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Contribution of Phosphorus to the Great Lakes from Agricultural Land in the Canadian Great Lakes Basin: Phosphorus Integration Report: Agricultural Watershed Studies, Task Group C, Canadian Section, Activity 1

International Reference Group on Great Lakes Pollution from Land Use Activities

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INTERNATIONAL REFERENCE GROUP ON GREAT LAKES POLLUTION FROM LAND USE ACTIVITIES

INTERNATIONAL JOINT COMMISSION

CONTRIBUTION OF PHOSPHORUS TO THE GREAT LAKES FROM AGRICULTURAL LAND IN THE CANADIAN GREAT LAKES BASIN

Agricultural Watershed Studies

Task Group C (Canadian Section) - Activity 1
International Reference Group on Great Lakes
Pollution from Land Use Activity

Phosphorus Integration Report

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DISCLAIMER

The information presented in this report is an integration of the data from several projects conducted as a part of the efforts of the International Reference Group on Great Lakes Pollution from Land Use Activities (PLUARG), an organization of the International Joint Commission, established under the Canada-U.S. Great Lakes Water Quality Agreement of 1972. The conclusions are the responsibility of the authors and not of those responsible for the individual projects. The results and conclusions do not necessarily reflect the views of the Reference Group or its recommendations to the Commission.

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1.0 SUMMARY

The contributions of phosphorus to the Great Lakes from agricultural land and the associated activities in Southern Ontario have been estimated primarily from the information obtained from the monitoring data and the several detailed studies conducted in the representative agricultural watersheds. Because there is very limited agricultural activity in the Northern Ontario portion of the Canadian Great Lakes Basin, the estimates made are thought to be valid for the total Canadian Great Lakes Basin.

Regression equations were developed to relate the unit area loads of total P and total dissolved P to watershed characteristics. The total P unit area loads were predicted (R^2=0.86) by a regression including % clay in the surface soil and the proportion of the area in row crops. The total P unit area load increased with increasing % clay in the surface soil due probably to increased sediment load. The unit area load also increased with increasing proportion of row crop. This is due to two factors; increased erosion and hence increased sediment load, and increased fertilizer phosphorus use associated with row crop production. The total dissolved P unit area loads were predicted (R^2=0.83) by a regression including % clay and amount of fertilizer and manure P added in the watershed. These regressions were used to estimate the contributions from agricultural activities in subbasins of the Grand and Saugeen River Basins and finally for all subbasins in Southern Ontario.

The contributions of total P from cropland, livestock operations, streambank erosion and unimproved agricultural land were estimated independantly for the agricultural watersheds and for the subbasins of the Grand and Saugeen River Basin. It was estimated that about 70% of the agricultural contribution of total P could be attributed to runoff from cropland, 20% to livestock operations, and 5% to each of streambank erosion and runoff from unimproved agricultural land. About 40% of the total P was estimated to be in the dissolved form. Additional sources which were found to cause localized contributions were: (1) private waste disposal systems located close to drainage ditches or which were directly connected to field drainage systems; (2) contribution from subsurface drainage of cultivated organic soil areas; and (3) drainage from farm yards including seepage from silos.

Extrapolation to the Grand and Saugeen River Basins using the regression equations indicated that 50 to 70% of the total P load in these Rivers could be attributed to agricultural activities.

The regression equations were also used to estimate the unit area loads of total P in over 300 subbasins in the Southern Ontario portion of the Great Lakes Basin. The unit area loads of total P from agricultural land ranged from 0.15 to 1.66 kg/ha/yr. The higher values were found in the southwestern portion of the basin where intensive row crop production is practised on clay soils.

The regression equations were developed for small agricultural waterhseds (20 to 60 km^2) and thus predict the delivery to the outlets of watersheds of similar size. However, if a delivery ratio of 1 is assumed for transport of phosphorus from the outlets to the Lakes, the unit area loads can be used to estimate the loading to the Lakes. In this manner it was estimated that approximately 3000 tonnes of total P are contributed annually to the Great Lakes from agricultural land and associated activities in Southern Ontario. About 1200 tonnes (40%) of this phosphorus is in the dissolved form.

All of the estimates in this report are based on only one or two years of monitoring. While the estimates are the best that can be made, the very limited time base must be considered in any application of the information.

2.0 INTRODUCTION

The contributions of phosphorus from various agricultural activities in the Southern Ontario portion of the Great Lakes Basin have been estimated primarily from information obtained from the monitored data and the detailed studies conducted in the representative agricultural watersheds. Because there is very limited agricultural activity in the Northern Ontario portion of the Great Lakes Basin, the estimates made are thought to be valid for the total Canadian Great Lakes Basin.

No attempt has been made to present a review of the voluminous literature on agricultural contributions of phosphorus to ground and surface water. A comprehensive review of contributions to nutrient enrichment of Lake Erie, Lake Ontario and the international section of the St. Lawrence River from agricultural activities in Ontario was completed in 1973 (Hore and MacLean 1973). The major activity since that time has been related to the PLUARG program and thus is included in this report.

The major sources of phosphorus from agricultural activities are (1) surface runoff from cropland (2) runoff from livestock operations including runoff of winter spread manure (3) streambank erosion and (4) runoff from unimproved land. Additional sources that may be significant in localized areas are drainage waters from cultivated organic soils and seepage from private waste disposal systems. No attempt has been made to quantify the loads from the latter two sources in the basin, but they are discussed in further detail later in this report.

The forms of phosphorus that have received the major consideration are total P and total dissolved P. The total P includes sediment-associated and dissolved P. The use of total P on sediment is not the most sensitive measure of the P available to biological systems because a major portion may be in forms such as apatite that have a very low solubility. The proportion of the total P that is in "unavailable" forms will vary depending on the source of the sediment. The phosphorus on sediment derived from highly fertilized fields will have a higher degree of availability than would that on sediment derived from streambank erosion or from unimproved land. Although some consideration was given to this factor in the detailed studies, it has not been possible to partition the sediment-associated phosphorus from the various sources into "available" and "unavailable" forms.

This report presents the combined results of several studies in the agricultural watersheds in terms of the total agricultural contribution and the contribution from each of the four major sources. The information obtained from the agricultural watersheds has been extrapolated to provide estimates of the contribution from each source in the Grand and Saugeen River basins. Finally, the information has been extrapolated to provide estimates of the total contribution from agricultural sources in the remaining regions of the Southern Ontario portion of the Great Lakes Basin. It has not been possible to estimate the contribution from each individual source in the total basin.

3.0 AGRICULTURAL WATERSHED STUDIES

3.1 Agricultural Contribution

3.1.1 Total P

The agricultural watersheds were selected to represent the range of soils, climate, cropping systems and livestock enterprises found in the Ontario portion of the Lower Great Lakes Basin. Land use activities other than agriculture were very limited in the watersheds although there were clusters of non-farm residences in some watersheds. With the exception of the possible contribution from these residences, it was assumed that the total load from these watersheds was agricultural in origin. The total agricultural contribution in 1976 was determined for each watershed by subtracting the estimated load from non-farm private waste disposal systems from the total measured load for 1976 as calculated by the NAQUADAT method. The load from non-farm private waste disposal systems was estimated as follows: Estimates were obtained from Ontario Ministry of Environment of the proportion of the total load from each watershed that could be attributed to private waste disposal systems. It was assumed that this load would be from farm and non-farm residences in proportion to their numbers. Thus the load from non-farm private waste disposal systems was calculated.

The unit area P load from agricultural land was then calculated by dividing the total load from agricultural sources by the area of agricultural land in each watershed. (See Appendix Table A-1).

To determine the relation between watershed characteristics and unit area load of total P, stepwise multiple regression analyses were performed. The unit area P loads from the 14 watersheds (11 agricultural watersheds plus 3 additional watersheds for which similar information was available) were related to 14 watershed characteristics compiled by D.R. Coote. (See Appendix Table A-1 for data).

The simple correlations between the unit area loads and watershed characteristics are presented in Appendix Table A-2. Although several characteristics were significantly related, the multiple regression analyses indicated that two variables, % clay in the surface soil and % of the agricultural land in row crops, accounted for most of the variability. No other characteristic significantly improved the regression after the effects of these two variables were removed. Using the squares of the % clay (Cl^2) and % row crops (RC^2) significantly improved the regression compared to the linear terms. The regression equation is as follows:

$$\text{Total P(kg/ha/yr)} = -0.0930 + 0.000846\ (Cl^2) + 0.000212\ (RC^2)$$

$$R^2 = 0.86$$

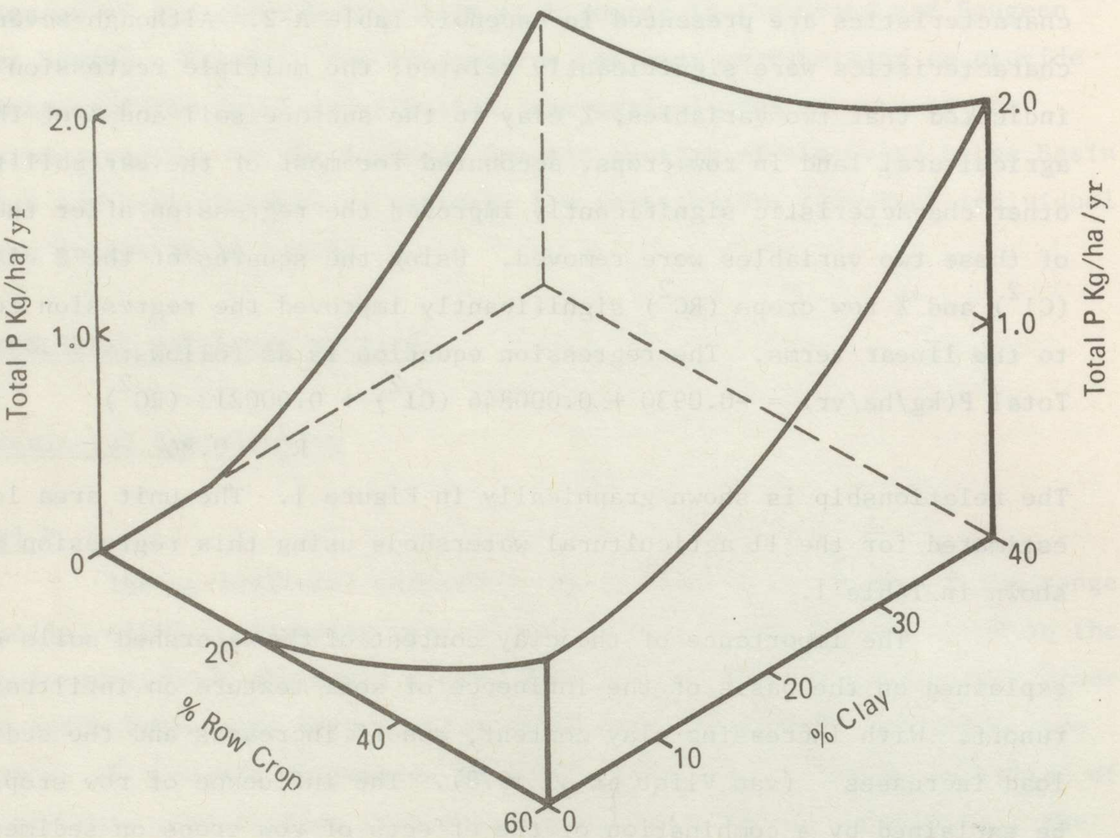
The relationship is shown graphically in Figure 1. The unit area loads estimated for the 11 agricultural watersheds using this regression are shown in Table 1.

