr)
Sanitary Landfill *	8,900	-	-	-	2640.	-	-
Processed Organic Waste Disposal +	17,550	12.4	0.19	11.	8.	0.005	0.006
Land Irrigation x	1,050	4,150.	0.13	270.	-	-	-

* Unit-Area Load $= [C_2 - C_1] \bullet [SF_{(July-Oct)}] \bullet \left\{ \frac{I\ (January-December)}{I\ (July-October)} \right\} \div Area$

where:
- C_2 = concentration downstream (Table 1)
- C_1 = concentration upstream (Table 1)
- I = ground-water gradient (0.082/.076)
- SF = stream flow volume (avg.0.06156 m^3/sec)

\+ Unit-Area Load $= \left\{ \left\{ \frac{C_3Q_1}{A_1} + \frac{C_3Q_2}{A_2} + \frac{C_4Q_3}{A_3} \right\} \div 3 \right\} \bullet \left\{ \frac{GAR}{AR} \right\}$

where:
- C_3 = tile drain concentration, Brantford site (Table 3)
- Q_1 = tile drain discharge, Brantford site (1784 m^3)
- A_1 = tile drain area, Brantford site (3.2 hectares)
- Q_2 = ground-water flow, Brantford site (4.2 m^3/ha/day; Note 1)
- A_2 = study area,Brantford site (16 hectares)
- C_4 = concentration difference between downgradient ground-water quality and background ground-water quality, Newmarket site(Table 2)
- Q_3 = ground-water flow, Newmarket site (4.6m^3/ha/day; Note 2)
- A_3 = study area, Newmarket site (3.2 hectares)
- GAR = gross waste application rate(Table 9)
- AR = waste application rate, Brantford and Newmarket sites (tables 2 and 3)

x Unit-Area Load $= C_5 \bullet [GAR] \bullet [1-A]$

where:
- C_5 = average waste concentration(Sullivan *et al* 1973)
- GAR = gross waste application rate (Table 9)
- A = attenuation factor (0.85 for Nitrogen and 0.97 for Phosphorus)

Note 1:

$$Q_2 = \frac{A_2 . \left\{ \text{annual precipitation (77 cm)} - \text{sewage water (3.3 cm)} - \text{evapo transpiration (64cm)} \right\}}{365.25\ \text{days}} - Q_1$$

Note 2:

$$Q_3 = \frac{A_3 . \left\{ \text{annual precipitation (78 cm)} - \text{sewage water (1.9 cm)} - \text{evapo transpiration (5.1 cm)} \right\}}{365.25\ \text{days}} - Q_1$$

Table 10. UNIT LOADS PER CAPITA

PARAMETER	GRAND RIVER BASIN			SAUGEEN RIVER BASIN	
	PRIVATE WASTE* DISPOSAL SYSTEMS (kg/capita/yr)	MUNICIPAL** EFFLUENT (kg/capita/yr)	TOTAL MUNICIPAL*** AND INDUSTRIAL DISCHARGES (kg/capita/yr)	PRIVATE WASTE* DISPOSAL SYSTEMS (kg/capita/yr)	MUNICIPAL** EFFLUENT (kg/capita/yr)
Total Phosphorus	0.26	0.30	0.46	0.27	0.72
Total Nitrogen	2.22	4.2	4.6	2.38	4.9
Chloride	5.0	57.8	64.4	5.4	26.4
Lead	-	0.002	0.006	-	0.0006
Zinc	-	0.05	0.06	-	0.009
Copper	-	0.007	0.02	-	0.009

* Unit load per capita $= ([C_1 \bullet P_1 \bullet V_1 \bullet 365] + [C_1 \bullet P_2 V_2 \bullet 365/4) \bullet (F + (1-A))$

where:
- C_1 = Effluent concentration (Table 5)
- P_1 = Population using year-round systems
  Grand River basin; 135,677
  Saugeen River basin; 32,509
- V_1 = Volume of waste water from year-round systems (168 L/person/day)
- P_2 = Population using seasonal dwellings (3 months usage; 4 persons per system)
  Grand River basin; 7,223 systems
  Saugeen River basin; 7,252 systems
- V_2 = Volume of waste water from seasonal dwellings (91 L/person/day)
- F = Failure (0.30)
- A = Attenuation (P =.95; N =.60; CL=0)