The importance of the clay content of the watershed soils can be explained on the basis of the influence of soil texture on infiltration and runoff. With increasing clay content, runoff increases and the sediment load increases (van Vliet et al 1978). The influence of row crops can be explained by a combination of the effects of row crops on sediment load (van Vliet et al 1978) and on the higher fertilizer phosphorus use associated with row crop cultivation. The fertilizer P addition in the watersheds was closely related to the % row crops (r = 0.86). This aspect will be discussed in more detail later in this report (See Sec. 3.8).

..2 Total Dissolved P

The proportion of the measured loads of total P from the agricultural watersheds that was in the dissolved form ranged from 25-60% with a mean of 43%.

Relationships between total dissolved P and watershed characteristics were developed in a manner similar to that described for total P. The correlation coefficients for the linear relationships of total dissolved P and watershed characteristics are presented in Appendix Table A-2.



$$\text{TOTAL P(Kg/ha/yr)} = -0.0939 + 0.000846\ (\text{Cl})^2 + 0.000212\ (\text{RC})^2$$

$$R^2 = 0.86$$

Figure 1. The relationship between total P from agricultural land and % clay in surface soil and % of the agricultural land in row crops.

Table 1: Unit Area Loads of Total Phosphorus from Agricultural Watersheds.

Watershed	Estimated Unit Area Load From:			
	Agricultural Activities[1]	Cropland[2]	Livestock[3]	Streambank Erosion[4]
	kg P/ha/yr			
Ag - 1	1.79	1.65	0.01	0.11
Ag - 2	0.18	0.65	0.01	0.007
Ag - 3	1.10	0.56	0.12	0.02
Ag - 4	0.51	0.78	0.19	0.11
Ag - 5	0.69	0.81	0.14	0.005
Ag - 6	0.15	0.31	0.12	0.003
Ag - 7	0.03	0.31	0.06	0.005
Ag - 10	1.32	1.09	0.12	0.01
Ag - 11	0.71	0.	0.10	0.05
Ag - 13	0.85	1.43	0.01	0.02
Ag - 14	0.57	0.32	0.13	0.05
Weighted Mean	0.65	0.68	0.08	0.03

[1] Estimated from regression of monitored total P unit area load (NAQUADAT Method) on watershed characteristics

[2] Estimated load from cropland (See footnote to Table 3) divided by area of cropland (cultivated crops plus hay)

[3] Estimated load from livestock (Tonnes) divided by area of agricultural land

[4] P load from streambank (Table 3)/total area of watershed.

Two watershed characteristics, % clay (Cl) and fertilizer + manure P (Kg/ha) added (P) were the only variables which were significantly related to the unit area load of total dissolved P. The regression equation developed is as follows:

$$\text{Total dissolved P(kg/ha/yr)} = -0.217 + 0.0122\ \text{Cl} + 0.0103\ \text{P}$$

$$R^2 = 0.83$$

The relationship is shown graphically in Figure 2 and the unit area loads estimated for the 11 agricultural watersheds using the regression are presented in Table 2.

The fertilizer + manure P added is a major factor in accounting for the dissolved P load. This factor has replaced the % row crops found to be important in accounting for the variation in total P load. The fertilizer + manure P added would alter the "available P" to a much greater extent than the total P and therefore has a more direct effect on dissolved P than does the % row crops.

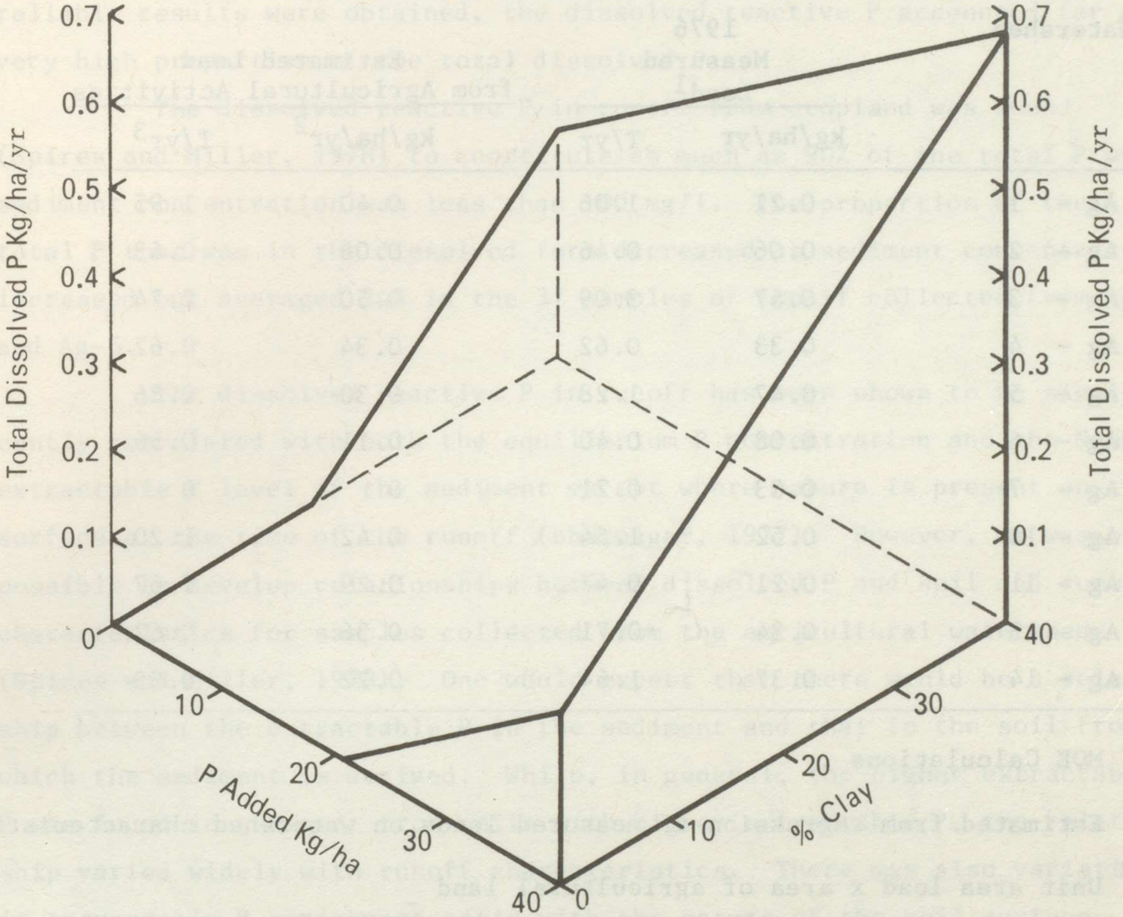
3.2 Contribution from Cropland

3.2.1 Sediment Associated P

A model has been developed (Spires and Miller, 1978) for predicting the sediment associated phosphorus in runoff from cropland. The model is based on the following relationship.

Sediment P load = Sed. Load x P conc. in surface soil x P Enrichment ratio.

Attempts were made to estimate the sediment load from monthly gross erosion values (van Vliet et al, 1978) and monthly delivery ratios (van Vliet et al, 1978) for each watershed. However, valid estimates could not be made for delivery ratios. Consequently measured sediment load values were used in calculating sediment P load from the Ag watersheds. The average P concentration in the surface soil was obtained from analysis of some 200 surface soils from the Ag watersheds (Spires and Miller, 1978). The P enrichment ratio was calculated using a relationship between enrichment and sediment concentration developed (Spires and Miller, 1978) from runoff samples collected from Ag-4, Ag-5, Ag-13 and Ag-1. (For further details see Spires and Miller, 1978).



Total Dissolved P(Kg/ha/yr) = -0.217 + 0.0122 Cl + 0.0103 P

$R^2 = 0.83$

Figure 2. The relationship between total dissolved P from agricultural land and % clay in the surface soil and amount of fertilizer plus manure P added in the watershed.

Table 2: Estimated Annual Total Dissolved Phosphorus Load from Agricultural Watersheds

Watershed	1976 Measured Load[1]		Estimated Load from Agricultural Activities	
	kg/ha/yr	T/yr	kg/ha/yr[2]	T/yr[3]
Ag - 1	0.21	1.06	0.40	1.95
Ag - 2	0.06	0.46	0.08	0.63
Ag - 3	0.57	3.09	0.50	2.74
Ag - 4	0.33	0.62	0.34	0.62
Ag - 5	0.47	1.28	0.30	0.86
Ag - 6	0.08	0.40	0.11	0.56
Ag - 7	0.03	0.21	0	0
Ag - 10	0.52	1.54	0.42	1.20
Ag - 11	0.21	0.47	0.29	0.67
Ag - 13	0.34	0.71	0.36	0.62
Ag - 14	0.37	1.64	0.22	0.95

[1] MOE Calculations

[2] Estimated from regression of measured loads on watershed characteristics

[3] Unit area load x area of agricultural land

3.2.2 Dissolved Reactive P

Difficulties were encountered in measuring total dissolved P in runoff from cropland (Spires and Miller, 1978). In those samples for which reliable results were obtained, the dissolved reactive P accounted for a very high proportion of the total dissolved P.

The dissolved reactive P in runoff from cropland was found (Spires and Miller, 1978) to constitute as much as 90% of the total P when sediment concentration was less than 100 mg/l. The proportion of the total P that was in the dissolved form decreased as sediment concentration increased but averaged 24% in the 37 samples of runoff collected from Ag-4 and Ag-5.

The dissolved reactive P in runoff has been shown to be significantly correlated with both the equilibrium P concentration and the $NaHCO_3$-extractable P level of the sediment except where manure is present on the surface at the time of the runoff (Bhatnagar, 1977). However, it was not possible to develop relationships between dissolved P and soil and runoff characteristics for samples collected from the agricultural watersheds (Spires and Miller, 1978). One would expect that there would be a relationship between the extractable P in the sediment and that in the soil from which the sediment is derived. While, in general, the higher extractable P was found in sediment from soils with higher extractable P, the relationship varied widely with runoff characteristics. There was also variation in extractable P enrichment ratio with the nature of the soil surface (Bhatnagar, 1977). Thus it has not been possible to develop a relationship to predict the dissolved P in runoff from cropland.

In general, it can be stated that the dissolved P will be greater from fields that have a high available P level and from fields that have manure on the surface. The dissolved reactive P in runoff from fields with manure on the surface ranged from 0.19 - 1.42 mg/l with a mean of 0.69 mg/l compared to a range of 0.07 - 0.21 and a mean of 0.08 mg/l for runoff from fields with no surface manure.

In estimating the total P contribution from cropland, it has been assumed that dissolved P constituted the same portions of the total P as it did for the total agricultural contribution. The total P contribution from cropland in the Ag watersheds was estimated by adding the dissolved P contribution based on this assumption to the sediment-associated P estimated from the relationship described in section 3.2.1. The results are presented in Table 3. The unit area load of total P from cropland in each watershed,

Table 3: Annual Total Phosphorus Load (Tonnes/year) from Sources Within the Agricultural Watersheds.

Watershed	1976 Measured Load		Estimated Load From:					
			Agriculture		Cropland[5]	Livestock[6]	Streambank[7] Erosion	Unimproved[8] Land
	Beale R.E.[1]	NAQUADAT[2]	Regression[3]	Sum of Sources[4]				
Ag - 1	6.50	8.69	8.63	8.20	7.55	0.06	0.57	0.02
Ag - 2	2.06	1.85	1.39	3.50	3.17	0.05	0.05	0.23
Ag - 3	5.67	5.46	6.63	3.95	3.12	0.66	0.13	0.04
Ag - 4	1.86	1.40	0.93	1.93	1.38	0.34	0.20	0.01
Ag - 5	4.60	3.21	1.99	2.40	1.96	0.39	0.01	0.04
Ag - 6	0.90	0.80	0.79	1.91	1.16	0.58	0.02	0.15
Ag - 7	0.50	0.53	0.13	0.84	0.40	0.28	0.03	0.13
Ag - 10	4.64	4.43	3.86	3.03	2.60	0.35	0.04	0.04
Ag - 11	1.17	0.70	1.54	0.39	0.00	0.23	0.15	0.01
Ag - 13	1.82	1.51	1.41	2.22	2.17	0.01	0.03	0.01
Ag - 14	3.67	2.66	2.51	2.07	1.26	0.56	0.22	0.03

1 Calculated from OME monitored data using Beale Ratio Estimator method

2 Calculated from OME monitored data using NAQUADAT method

3 Unit area load from agricultural land estimated from regression (Table 1) x area of agricultural land

4 Sum of estimated load from cropland, livestock, streambank erosion and unimproved land

5 Sediment associated P + Dissolved P from cropland. Sediment associated P estimated from model based on gross erosion, estimated delivery ratio and estimated P enrichment ratio. Dissolved P calculated assuming proportion of total P from cropland that was in dissolved form was the same as for that from agricultural land:

$$\text{Dissolved P from Cropland} = \frac{\text{Sed. Assoc. P from Cropland (Model)}}{\text{Total P from Ag Land (Regr)} - \text{Diss. P Ag Land (Regr)}} \times \text{Diss. P Ag Land}$$

6 Estimated by Robinson and Draper (See Livestock Integrators Report)

7 Streambank sediments estimated by K. Knap x average P conc. (0.733) x P Enrichment ratio (1.1)

8 Calculated assuming unit area load of 0.08 kg/ha of unimproved land

calculated by dividing the total estimated load by the area of improved cropland, is presented in Table 1.

3.3 Contribution from Livestock

The contributions of total P from activities related to livestock have been estimated by Robinson and Draper, 1978. These estimations included direct runoff from livestock holding facilities, manure storage and from manure spread on frozen or snow-covered land. There may be some duplication of the contribution from runoff from winter spread manure with the estimated contribution from cropland. About 10% of the runoff samples from which the cropland contribution was estimated were from fields with winter spread manure. This duplication would not be sufficient to alter the general relationships of the sources.

The estimated contribution from livestock operations in each of the agricultural watersheds is shown in Table 3. The unit area loads, calculated by dividing the total load by the area of agricultural land, are presented in Table 1.

3.4 Contribution from Streambank Erosion

The estimated contribution of total P from streambank erosion in each watershed is based on the estimates of streambank erosion made by Knap (Knap, 1978). The estimated streambank sediment load (Tonnes) was multiplied by the average P concentration in soils (0.733 kg/tonne) and the estimated P enrichment ratio (1.1).

The results of these estimates are presented in Tables 1 and 3.

3.5 Contribution from Unimproved Land

Unimproved land was assumed to have a unit area load of 0.08 kg/ha/yr. This value has been found for forested watersheds. The soils in these watersheds were coarse-textured. Thus the value of 0.08 may be lower than the average for unimproved land. However, no other estimates were available. The total load in each watershed from unimproved land presented in Table 3 was calculated by multiplying the area of unimproved agricultural land in the watershed by 0.08.

3.6 Contribution from Private Waste Disposal Systems

Effluent from septic tank systems contains high concentrations of P (Chan, 1977). This phosphorus is adsorbed on soil particles and is rapidly attenuated as the effluent percolates through the disposal bed and is usually below the criteria set for public surface water quality within 10 m from the tile field (Chan, 1977). This distance might be somewhat greater if spetic tank systems were installed in poorly drained sites. Phosphorus adsorption is considerably reduced under anaerobic conditions. Even under these conditions, the distance required to effectively attenuate the phosphorus is probably not more than 25 to 30 meters.

There was evidence of a relatively major contribution of phosphorus from private waste disposal systems in watershed Ag-13 in Essex Co. This watershed had a much greater number of rural residences than any of the other agricultural watersheds. These residences were concentrated along Hwy. 77 north of Leamington. The phosphorus concentrations downstream from Hwy. 77 were considerably greater than those upstream (Gaynor, 1977). This was particularly true for one tributary that passed close to a major concentration of rural residences. As well as a high P concentration, this tributary also exhibited a much higher Na concentration than the remainder of the watershed. This is further evidence of contribution from private waste disposal systems as effluent from septic tanks has a high Na content. In addition to the rural residences, a mushroom production operation was located adjacent to this tributary downstream from the rural residences. Phosphorus concentrations downstream from the mushroom operation were not higher than those between the mushroom operation and the rural residences (Spires and Miller, 1978). This indicates that the rural residences were the likely source of the phosphorus.

Private waste disposal systems are not considered to be an important source of P to the Great Lakes. However, they may have a marked effect on local water quality if the tile bed is within a few meters of an open ditch or where the tile bed is directly connected to a field drainage system.

3.7 Contribution from Subsurface Drainage

The contribution of P from subsurface drainage in mineral soils is considered to be insignificant in relation to the contribution from surface runoff. This is due to the very great phosphorus adsorption capacity of mineral soils in Ontario.

Contributions from subsurface drainage water from organic soils, however, may be very high on a unit area basis as shown by a study of nutrient content of tile drainage water in the Erieau marsh (Miller, M.H., 1974). The average total P content of tile drainage water from one site during the period 1971-1975 was 31.4 kg P/ha/yr. The average for the three sites monitored was 22.2 kg P/ha/yr. The soils from which this drainage water originated have been very heavily fertilized for many years. Current phosphorus fertilizer applications are about 100 kg P/ha which is about 10 times that which would be recommended from the soil test.

The contribution of P from the Erieau marsh is likely much greater than that from other cultivated organic soils in Ontario. Laboratory leaching and adsorption studies (Miller, M.H., 1978) have indicated that the organic soil in Erieau marsh has a much lower P adsorption capacity than that from the Bradford and Grand Bend marshes. This appears to be due to a lower content of Fe and Al in the soil from Erieau marsh. In addition, fertilizer P applications in the Erieau marsh are considerably higher than those in other areas.

The total area of cultivated organic soil in Ontario is relatively small (about 7000 ha). Thus the P contribution is relatively insignificant in terms of the Great Lakes. The effect on local bodies of water such as Rondeau Harbour, however, is very serious. Even if the excessive use of fertilizer was discontinued immediately, the high concentrations of P in the drainage water would continue for at least 10 years.

Consideration should be given to the ability of the soil to retain phosphorus before organic soil areas are developed for crop production. An analysis of the soil for total Fe and Al will give a reasonable indication of the retention ability (Miller, M.H., 1978).

3.8 Additional Sources

Additional localized sources of phosphorus from agricultural activities have been identified. One location studied in Project 20 exhibited very high concentrations of phosphorus in tile drainage water during early fall sampling. Drainage from recently filled silos which was directly linked to field drainage was thought to be the source (Beak Consultants Ltd., 1977). Other similar sources would be drainage from feedlot operations, milking parlours etc. that was directly linked to field drainage systems.

These sources may result in very high localized concentrations of phosphorus in streams. No estimate has been made of the frequency of occurrence of such situations but the total contribution is thought to be insignificant in relation to other sources.

3.9 Fertilizer Phosphorus Use in Agricultural Watersheds

The average fertilizer P use on the crops grown in each watershed was obtained from the report on land use in the Agricultural watersheds, (Frank and Ripley, 1978). These data are presented in appendix table A-3 and are summarized by crop and by watershed in Table 4.

The average amount of fertilizer P required for most economic production has also been estimated for each crop in each watershed. This estimate is the average requirement for that crop in the county in which the watershed is located as indicated by the soil test of samples submitted during the period July 1, 1975 to June 30, 1976. There are two assumptions in this estimate which must be recognized in any interpretation. The first assumption is that the requirements for a particular crop in the watershed is similar to that in the whole county. The second assumption is that the average requirement as indicated by soil test is the true average requirement for the county. Approximately 15-20% of the farmers in Ontario submit soil samples in any given year. The average requirements for a county don't vary greatly from year to year indicating a reasonable consistency. It is possible, however, that farmers with either a higher or a lower requirement than the average for a county submit samples on a more regular basis. Recognizing the presence of these assumptions, the estimates obtained are the best estimates that can be made of the fertilizer P requirements. While some discrepancies undoubtedly exist for individual crops in individual watersheds as presented in appendix table A-3, the overall averages for crops and for watersheds presented in Table 4 are considered to be quite reliable.