** Unit Load per capita $= \dfrac{\text{Total Volume Municipal Effluent}}{\text{Sewered Population}}$

*** Unit Load per capita $= \dfrac{\text{(Total Volume Municipal Effluent) + (Total Volume direct industrial discharges to receiving streams)}}{\text{Sewered Population (379,000 Grand River basin; 24,500 Saugeen River basin)}}$

10.3 TOTAL LOAD ESTIMATES

Based on unit load estimates, total loads for various land uses in the Grand River and Saugeen River pilot watersheds were computed. The total estimated load is based on the sum of all diffuse and point-source loads in the pilot watersheds. Loads for the major land uses within the pilot watersheds are presented in Table 11. The monitored loads at the mouths of the pilot watersheds have been included for comparative purposes. The proportion of the load at the mouth of the pilot watersheds that can be attributed to the waste disposal practices studied for the PLUARG program are presented in Table 12.

Table 11. RELATIVE SIGNIFICANCE OF SOURCES WITHIN THE PILOT WATERSHEDS (after Hore and Ostry, 1978)

	Monitored Load At Mouth		Total* Estimated Load At Mouth	Urban	Rural	Wooded/ Idle	Extractive, Transport. Corridors Misc.	Processed Organic Waste Disposal	Sanitary Landfills	Land Irrigation From Waste-water Lagoons	Private Waste Disposal	Point Sources
	1975	1976										
GRAND RIVER												
Area (668,000 ha)	--		-	(20,000ha)	(504,000ha)	(127,000 ha)	(11,430ha)	(5,110ha)	(530ha)	(100ha)	-	-
Total Phosphorus(mt/yr)	4386	19	701	28	452	11	-		-	0.1	35	174
Total Nitrogen (mt/yr)	7,680	9,330	8,700	169	5,860	654	-	-	-	-	300	1,726
Chloride (mt/yr)	65,100	69,900	80,600	-	10,100	2,540	41,800	40	1,40	-	670	24,040
Lead (mt/yr)	-	15	20	8	8	2	-	-	-	-	-	2
Zinc (mt/yr)	65	91	90	10	54	2	-		-	-	-	23
Copper (mt/yr)	29	29	30	2	18	4	-	-	-	-	-	6
SAUGEEN RIVER												
Area (400,000/ha)	--		-	(3,970 ha)	(258,000ha)	(131,000ha)	(6,830ha)	(109ha)	(230ha)	(10ha)	-	-
Total Phosphorus (mt/yr)	204	160	273	3	229	13	-	-	-	1	9	18
Total Nitrogen (mt/yr)	3,130	3,420	3,870	26	2,969	675	-	-	-	2	78	120
Chloride (mt/yr)	14,400	14,700	16,300	79	5,100	2,620	7,100	1	610	-	176	647
Lead (mt/yr)	-	7	13	2	8	3	-	-	-	-	-	-
Zinc (mt/yr)	25	39	32	2	27	3	-	-	-	-	-	-
Copper (mt/yr)	18	14	13	-	9	4	-	-	-	-	-	-

* Sum of all diffuse and point source loads. Diffuse loads were estimated by multiplying the specific land-use area in the pilot watershed by its respective unit-area load.