These data indicate that, on the average, fertilizer P additions exceed the estimated requirements for all crops except hay-pasture. The greatest excess occurs with vegetable crops followed by tobacco and corn. The excess application also varies from watershed to watershed due partly to the different crops grown but also to the general attitude of the farmers to fertilization.

Table 4: Fertilizer Phosphorus Applied in Agricultural Watersheds in Relation to Requirements by Soil Test.

BY WATERSHED				BY CROP	
Watershed No.	County	Ratio of Fertilizer P Applied[1] / Fertilizer P Required[2] — All Crops	Ratio of Fertilizer P Applied[1] / Fertilizer P Required[2] — Cultivated[3] Crops	Crop	Fertilizer P Applied[1] / Fertilizer P Required[2]
1	Essex	1.9	1.9	Corn	2.4
2	Norfolk	3.6	3.8	Barley	1.8
3	Huron	2.0	2.5	Wheat	1.9
4	Wellington	0.8	1.1	Soybeans	0.6
5	Oxford	2.1	2.2	Tobacco	3.6
6	Huron	0.7	1.5	Mixed Grain	1.8
7	Northumberland	2.1	2.8	White Beans	4.7
10	Niagara N	0.6	1.5	Oats	1.6
11	Peel	1.1	2.0	Potato	4.2
13	Essex	4.0	4.0	Tomato	5.0
14	Bruce	0.4	1.3	Hay-Pasture	0.2

[1] Fertilizer P Applied obtained from PLUARG Report - Land Use Activities in Eleven Agricultural watersheds in Southern Ontario, Canada 1975-1976. R. Frank and B.D. Ripley.

[2] Fertilizer P Required obtained from Summary Report for Ontario Soil Testing Service, July 1, 1975 to June 30, 1976. Department of Land Resource Science, University of Guelph.

[3] Excluding Hay-Pasture.

The application of fertilizer P in excess of that required for most economic crop production will increase the level of available P in the soil and hence the amount of phosphorus in runoff from the fertilized fields. The dissolved P concentration in runoff will be increased to a greater extent than will total P reflecting the greater solubility of the recently applied phosphorus. This fact is reflected in the dependence of dissolved P unit area loads in the agricultural watersheds on the fertilizer + manure P added (See Section 3.1.2). Although fertilizer P additions are essential to economic crop production on many soils, applications in excess of requirements unnecessarily increase the phosphorus content of runoff. It must be recognized that reducing the phosphorus application to required amounts will not reduce the amount in runoff appreciably for many years. However, increased use of greater amounts than required will further increase the amount in runoff.

The reasons for the excess phosphorus application in relation to the estimated requirements are complex. Due to past fertilizer use, the level of available phosphorus in many soils has increased to the point that very low amounts of fertilizer P are required. Many soil tests indicate no phosphorus requirement. This is very difficult for farmers to accept. They have seen their yields increase with fertilizer use in the past and are not prepared to plant their crops without some fertilizer phosphorus. In many cases, their fertilizer application equipment will not apply less than 150 kg/ha. With increasing nutrient concentrations in fertilizers, they may apply 50 or more kg P_2O_5/ha when perhaps 20 or even none is required.

The fertilizer requirements by soil test are based on extensive research data from all areas of Ontario. They have been substantiated by demonstrations in several counties conducted by OMAF advisory personnel. Increased effort in terms of promotion and demonstration to increase the acceptance of the soil test is the most feasible approach to reduce the instances of over fertilization.

3.10 Discussion of Agricultural Watershed Studies

The agricultural watershed studies have provided a much greater understanding of the phosphorus contributions from agricultural land and the factors that affect them. It is apparent that runoff from cropland is the major source of phosphorus from agricultural activities, followed by livestock, streambank erosion and runoff from unimproved land. The proportion of the total sum of the sources that was estimated to come from cropland ranged from less than 50 to 92% with an average of 70%. The proportion estimated to come from livestock ranged from less than 1 to 60% with an average of 20%. The contribution from streambank erosion and unimproved agricultural land averaged 7% and 3% respectively.

It is also apparent that three characteristics, clay content of surface soil, proportion of the area in row crops, and phosphorus added, are the major determinants of the phosphorus contribution from agricultural watersheds.

The loadings presented in Table 3 from the four sources, cropland, livestock, streambank erosion, and unimproved land are independent estimates. The agreement of the sum of these sources with the load estimated by regression and with the measured load is reasonably good. It must be realized, however, that the estimate for cropland is not entirely independent of the measured load; the monitored sediment load was used in estimating the load from cropland (Spires and Miller, 1978). The agreement that exists is encouraging and gives us confidence in attempting to extrapolate the data to larger areas.

4.0 EXTRAPOLATION TO SUBBASINS OF THE GRAND AND SAUGEEN RIVER BASINS

The information obtained in the agricultural watershed studies has been extrapolated to the subbasins of the Grand and Saugeen River Basins shown in Figures 3 and 4 respectively. Estimates were made of the total contribution from agricultural activities and from each of the four major sources; cropland, livestock, streambank erosion and unimproved land.

The estimated total P loads are presented in Table 5 along with the 1976 measured load. The estimated load at each point in the basin is the sum of the load from each subbasin upstream of that point. The estimates thus assume a delivery ratio of 1; all the phosphorus estimated at a point in the upper reaches is assumed to arrive at the mouth.

The load from agricultural activities estimated by regression can be compared directly to the 1976 measured load because the regression was developed using 1976 monitored data. However, the estimates for contribution from cropland were made using long term rainfall data and would not necessarily be comparable to 1976 values.

The loads from agricultural activities estimated by regression compare quite realistically with the 1976 measured load. With the exception of SR-2, the estimated load for those subbasins that have little non-agricultural activity (GR-13, GR-14, GR-6, SR-5), is very close to the

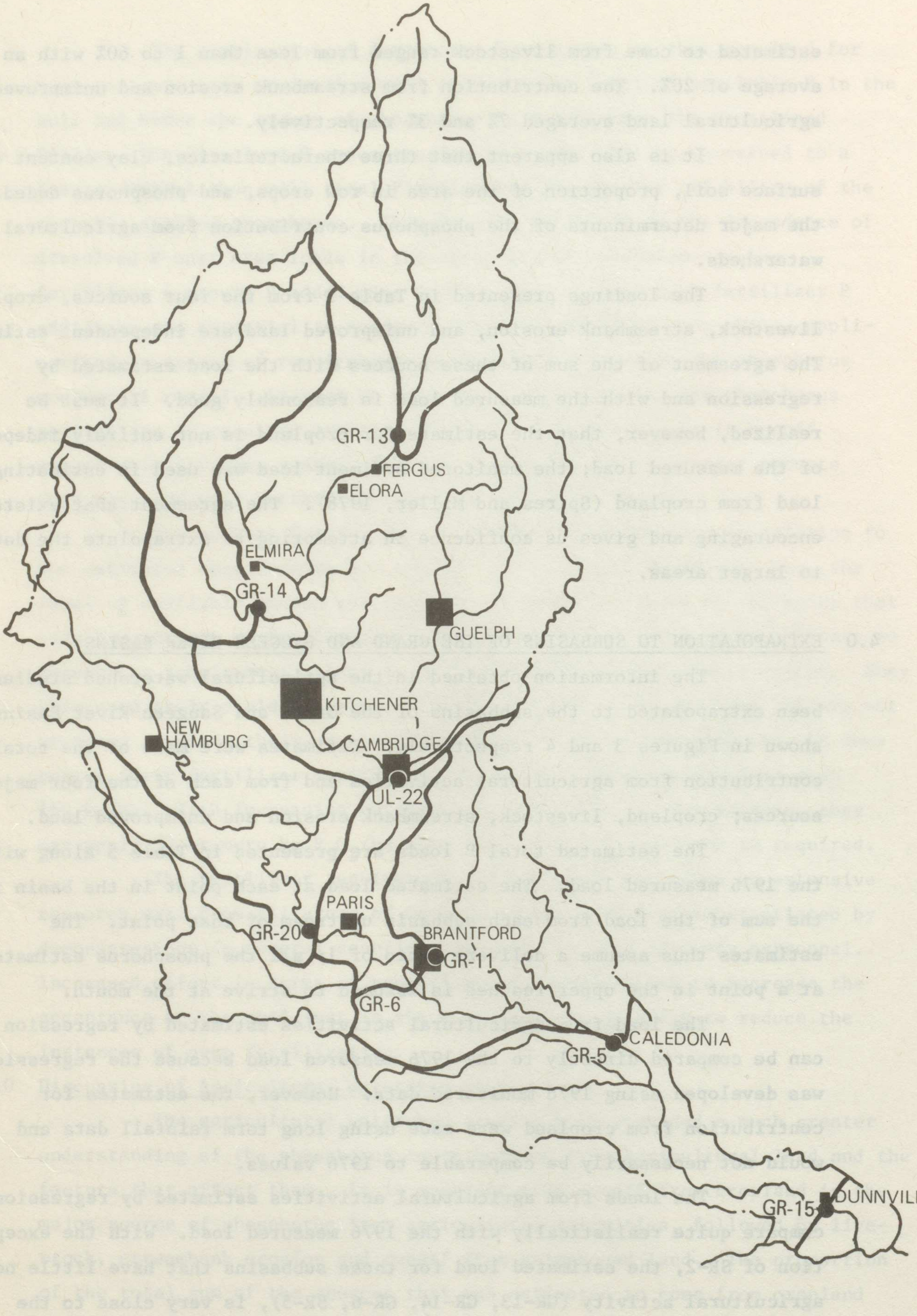


Figure 3. Subbasins of the Grand River Basin used in extrapolation of data from the Agricultural Watersheds.