Table 12. PROPORTION OF THE PILOT WATERSHED LOAD ATTRIBUTABLE TO WASTE DISPOSAL

LAND USE OR WASTE DISPOSAL PRACTICE	AREA (ha)	POPULATION	PARAMETERS (EXPRESSED AS "PERCENT OF THE TOTAL LOAD AT THE MOUTH OF EACH PILOT WATERSHED")					
			TOTAL PHOSPHORUS	TOTAL NITROGEN	CHLORIDE	LEAD	ZINC	COPPER
GRAND RIVER	668,000	514,000*						
Point Sources	-	379,000+	25.	20.	30.	11.	25.	21.
Private Waste	-	135,000#	5.	3.	0.8	Nil	Nil	Nil
Sanitary Landfills	530	-	Nil	Nil	2.	Trace	Trace	Trace
Processed Organic Waste	5,110	-	0.1	Trace	Trace	Trace	Trace	Trace
Land Irrigation	100	-	Trace	Trace	Trace	Trace	Trace	Trace
SAUGEEN RIVER	400,000	57,500*						
Point Sources	-	24,500+	7.	3.	4.	0.1	0.7	2.
Private Waste	-	33,000#	3.	2.	1.	Nil	Nil	Nil
Sanitary Landfills	230	-	Nil	Nil	4.	Trace	Trace	Trace
Processed Organic Waste	109	-	0.3	Trace	Trace	Trace	Trace	Trace
Land Irrigation	10	-	Trace	Trace	Trace	Trace	Trace	Trace

* Basin Population

\+ Sewered Population

\# Population using Septic Tank Systems

11.0 DATA INTERPRETATION AND CONCLUSIONS

11.1 CAUSES AND SOURCES OF POLLUTANT CONTRIBUTIONS

The major pollutants from waste disposal practices studied under the PLUARG Task 'C' program were tentatively identified as follows:

Sanitary landfill	-chloride
Processed organic waste disposal	-phosphorus, nitrogen, and trace elements
Land irrigation from wastewater lagoons	-phosphorus and nitrogen
Private waste disposal	-phosphorus and nitrogen
Point sources	-phosphorus, nitrogen, chloride, trace elements and organic chemicals.

With the exception of point-source discharges, the other waste disposal practices identified above utilize a subsurface environment to attenuate or treat the contaminants that they produce. The attenuating mechanisms consist of bacterial decomposition, dilution with subsurface water, chemical and physical reactions in the wastewater and between the wastewater and the surrounding soils through which the wastewater passes. Other mechanisms influencing the contamination of the subsurface environment are the volume of contaminant, the rate at which it reaches the ground-water flow system, the position of the source of contamination within the ground-water flow system and the hydraulic properties of the materials through which the wastewater passes. As a consequence of all these highly variable factors, site-specific investigations are usually required to quantitatively assess an environmental impact at any site.

11.1.1 Sanitary Landfill

PLUARG studies conducted at the Violet sanitary landfill site, located in the Wilton Creek drainage basin, Ontario, (Figure 2), suggest that the leachate generated at the landfill site is a potential contaminant when compared with Provincial Water Quality Objectives (Anon., 1978). The leachate composition ranges from one to three orders of magnitude higher than Provincial Water Quality Objectives for the parameters chloride, ammonia nitrogen, total phosphorus, nickel, copper, lead and cadmium (Table 1). Ground water, downgradient of the landfill site also contains higher concentrations than the background ground water for the major chemical ions, carbon, nitrogen, trace elements, COD and phenolic compounds (Table 1). However, the migration of pollutants to the receiving water is minimal as indicated by a comparison of the water quality from paired samples upstream and downstream of the landfill site (Table 1). These data suggest that only chlorides are being delivered to the receiving stream in any appreciable amount. The other parameters approach or are below background water-quality values indicating that they have been attenuated in the subsurface passage of the leachate from the site to the stream, a distance of approximately 35 metres.

11.1.2 Processed Organic Waste Disposal on Agricultural Lands

Comparison with Provincial Water Quality Objectives (Anon., 1978) indicates that the composition of processed organic waste ranges from one to four orders of magnitude greater for all parameters than the stated criteria as shown in tables 2 and 3. However, chemical analysis of surface runoff, soil, biomass and ground water from the PLUARG studies at two sites where processed organic waste was spread on agricultural lands (Newmarket and Brantford, figures 3 and 4), suggests that the major pollutants to receiving waters from this disposal practice are phosphorus, nitrogen and trace elements.

Monitoring data suggest that excessive accumulations of these parameters are not occurring in the soils or plants. The presence of pollution indicator bacteria in runoff and ground water suggests, that under favourable conditions, bacterial contamination may be a potential health hazard.