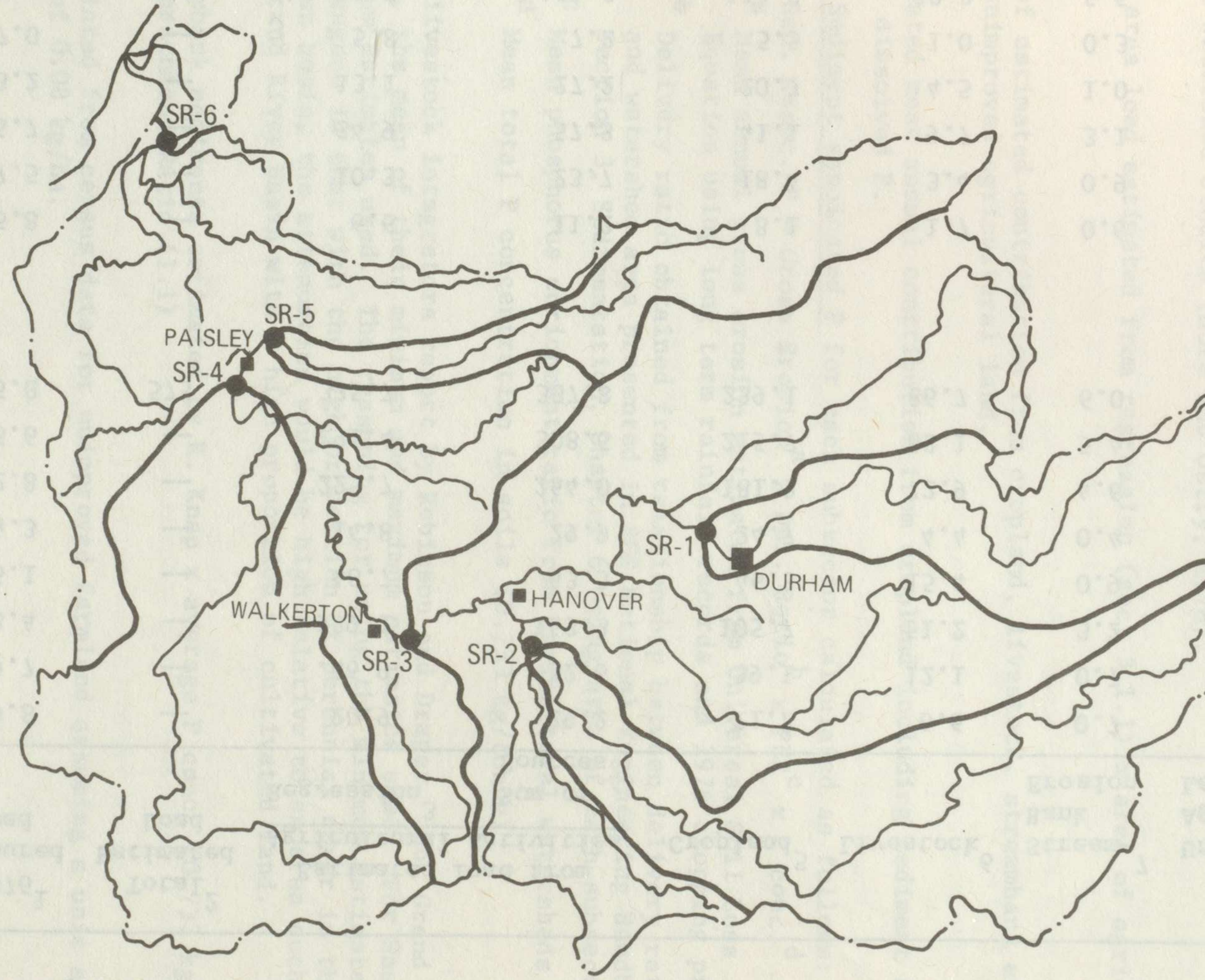


Figure 4. Subbasins of the Saugeen River Basin used in extrapolation of data from the Agricultural Watersheds.

Table 5: Estimated loads of total P (Tonnes/year) from agricultural sources in subbasins of the Grand and Saugeen River Basins. (See Page 23 for footnotes)

	1976[1] Measured Load	Total[2] Estimated Load	Estimated load from Agricultural Activities		Cropland[5]	Livestock[6]	Stream-[7] Bank Erosion	Unimproved[8] Agricultural Land
GRAND RIVER			Regression[3]	Sum of Sources[4]				
GR - 13	19.8	--	20.9	29.2	21.2	6.6	0.7	0.7
GR - 14	59.7	--	46.9	52.6	39.1	12.1	0.7	0.7
UL - 22	373.4	--	139.1	163.3	105.7	51.2	3.2	3.2
GR - 20	165.1	--	48.7	63.5	46.3	15.4	0.9	0.9
GR - 6	14.3	--	14.8	29.9	24.7	4.4	0.4	0.4
GR - 11	652.8	--	225.7	264.0	181.9	72.9	4.6	4.6
GR - 5	465.6	--	291.4	308.6	215.7	82.1	5.4	5.4
GR - 15	605.8	575	325.7	337.8	239.1	86.7	6.0	6.0
SAUGEEN RIVER								
SR - 1	5.8	--	6.6	11.2	8.1	1.7	0.6	0.8
SR - 2	67.5	--	10.3	23.7	18.4	3.4	0.9	1.0
SR - 3	46.7	--	34.9	57.3	41.1	9.7	3.1	3.4
SR - 4	13.2	--	13.1	27.2	20.7	4.5	1.0	1.0
SR - 5	7.0	--	5.8	7.2	5.5	1.0	0.3	0.4
SR - 6	158.4	134	90.7	151.3	111.7	28.2	5.5	5.9

Table 5 cont'd

1 Measured and calculated by Ontario Ministry of the Environment using the Beale Ratio Estimator.

2 Total estimated load at outlet to basin. Sum of estimated load from agricultural activities (regression) and estimated load from all non-agricultural sources as presented in Reports of Grand and Saugeen River Pilot Watershed Studies (Hore and Ostry, 1978).

3 Unit area load estimated from regression (sec. 3.1.1) x area of agricultural land.

4 Sum of estimated contribution from cropland, livestock, streambank erosion and unimproved agricultural land.

5 Estimated mean annual contribution from cropland including sediment associated P and dissolved P.

<u>Sediment assoicated P</u> for each subsector calculated as follows:

Sed. Assoc. P = Gross Erosion[a] x Del. Ratio[b] x PER[c] x P conc.[d]

[a] Mean annual gross erosion estimated from Universal Soil Loss Equation using long term rainfall records and 1976 cropping practices.

[b] Delivery ratio obtained from relationship between delivery ratio and watershed area presented in SCS National Engineering Handbook, Section 3, Sedimentation, Chapter 6 using area of each subsector.

[c] Mean phosphorus enrichment ratio from agricultural watersheds (2.26)

[d] Mean total P concentration in soils (0.733 kg/tonne)

6 From livestock integrators report by Robinson and Draper. For Grand River basin, the mean of their minimum and maximum estimates used. For Saugeen, minimum estimates used. The reasoning for using the minimum estimate for the Saugeen is that with the high proportion of perennial cover in the Saugeen basin, the attenuation would be high relative to an area such as the Grand River Basin with a high proportion of cultivated land.

7 Streambank sediments estimated by K. Knap x average P conc. (0.733 kg/tonne) x P Enrichment Ratio (1.1)

8 Calculated from census data for unimproved farmland assuming a unit area load of 0.08 kg/ha.

measured load. This gives a reasonable degree of confidence to the estimates. Based on the regression estimates, the load from agricultural activities represents 54% and 57% of the total measured load for the Grand and Saugeen River basins respectively. The estimated agricultural contribution as a proportion of the total estimated load is 57% for the Grand and 68% for the Saugeen River Basin. These two bases for estimating the proportion of the load attributable to agriculture give values that are not greatly different and are probably well within the range that would be associated with either method. Thus it can be concluded that 50 to 60% of the total P in the Grand River and 60% to 70% of the total P in the Saugeen River can be attributed to agricultural land and the associated activities.

The contribution from agricultural activities estimated from the sum of the four sources is more variable than that estimated from the regression. The sums of the sources compare very closely with those estimated by regression for the Grand River Basin but were higher than those estimated by regression for the Saugeen River Basin. The estimates for the Saugeen Basin were greater than the measured load in 3 of the 6 subbasins. This apparent overestimation is probably due to overestimation of the load from cropland, which was the major source.

The overestimation of the contribution from cropland is thought to be due to the delivery ratio used in the calculation of sediment load from cropland. These ratios were obtained from the SCS National Engineering Handbook and are based on watershed area; the ratio decreases with increasing area. The areas used in the calculations were those of the individual subbasins. Thus a separate delivery ratio was used for the area draining through SR-1, SR-2 and SR-3 and a separate sediment load calculated. The in-stream delivery was assumed to be 1.0 so that the sediment load passing SR-3 was the sum of that from SR-1 and SR-2 plus that from the area between SR-2 and SR-3. Another approach tried was to use a delivery ratio based on the total area draining through SR-3. This ratio would be lower than that for each subbasin and would result in a lower P contribution. In effect, this approach assumes an in-stream delivery ratio of less than 1. The latter approach resulted in more realistic values of P loads for the Saugeen basins, but predicted quite low loads in the Grand River Basins. Obviously, the estimate of delivery ratio is very critical to estimates of the contribution from cropland.

The estimated loads from each source as a % of the total sum of the agricultural sources were as follows:

Grand River Basin; 71% from cropland, 26% from livestock, 2% from streambank erosion and 2% from unimproved agricultural land.

Saugeen River Basin; 74% from cropland, 19% from livestock, 4% from streambank erosion and 4% from unimproved agricultural land.

These values compare reasonably well with the proportion from each source in the 11 agricultural watersheds.

Combining the estimates from the Grand and Saugeen River Basins with those from the 11 Agricultural watersheds, it can be estimated that about 70% of the agricultural contribution of phosphorus in the Lower Great Lakes Basin comes from cropland, 20% from livestock, 5% from streambank erosion and 5% from unimproved agricultural land.

From the extrapolation to the Grand and Saugeen Basins, it can be concluded that the contributions of total P from agricultural activities estimated by regression are reasonably reliable. This gives sufficient confidence in the regression to justify its use in extrapolation to other subbasins of the Ontario portion of the Lower Great Lakes Basin. Attempts to estimate the cropland contribution are not justified because of the difficulty in estimating a reliable value for sediment delivery ratio.

5.0 EXTRAPOLATION TO ONTARIO PORTION OF LOWER GREAT LAKES BASIN

5.1 Total Phosphorus

The unit area load of total phosphorus from agricultural land in each of more than 300 subwatersheds in the Ontario portion of the Lower Great Lakes Basin was estimated by the regression presented in section 3.1.1. This regression was developed using the monitoring data for the period January 1 to December 31, 1976. As this report was being finalized, monitoring data for the period January 1 to March 31, 1977 became available. This permitted unit area loads to be calculated for each of the 11 agricultural watersheds based on two years of data (April 1, 1975 to March 31, 1977).