11.1.2.1 Surface Runoff: Precipitation, topography, season, cover crop, soil type, composition of the processed organic waste and application rate will effect the composition of the runoff from a disposal site. Surface runoff from the Newmarket site was found to be variable and the average chemical composition of five runoff events in 1976 is shown in Table 2. In comparison with the Black River at the Newmarket site, levels of nitrogen, phosphorus and trace elements in surface runoff from the site were up to one order of magnitude higher (Table 2) than the receiving stream. Analyses for organochlorine compounds, triazene herbicides and PCBs were at non-detectable levels. Levels of pollution indicator bacteria in surface-water runoff (Table 2) were within permissible levels as stated in the Provincial Water Quality Objectives (Anon., 1978). Surface runoff was not measured at the Brantford site because of flooding by the Grand River during runoff events (Table 3). Analyses of the flood water are included in Table 3 for comparative purposes only.

11.1.2.2 Soils: Trace elements and phosphorus are present in significant quantities in processed organic waste (sludge quality, tables 2 and 3) and have a high affinity for or sorption on particulate matter. Consequently, uncontrolled spreading of processed organic waste may lead to increased levels of these materials in the soil at a site. Comparison of the sludge amended soils from the Newmarket and Brantford sites with average values for Ontario soils (tables 2 and 3) suggest that very little accumulation, if any, is occurring at either site.

11.1.2.3 Biomass: With respect to accumulation and toxicity of trace elements in vegetation, Webber (1979) indicates that:

> "elevated levels of zinc, copper and nickel may depress crop yields, but the crops exhibit little, if any, toxicity to animals; high levels of manganese, iron, aluminum and chromium pose relatively little hazard because of either high plant tolerance and/or non-accumulation; arsenic tends to accumulate in the roots and most of the edible portions of the plants are well below the critical concentration (2.6 ppm); low levels of selenium, antimony and mercury are normally found in sludge and consequently the potential hazard is low; and that lead exhibits a low degree of potential toxicity in the concentrations found in sludge."

Comparison of biomass concentrations from the Newmarket and Brantford sites with acceptable levels as shown in Table 4 (Bates, 1969), suggest that excessive build-up in the plants and the plant tissue is not occurring as a result of processed organic waste spreading.

11.1.2.4 Ground Water: Monitoring of ground water at the two study areas suggests that increased levels of phosphorus and nitrogen in the ground water downgradient of the sites are occurring as a result of processed organic waste spreading (tables 2 and 3). Increased levels of some trace elements (lead and cadmium at Newmarket; nickel at Brantford) in the ground water were also observed. Levels of pollution indicator bacteria in ground water from the study areas (tables 2 and 3) were within permissible levels, as stated in the Provincial Water Quality Objectives for total and fecal coliforms (Anon., 1978). Their presence is an indication of potential bacterial pollution and under favourable conditions pathogenic micro-organisms, if present in the processed organic waste, could constitute a potential health hazard. Analyses for synthetic organic materials (organochlorine compounds, triazine herbicides and PCBs) showed non-detectable limits at both study sites.

11.1.3 Land Irrigation from Wastewater Lagoons

The results of the two investigations at Smithville and Shelburne, conducted by the Ontario Ministry of the Environment (Ehlert 1973 and 1975), relating to overland runoff and spray irrigation of wastewater, respectively, were used to supplement the PLUARG studies on waste disposal practices. Comparison of the chemical composition of the sewage effluent with parameters noted in the Provincial Water Quality Objectives (Anon., 1978) suggests that the potential pollutants are phosphorus and nitrogen (Table 5). Elevated levels of phosphorus and nitrogen were found in the ground water and surface runoff from the sites. The presence of pollution indicator bacteria in the ground water suggests that bacterial contamination from wastewater irrigation may be considered as a potential health hazard.