A multiple regression analysis similar to that described in Sec. 3.1.1 was conducted using the two-year unit area loads. (Coote, et al. 1978). The regression obtained was as follows:

$$\text{Total P (Kg/ha)} = 0.149 + 0.000655(\text{Cl}^2) + 0.000162(\text{RC}^2)$$

$$R^2 = 0.92$$

The same two variables account for the variation in the unit area loads in both sets of data. However, the predicted unit area loads in watersheds with low clay content and a low proportion of row crops are higher with the regression based on the two-year data. The prediction for watersheds with medium or fine-textured soils, or with a significant proportion of the area in row crops was very similar with the two regressions. The divergence of the two regressions is likely due to inclusion of 3 additional watersheds which had very low unit area loads in the regression based on one year of monitoring data. Data were not available for the two year period for these watersheds so they were omitted from the regression based on the two-year data. The regression based on the two-year data base is considered to be more realistic since it does not predict negative values and should be more reliable because of the longer monitoring period. Hence this regression was used to estimate the unit area loads of total P from the Ontario portion of the Lower Great Lakes Basin. The average % clay in the surface soil and the % of the farmland in row crops were obtained from 1971 census data adjusted for changes in cropping practices from 1971 to 1976 as indicated in Agricultural Statistics for Ontario, 1976, for the county in which the watershed occurs (Coote et al, 1978). Some enumeration areas were suppressed in the census data to maintain confidentiality. It was assumed that the land use in the suppressed EA's was similar to that in the non-suppressed EA's.

The unit area load (kg/ha/yr) of total P from agricultural activities for each subbasin in the Ontario portion of the Lower Great Lakes Basin is presented in Appendix table A-4. The location of each subbasin is shown on Appendix Figure A-1. Figure 5 shows the unit area loads for each region in the basin grouped into six classes. In considering this information, it must be remembered that the values are the unit area loads from only the agricultural land in the subbasin. They do not necessarily reflect the unit area loads from the subbasin as a whole. However, where a large proportion of the area is in farmland and there are no other major sources such as urban centers, the unit area loads from the total subbasin would not vary markedly from those estimated for the agricultural land. The proportion of the area of each subbasin that is in farmland is presented in Appendix Table A-4.

The regression equations are based on the unit area loads calculated from phosphorus loadings at the outlet of small agricultural watersheds (20 to 60 km^2). Use of the regressions to estimate loadings

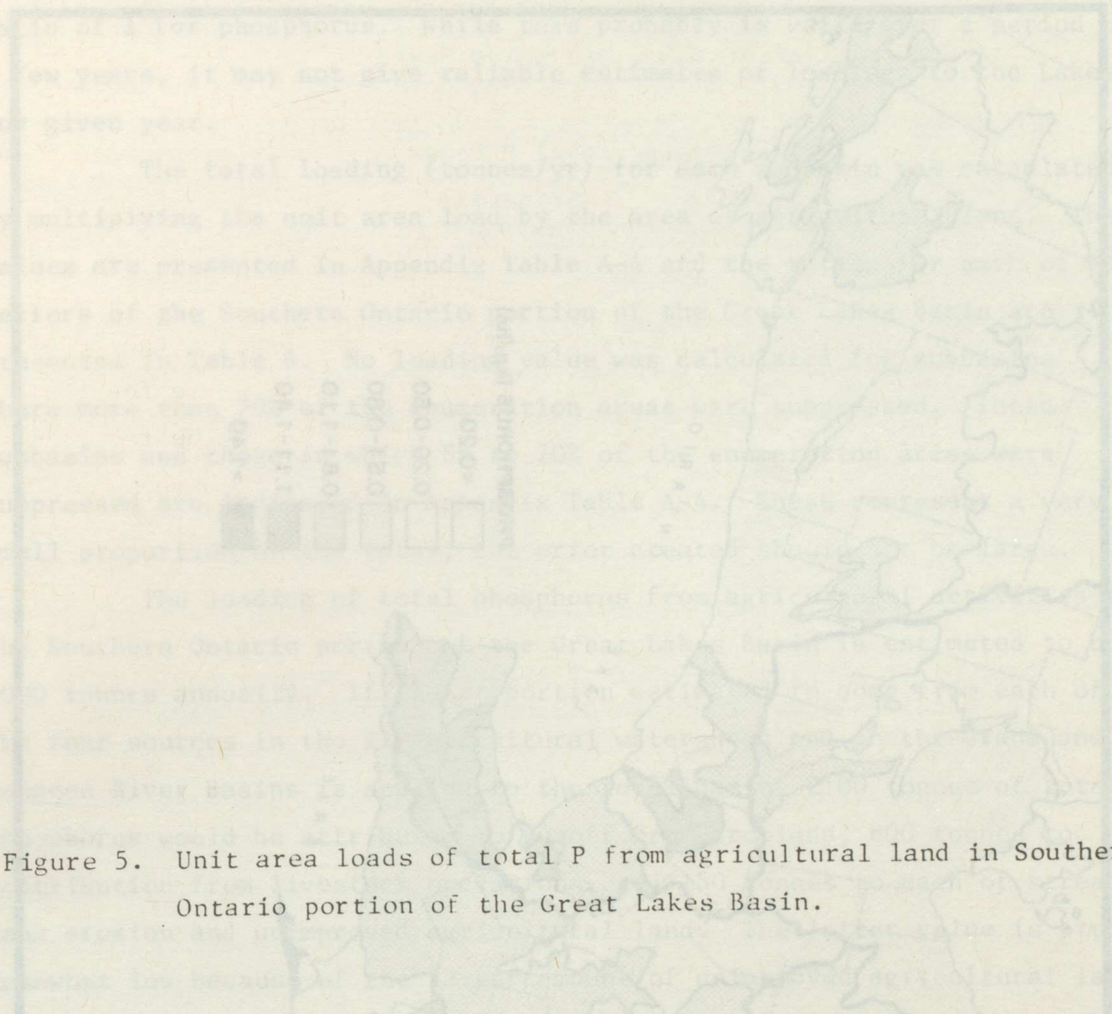
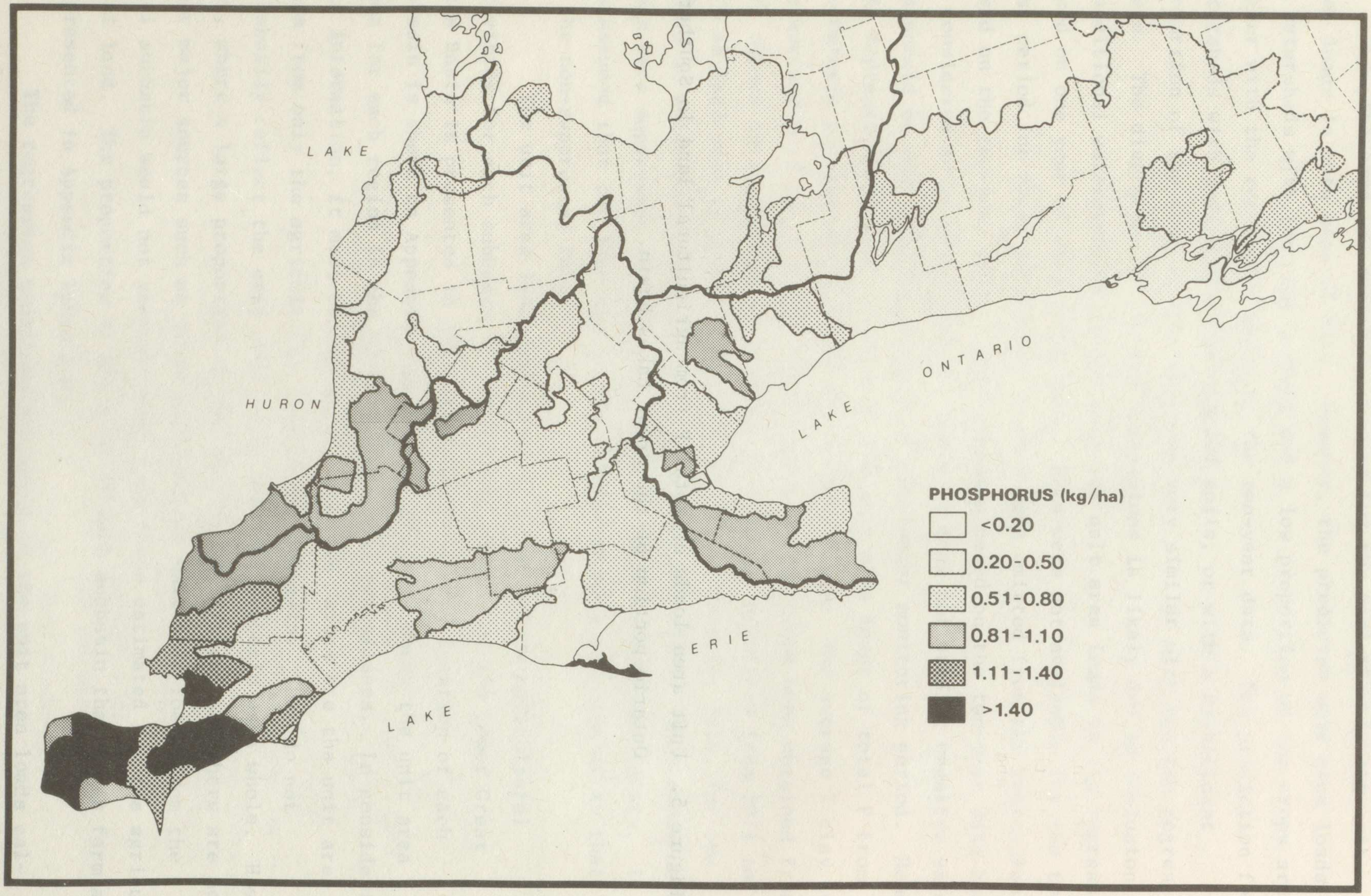


Figure 5. Unit area loads of total P from agricultural land in Southern Ontario portion of the Great Lakes Basin.



LAKE
HURON
LAKE
ONTARIO
LAKE
ERIE
PHOSPHORUS (kg/ha)
<0.20
0.20-0.50
0.51-0.80
0.81-1.10
1.11-1.40
>1.40

from larger watersheds requires the assumption of an instream delivery ratio of 1 for phosphorus. While this probably is valid over a period of a few years, it may not give reliable estimates of loadings to the Lakes for any given year.

The total loading (tonnes/yr) for each subbasin was calculated by multiplying the unit area load by the area of agricultural land. The values are presented in Appendix Table A-4 and the totals for each of four sectors of the Southern Ontario portion of the Great Lakes Basin are presented in Table 6. No loading value was calculated for subbasins where more than 70% of the enumeration areas were suppressed. These subbasins and those in which 50 to 70% of the enumeration areas were suppressed are indicated in Appendix Table A-4. These represent a very small proportion of the total; the error created should not be large.

The loading of total phosphorus from agricultural activities in the Southern Ontario portion of the Great Lakes Basin is estimated to be 3000 tonnes annually. If the proportion estimated to come from each of the four sources in the 11 agricultural watersheds and in the Grand and Saugeen River Basins is applied to the total basin, 2100 tonnes of total phosphorus would be attributed to runoff from cropland, 600 tonnes to contribution from livestock operations, and 150 tonnes to each of stream-bank erosion and unimproved agricultural land. The latter value is probably somewhat low because of the larger amount of unimproved agricultural land in the basin as a whole than in the Grand and Saugeen basins. The value for the contribution from livestock operations is considerably higher than the value (318 tonnes) estimated by Robinson and Draper 1978. This suggests that the proportion of the total load attributable to this source in the total basin may be less than 20%.

These estimates represent the loadings from only the Southern Ontario portion of the Great Lakes Basin. However, because of very limited agricultural activity, the contribution from the Northern Ontario portion is considered to be negligible. These loadings are considered to be valid estimates of the total loadings from agricultural land and associated activities in the Canadian Great Lakes Basin.

Also presented in Table 6 are values for the 1976 estimated loads of total P to Lake Huron, Lake Erie and Lake Ontario from all Canadian sources. Although one must be cautious in comparing estimates arrived at in such diverse manners, the values for total loadings and agricultural loadings presented in Table 6 are based on very intensive studies and are

Table 6: Estimated total P loadings from all sources and estimated loadings from agricultural land in sectors of the Southern Ontario portion of the Great Lakes Basin.

	1976 Estimated Total P Loads[1]		Estimated Load from Agricultural Land	
	Total	Tributary Diffuse	Total P	Dissolved P
	tonnes		tonnes	
Lake Huron (Including Georgian Bay)	1194	993	778	375
Lake Erie	1886	1423	1578	581
Lake Ontario	2842	1233	639	237
Total	5922	3654	2995	1193

1 Taken from Draft working Document of PLUARG Final Report, April 1978, Table 4. Loadings from atmospheric sources, shoreline erosion and upstream lakes not included.

the best estimates that can be made at this time. Based on these estimates, it can be included that contributions of total P from agricultural land and associated activities represent about 50% of the total loading and about 80% of the loading from tributary diffuse sources in the Canadian Great Lakes Basin in 1976.

The estimates of agricultural loadings are based on only one or two years of monitoring data. While the values appear to be realistic when compared with measured or estimated total loads for the same period, comparison with long term monitoring data has not been possible. Therefore considerable caution must be exercised in applying the data on a long term basis.

It must also be recognized that the estimated loadings include background levels. Thus a portion of these loadings would continue to occur even if no agriculture existed in the basin.

5.2 Total dissolved phosphorus

It was not possible to develop a regression for total dissolved phosphorus based on two years of monitoring data due to a change in filtering technique late in 1975. Hence unit area load and total loadings of total dissolved phosphorus were calculated for each subbasin using the regression presented in section 3.1.2. The results are presented for each subbasin in Appendix Table A-4 and are summarized in Table 6.

Approximately 1200 tonnes/year of total dissolved P in the Ontario portion of the Lower Great Lakes Basin can be attributed to agricultural activities. This represents 40% of the total P load attributable to agricultural activities.

6.0 REMEDIAL MEASURES

If PLUARG finds that reductions in phosphorus inputs to the Great Lakes from agricultural activities in Ontario are necessary, the application of remedial measures to reduce the phosphorus in runoff from cropland and to reduce the contribution of phosphorus from livestock operations will be required. These two sources constitute 90% of the total inputs from agricultural activities. Remedial measures that could be applied to livestock operations are discussed elsewhere (Robinson and Draper, 1978).

Remedial measures for reduction in phosphorus inputs due to runoff from cropland are closely related to measures to control erosion and sediment delivery from cropland because approximately 60% of the phosphorus in runoff is associated with the sediment. There are numerous practices that can be used to control erosion and sediment delivery. These have been presented elsewhere in considerable detail (Stewart et al, 1975).

In addition to control of erosion and sediment delivery, there are remedial measures that are specific for phosphorus.

Sediments from agricultural land may be enriched in phosphorus due to applications of manure and/or commercial fertilizer. In the areas which are frequently hydrologically active and which yield eroded sediment to streams, measures designed to minimize the enrichment of these soils with phosphorus may have some effect on phosphorus loads, though the phosphorus content of the soil is generally so high compared to agriculturally added phosphorus that reductions on total phosphorus may be very small. Greater reductions would occur in the forms of P which are more readily available to aquatic life. Measures such as restricting phosphorus inputs as fertilizer or manure to those recommended from a soil phosphorus test should be considered. However, it must be recognized that these measures would not significantly reduce the phosphorus in runoff for several years. Once a soil is enriched by addition of fertilizer and/or manure, it requires several years of cropping to reduce the concentration of available P. The measures would, however, avoid further unnecessary enrichment.

Soluble phosphorus in runoff water from frequently hydrologically active areas may be increased by increased phosphorus fertility levels and by poor management of phosphorus fertilizer or manures. Specifically, failure to incorporate fertilizer or manures into the soil may lead to high concentrations of soluble phosphorus in the runoff water. Remedial measures to reduce this problem would include incorporation of manure into the soil as soon as possible after application, and prior to a runoff-causing event. Much of the phosphorus fertilizer is band applied and hence incorporated on application. Incorporation of broadcast fertilizers should be encouraged in areas where water quality may be affected.

Organic soils may yield large quantities of phosphorus to drainage water as a result of drainage works which increase soil decomposition rates, and as a result of fertilizer applications for crop production. These fertilizer applications have been found to be greatly in excess of requirements for crop production in some instances, and reducing application rates to crop needs would reduce loadings from these areas. Although the reductions would occur more rapidly than with mineral soils, excessive concentrations in drainage water would continue for 10 years or more. The area of cultivated organic soils in Ontario is very small, being in essentially five locations. Thus the impact on the total load to the Great Lakes is relatively insignificant. However, localized effects may be quite significant. It is suggested that the potential for water pollution be considered in any proposals to develop additional organic soil areas.

A set of effective remedial measures can only be developed through detailed consideration of a specific area. Examples of sets of remedial measures have been developed for four of the detailed agricultural watersheds by a group at the University of Guelph consisting of W.T. Dickinson, M.H. Miller, J.B. Robinson and G.J. Wall. The cost of each practice and the reduction in sediment and phosphorus loads have been estimated. These examples are presented as Appendix Tables A-5.

They should be used only as illustrations of an approach to remedial measures and not as final answers for these specific watersheds.

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A P P E N D I X

Table A-1: Characteristics of Agricultural Watersheds. (Compiled by D.R. Coote)

	WATERSHED													
	Ag-1	Ag-2	Ag-3	Ag-4	Ag-5	Ag-6	Ag-7	Ag-10	Ag-11	Ag-13	Ag-14	EX-1[6]	TU-3[6]	GR-8[6]
Total Area (ha)	5080	7913	6200	1860	3000	5472	5645	3025	2383	1990	4504	927	1709	6216
Area of Agricultural land (ha)	4820	7744	6026	1823	2888	5259	4354	2922	2173	1654	4394	870	1610	5887
Area of Cropland (ha)	4619	4872	5558	1696	2427	3717	3009	2385	2028	1516	3972	277	1338	3512
Surface Clay (%)[1]	35.0	6.6	30.0	25.0	20.0	15.7	9.9	40.0	30.0	10.5	27.5	14.6	13.0	10.5
Surface Sand (%)[1]	35.0	80.0	10.0	25.0	25.0	24.0	61.0	10.0	27.4	75.0	25.6	35.9	44.2	39.8
$NaHCO_3$ Extractable P (ppm)[2]	31.4	36.8	17.1	18.3	23.3	15.3	27.8	15.1	15.1	41.2	10.8	6.3	15.2	8.4
Fertilizer P added (kg/ha)[3]	18.9	21.1	19.4	10.1	16.8	5.3	6.0	5.5	8.3	40.5	4.9	3.6	9.6	6.7
Manure P added (kg/ha)[3]	1.0	0.4	14.5	14.5	10.0	8.0	3.4	8.8	5.7	0.3	7.7	1.9	4.9	5.3
Hay-Pasture (% of Total Area)[3]	1.7	3.0	17.9	37.2	22.8	33.4	28.5	44.2	41.3	0	66.6	18.9	29.7	30.4
Alfalfa (% of Total Area)[3]	1.0	0	10.0	32.0	3.0	19.0	14.0	33.0	28.0	0	23.3	--	--	--
Woodlot and Unimproved Land (%)[3]	3.9	36.3	7.6	6.9	15.4	28.2	37.6	17.8	7.5	7.0	9.4	64.0	15.9	38.2
Row Crops (% of Total Area)[3]	62.2	33.7	45.3	18.7	45.9	12.3	14.2	16.2	13.4	63.5	9.5	4.7	36.4	11.4
Corn (% of Total Area)[3]	23.0	10.1	31.3	18.7	42.3	12.3	10.4	16.2	11.3	22.8	9.5	7.0	32.9	10.1
Animal Units (No/ha)[4]	0.08	0.04	0.48	0.75	0.61	0.51	0.28	0.77	0.32	0.01	0.55	0.06	0.42	0.14
Stream and Gulley Density (km/km^2)	1.379	0.728	0.584	0.641	1.037	1.041	0.862	2.232	1.627	1.002	0.898	0.458	0.364	0.703
Rural Residences (No/km^2)[3]	4.1	2.5	2.6	3.8	1.4	2.8	3.2	5.4	7.8	17.3	1.3	2.7	3.7	2.1

1 From Ontario Soil Survey Reports and from Soil Survey of Watersheds (PLUARG-Project 7).

2 Estimated from Ontario Soil Testing Service Summary data for counties.

3 From R. Frank and B. Ripley. Land Use Activities in Eleven Agricultural Watersheds in Southern Ontario, Canada, 1975-76.

4 Calculated from numbers of livestock using animal unit coefficients from Agricultural Code of Practice for Ontario.

5 From National Topographic Services plus airphoto examination.

6 Values for non-Ag watersheds obtained from census data.

Table A-2: Correlation matrix for total P and total dissolved P loads and agricultural watershed characteristics.