11.1.3.1 Surface Runoff: In comparison with streamflow quality, the overland runoff of wastewater from the Smithville site appears to be contributing nutrients, BOD and suspended solids to the receiving waters of Twenty Mile Creek (Table 5). However, because of the high waste assimilative capacity of the receiving waters (i.e. relatively low volume of runoff in comparison to streamflow), the water quality of the stream is not degraded to any appreciable extent.

11.1.3.2 Ground Water: Infiltrating wastewater was monitored from the overland runoff at Smithville and spray irrigation at Shelburne. Data from these studies suggest that the soil materials significantly attenuate phosphorus and nitrogen, as suggested from the comparison of the effluent composition with the ground-water quality adjacent to the sites (Table 5). In conjunction with the reduction in nitrogen concentration, transformation from the complex organic nitrogen form to the highly soluble, inorganic nitrate form also occurs during infiltration.

Ehlert (1973) suggests that the presence of fecal coliform bacteria (ranging from 10/100 mL to 100/100 mL) in ground-water monitoring points at the Shelburne site is an indicator of bacterial contamination of the ground water. Ehlert also indicates that two months after spraying had been terminated, bacterial pollution was still monitored in the ground water. Consequently he concludes that under favourable conditions, pathogenic micro-organisms such as *Salmonella* which occur in raw sewage and sewage effluents, and can survive for long periods of time, can be considered to be a potential health hazard.

Analyses for bacterial viruses (bacteriophages) which are similar to human enteric viruses were carried out in both the lagoon effluent and ground water in an attempt to trace their migration pattern through soil and ground waters in the Shelburne study. It was concluded that passage of bacterial viruses through the soil was not occurring.

11.1.4 Private Waste Disposal

Compared with the Provincial Water Quality Objectives (Anon., 1978), concentrations of nitrogen, phosphorus, zinc, copper, lead and cadmium from septic-tank effluents exceed the stated criteria (Table 6). However, monitoring of the ground-water quality downgradient of nine study sites, suggests that only phosphorus and nitrogen are potential pollutants from private waste disposal systems (Table 6). Attenuation of these parameters to acceptable levels can occur providing sufficient soils materials and suitable ground-water conditions are available to treat the wastewater. In general, counts of pollution indicator bacteria in the ground water adjacent to six of the nine sites were below the Provincial Water Quality Objective of less than 1,000/100 mL (Table 6). However, their presence is an indication of potential bacterial pollution of the receiving waters.

11.1.5 Point Sources

Monitoring under the PLUARG program in the Grand River and Saugeen River pilot watersheds indicates that municipal and industrial effluent discharges contain significant concentrations of nutrients (especially phosphorus), chloride, trace elements and organic chemicals (Table 7) which exceed the Provincial Water Quality Objectives (Anon., 1978). Pollutant inputs from point sources in the Saugeen River basin are not as extensive as in the Grand River basin because of the smaller urban population and less diverse industry, as indicated below:

	Saugeen River	Grand River
Basin Population	57,500	514,000
Urban or sewered population (in percent of basin population)	24,500 (43%)	379,000 (73%)
Number of Sewage Treatment Plants (STPs)	9	22
Number of Industries treated by STPs	5	greater than 650
Annual Volume of Waste-water treated by STPs	7×10^6 m^3 (0.2 m^3/sec.)	93×10^6 m^3 (2.9 m^3/sec.)
Historic Annual Low Flows	7 to 14 m^3/sec	5 to 15 m^3/sec.
Number of industries discharging directly to receiving streams	1	95

Industries in the Saugeen River basin include poultry, dairy operations, furniture manufacturing and minor metal processing. In contrast, the larger urban population in the Grand River basin is serviced by industries such as textile, rubber manufacturing, metal processing, chemical and food processing. Consequently, pollutant levels from point sources in the Grand River basin are higher (Table 7), particularly the pesticides, organic chemicals and trace elements.

11.2 EXTENT OF POLLUTANT CONTRIBUTION AS UNIT LOADINGS FROM LAND–USE AREAS WITHIN THE PILOT WATERSHEDS

11.2.1 Unit-Area Loads

The extent of pollutant contribution from a specific area is dependent on the magnitude of the sum of all the pollutant discharges from the various land uses and practices in that area during a given period of time. This pollutant contribution can be reduced to a unit-area load which is the total load divided by the contributing area. If the contributing area has a single land use, then the unit-area load will be representative of that particular land use. 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.

11.2.1.1 Surface Water: Sites used for sanitary landfilling, processed organic waste disposal and land irrigation from wastewater lagoons are designed to minimize losses to surface runoff. Under the PLUARG studies, surface runoff was only monitored from the processed organic waste disposal study at Newmarket. Using data from five runoff events in the spring of 1976, unit-area loads were computed for nutrients, chloride and trace elements (Table 8). The spreading of the processed organic waste was occurring on agricultural land (i.e. grass-hay crop) and the computed unit-area loads fall within the range calculated by Avadhanula (1979) for runoff from agricultural lands (Table 8). Further examination of these data indicates that the values computed for runoff from the Newmarket site fall considerably below the mean value for runoff from agricultural land. This suggests that the impact of spreading processed organic waste on the low-intensity agricultural land (at the Newmarket site) is minimal.

11.2.1.2 Ground Water: In terms of ground-water quality, providing sufficient earth materials and suitable ground-water conditions are available between the site and where ground-water discharge occurs, most pollutants will be attenuated to below detectable limits. Under these circumstances, the effect on receiving stream water quality will be minimal. However, the impact on the ground-water system can be potentially large.

Where applicable, the pollutant loads to the ground-water systems from sanitary landfilling, processed organic waste disposal (on agricultural land) and land irrigation from wastewater lagoons was estimated using monitoring data for nutrients, chloride and trace elements (Table 9). These loads were then adjusted, as shown in Table 9, to estimate a unit-area loads to the receiving streams from the ground-water systems.

In comparison with pollutant inputs from surface runoff (Table 8) on agricultural land, unit-area loads from ground water (Table 9) are significant for chloride from sanitary landfilling (56 times as large) and nitrogen from land irrigation from wastewater lagoons (23 times as large). The remaining ground-water inputs are comparable to pollutant loads for surface runoff from agricultural lands.

11.2.2 Unit Loads

Some waste disposal practices, such as point sources and private waste disposal, do not lend themselves to a strict unit-area load calculation. Unit loadings independent of area provide a more suitable method of reporting the loads from these sources. Unit loads per capita per year are presented in Table 10 for private waste disposal and point sources in the Grand River and Saugeen River pilot watersheds. The pollutant loading estimate from private waste disposal presumes that 30% of the existing systems failed to remove pollutants from the septic-tank effluent, on a yearly basis (Chan, 1978). For example, the ponding of effluent on the ground surface at various times of the year can occur with subsequent delivery of pollutants to receiving streams by surface runoff.

Unit loads for total phosphorus from municipal and private sewage sources vary from 0.3 kg/capita/yr in the Grand River pilot watershed to 0.7 kg/capita/yr in the Saugeen River pilot watershed (Table 10). The low unit loads in the Grand River basin, compared to the Saugeen River basin, reflect the phosphorus removal facilities required by the Province of Ontario as part of the phosphorus removal program at wastewater treatment plants (STPs) in the lower Great Lakes.

Total nitrogen varies from approximately 2 kg/capita/yr from private waste disposal systems to approximately 5 kg/capita/yr from wastewater treatment plant effluents in the pilot watersheds. Chloride ranges from 5 kg/capita/yr from private waste disposal systems to approximately 60 kg/capita/yr from wastewater treatment plants in the Grand River watershed. The higher values for trace elements and chloride in the Grand River watershed reflect the more industrialized nature of the watershed in comparison with the more rural Saugeen River watershed.

11.3 RELATIVE SIGNIFICANCE OF SOURCES WITHIN THE PILOT WATERSHEDS

Unit-area load derived from the PLUARG studies were used in conjunction with the basin-wide inventory of all land uses in the Grand River and Saugeen River pilot watersheds to estimate a total load by summation at the mouths of the watersheds. The magnitude of these summed loads compared favourably, by less than a factor of two, with the monitored load at the respective mouths (Table 11). Consequently,the estimated loads computed from the unit-area loads were considered to be reasonable estimates of the pollutant inputs to the pilot watersheds.

For ease of comparison, loads for the waste disposal practices studied under the PLUARG program are presented in Table 12 according. to the proportion of the load at the mouth of the pilot watershed which could be attributed to that particular land use or waste disposal practice. These data (Table 12) suggest that point sources contribute 20 to 30% of the nutrient and chloride load at the mouth of the Grand River, an urbanized watershed. However, in a predominantly rural watershed such as the Saugeen River, this proportion is quite low, from 3 to 7% of the load at the mouth.

Private waste disposal was estimated to contribute less than 5% of the nutrient and chloride load at the mouths of the pilot watersheds. As indicated earlier, this value assumes a 30% failure rate in the ability of systems to remove pollutants (Chan, 1978).

Processed organic waste disposal and land irrigation of wastewater effluent were found to contribute very little to the impairment of Great Lakes water quality. However, these practices are not widespread in the pilot watersheds and consequently their impact is minimal. If these practices were to be widespread, the pollutant contribution could become significant because of their potentially high unit-area loads, even after renovation or pollutant attenuation considerations.

12.0 RECOMMENDATIONS

Sound water management strategies require consideration of the environment as a whole including land, air and water aspects, as well as the consequence of a management strategy on the social fabric of the basin. The implementation of any water management practice has a 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.

Remedial or preventative strategies are 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 cost 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 is an important factor in dictating the required degree of treatment. Small amounts and/or infrequent inputs of toxic and persistent materials, such as 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 long periods of time because of their persistent nature. Bioaccumulation in the food chain may also serve to aggravate the problem of controlling these kinds of materials.

Treatment and recycling of waste materials is the ultimate solution to the disposal of wastes. Obvious control strategies for waste disposal practices in present use are the retention of contaminants to prevent them from reaching the receiving waters. For those land-use practices that initially impact on the ground-water system, properly designed sites that take advantage of dilution, bacterial decomposition and chemical and physical reactions in the waste and between the soil and the waste will minimize the ultimate impact on receiving stream water quality. Schemes that renovate the natural environment, such as infiltration of wastewater which recharges the ground-water system as well as providing a degree of effluent renovation, should be encouraged.

12.1 FEASIBLE REMEDIAL MEASURES

12.1.1 Sanitary Landfills

If wastes are enriched with heavy metals and organic chemicals, accumulations in the soil from land disposal of such wastes could ultimately create an environmental health hazard. Proper design and management of sanitary landfill sites, utilizing the natural attenuating capacity of the soil for removing pollutants from leachate generated by the 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.

12.1.2 Processed Organic Waste Disposal

Guidelines for processed organic waste disposal 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 processed organic waste on agricultural lands.

12.1.3 Land Irrigation from Wastewater Lagoons

Guidelines used in existing approval procedures by the Ontario Ministry of the Environment presently provide adequate protection of the quality of ground and surface waters from contamination by land irrigation of wastewater effluent.

12.1.4 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 ground water and receiving stream water quality with respect to phosphorus, nitrogen and bacterial contamination. 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.

Transporting suitable soils with high exchange capacities to the site may also be considered. Alternative strategies are the use of other disposal methods such as humus toilets or other suitable soils with high exchange capacities; however, the cost of this latter alternative will be directly related to the cost of transporting these materials to the site. Nitrogen transformation of organic nitrogen that accumulates in the septic systems can create localized ground-water problems as a result of nitrate leaching.

Providing a septic tank/tile field system is designed and constructed according to current Provincial regulations on proper soil types, the proposed minimum distance between tile fields, wells and surface waters are considered adequate to avoid contamination of drinking water and to protect the surface waters.

12.1.5 Point Sources

Surveillance of municipal and industrial sources is a Provincial responsibility and remedial action is recommended when problem areas are identified. Existing Provincial regulations are adequate to control point sources. Consequently, recommendations for point sources were not considered under the PLUARG study.

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