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
Y_1 -Total P (kg/ha)	0.76	-0.42	0.27	0.33	0.28	0.47	-0.13	-0.10	-0.62	0.56	0.49	0.33	0.10	0.57
Y_2 -Total Dissolved P (kg/ha)	0.71	-0.49	0.12	0.34	0.53	0.60	0.09	0.06	-0.67	0.42	0.46	0.49	0.16	0.42
X_1 -Surface Clay (%)		-0.76	-0.24	-0.18	0.46	0.04	0.35	0.43	-0.57	0.06	0.16	0.52	-0.06	0.66
X_2 -Surface Sand (%)			0.69	0.51	-0.76	0.17	-0.56	-0.58	0.28	0.27	-0.21	-0.73	0.40	0.31
X_3 -$NaHCO_3$ Extract P (ppm)				0.81	-0.44	0.64	-0.70	-0.66	-0.28	0.73	0.22	-0.40	0.52	0.09
X_4 -Fertilizer P added (kg/ha)					-0.27	0.89	-0.72	-0.68	-0.40	0.86	0.42	-0.41	0.69	-0.04
X_5 - Manure P added (kg/ha)						0.17	0.49	0.53	-0.39	-0.18	0.35	0.85	-0.35	-0.01
X_6 -Fert. & Manure P added (kg/ha)							-0.49	-0.43	-0.59	0.78	0.57	-0.02	0.58	-0.02
X_7 -Hay-Pasture (% of total area)								0.84	-0.12	-0.72	-0.27	0.68	-0.35	0.21
X_8 -Alfalfa (% of total area)									-0.13	-0.70	-0.32	0.67	-0.16	0.31
X_9 -Woodlot and Unimproved (%)										-0.53	-0.52	-0.40	-0.33	-0.34
X10 -Row Crop (% of total area)											0.70	-0.27	0.44	0.00
X_{11} -Corn (% of total area)												0.30	0.04	-0.09
X_{12} -Animal Units (No/ha)													-0.32	0.27
X_{13} -Rural Residences (No/km^2)														0.27
X_{14} -Stream and Gully Density (km/km^2)														

Required for significance (1, 12 d.f)

5% - 0.53

1% - 0.66

Table A-3: Fertilizer phosphorus use in Agricultural Watersheds Relative to Requirements as Indicated by Soil Test.

Watershed No.	County	Crop	Hect.[1] Grown	Fertilizer Phosphorus Applied[1]	Fertilizer Phosphorus Recommended[2]	Applied / Recommended
				kg P/ha/yr		
1.	Essex	Corn	1191	36	9	3.9
		Wheat	1278	31	20	1.6
		Soybeans	1935	3	5	0.6
		Veget.	92	201	-	-
2.	Norfolk (Elgin)	Tobacco	1458	84	23	3.7
		Corn	759	43	9	4.9
		Hay-Past.	223	1	11	0.1
3.	Huron (Perth)	Corn	1776	28	14	2.0
		W. Bean	686	27	6	4.8
		M. Grain	872	20	7	2.8
		Barley	307	28	13	2.1
		Wheat	269	23	7	3.3
		Hay	558	5	13	0.4
		Past.	458	10	13	0.8
4.	Well.	Corn	462	18	15	1.2
		M. Grain	779	18	17	1.1
		Hay	767	3	14	0.2
		Wheat	96	4	12	0.3
5.	Oxford	Corn	1249	26	11	2.4
		Hay-Past.	588	10	7	1.5
		M. Grain	152	18	15	1.2
		Barley	75	22	7	3.0
		Oats	116	14	6	2.5
		Veg.	107	88	-	-
6.	Huron (Well.)	Corn	641	17	14	1.3
		M. Grain	1936	14	7	1.9
		Barley	228	13	13	1.0
		Past.	815	<1	13	<0.1
		Hay	933	<1	13	<0.1
7.	Northumberland	Corn	649	21	7	2.8
		Oats	249	5	5	1.1
		Hay	681	12	4	2.9
		Tobacco	95	100	31	3.2
		Past.	1094	<1	4	0.1
10.	Niagara North	Corn	484	18	13	1.4
		Oats	299	12	7	1.7
		Hay	962	1	13	0.1
		Past.	355	1	13	0.1
		Wheat	120	14	10	1.4
11.	Peel	Corn	282	24	14	1.6
		M. Grain	424	19	8	2.3
		Wheat	241	21	10	2.0
		Hay	632	<1	9	0.1
		Past.	401	1	9	0.1

.....2

Watershed No.	County	Crop	Hect.[1] Grown	Fertilizer Phosphorus Applied[1]	Recommended[2]	Applied / Recommended
				kg P/ha/yr		
13.	Essex	Corn	472	39	9	4.3
		Potato	280	102	24	4.2
		Tomato	183	107	21	5.0
		Tobacco	104	71	25	2.8
		Beans	68	34	17	2.0
		Soybeans	163	8	5	1.5
		Wheat	176	15	5	2.8
14.	Bruce	Corn	472	23	18	1.2
		M. Grain	614	17	13	1.3
		Hay	1153	1	15	0.1
		Pasture	2219	1	15	0.1

1 From PLUARG Report - Land Use Activities in Eleven Agricultural Watersheds in Southern Ontario, Canada 1975-1976 by R. Frank and B.D. Ripley.

2 From Summary Report - Soil Testing Service operated for O.M.A.F. by Department of Land Resource Science, University of Guelph. Summary of Samples submitted between July 1, 1975 and June 30, 1976.

Table A-4: Annual unit area loads and total loadings of total phosphorus and total dissolved phosphorus due to agricultural activities in subbasins of the Southern Ontario portion of the Great Lakes Basin as estimated by regression equations.

Watershed	Clay In Surf Soil	Manure and Fert. P Applied	% Of Farm Area In Row Crop	†% Of Total Area In Farms	Total Phosphorus Unit Area Load	Total Phosphorus Total Loading	Total Dissolved P Unit Area Load	Total Dissolved P Total Loading
	%	Kg/ha/yr	%	%	Kg/ha/yr	Tonnes	Kg/ha/yr	Tonnes
GEORGIAN BAY								
EC01	23.7	38.5	30.8	70.7	0.67	16.232	0.47	11.346
EC0201	30.3	11.0	4.0	37.1	0.75	0.958	0.27	0.338
EC020	16.0	19.5	14.2	39.8	0.35	1.405	0.18	0.721
EC0203	20.5	21.9	19.0	30.5	0.48	0.626	0.26	0.335
EC0204	17.8	19.1	19.9	59.8	0.42	1.808	0.20	0.846
EC0205	17.3	21.2	18.8	60.5	0.40	0.999	0.21	0.528
EC0301	11.9	18.5	20.5	54.4	0.31	5.658	0.12	2.174
EC0302*	17.4	8.6	4.8	40.1	0.35	4.235	0.08	0.968
EC04	11.1	18.3	15.3	61.1	0.27	7.758	0.11	3.094
EC0501	18.9	20.7	16.9	73.2	0.43	5.757	0.23	3.036
EC0502	18.2	19.4	14.0	77.8	0.40	6.204	0.20	3.192
EC0601	18.1	20.3	25.0	76.2	0.47	2.319	0.21	1.063
EC0602*	30.6	21.1	34.0	51.5	0.95	5.250	0.37	5.316
EC07	16.2	21.9	24.8	37.7	0.42	2.118	0.21	1.037
EC0801	13.4	22.1	33.2	65.8	0.45	1.915	0.17	0.750
EC0802	11.2	20.7	20.6	52.0	0.30	1.773	0.13	0.783
EC09	16.3	14.7	12.9	53.3	0.35	6.190	0.13	2.359
EC10	14.6	12.8	8.2	51.2	0.30	1.973	0.09	0.616
EC11	5.0	7.7	3.6	49.2	0.17	2.939	0	0
EC12	19.3	10.3	3.2	51.5	0.39	5.237	0.12	1.640
EC13	4.0	5.2	1.1	36.6	0.15	3.486	0	0
EC14*	--	2.5	0	14.5	0.15	0.323	0	0
EC16*	--	2.0	0	10.1	0.15	0.049	0	0
EC17*	6.0	5.3	0.9	25.5	0.17	3.096	0	0
ED02*	5.8	8.6	6.2	37.7	0.18	1.398	0	0
ED03	11.0	15.1	9.2	54.5	0.24	2.805	0.07	0.846
ED04	8.1	11.7	7.8	41.7	0.20	2.009	0	0.028
ED05	16.1	10.9	6.9	42.1	0.33	2.876	0.09	0.805
ED06	20.2	8.8	3.1	46.8	0.42	6.287	0.12	1.810
ED07	19.2	4.7	0.8	16.4	0.39	0.894	0.07	0.149
ED08	5.8	11.5	10.0	34.7	0.19	0.748	0	0
ED09	13.4	21.8	19.1	64.4	0.33	23.077	0.17	12.081
ED10	18.3	18.9	6.9	65.7	0.38	7.106	0.20	3.789
ED11	15.3	16.7	11.1	66.1	0.32	9.683	0.14	4.252
ED12	12.2	20.6	21.5	62.1	0.32	6.429	0.14	2.879
ED13	12.6	17.2	18.5	77.9	0.31	6.016	0.11	2.231
ED14	11.8	19.0	18.7	47.7	0.30	4.357	0.12	1.798
ED15	19.1	21.1	24.7	71.3	0.49	16.679	0.23	7.991
ED16*	5.8	13.7	14.4	18.9	0.20	2.167	0	0
Total for Georgian Bay						180.9		78.8

able A-4 Cont'd

Watershed	Clay In Surf Soil	Manure and Fert. P Applied	% Of Farm Area In Row Crop	†% Of Total Area In Farms	Total Phosphorus Unit Area Load	Total Phosphorus Total Loading	Total Dissolved P Unit Area Load	Total Dissolved P Total Loading
	%	Kg/ha/yr	%	%	Kg/ha/yr	Tonnes	Kg/ha/yr	Tonnes
				LAKE HURON				
FA01	9.0	10.1	1.5	39.7	0.20	3.054	0	0
FA02*	0	8.8	0.6	43.8	0.15	0.778	0	0
FA03	0	9.1	0.4	40.0	0.15	0.748	0	0
FA04*	0	7.5	0.6	6.7	0.15	0.360	0	0
FA07	0	7.5	0.5	6.7	0.15	0.131	0	0
FA08	0	8.2	0.4	10.2	0.15	0.355	0	0
FA09	13.3	18.0	5.2	49.2	0.27	2.046	0.13	0
FA10	19.6	17.7	7.3	76.5	0.41	20.765	0.20	10.350
FA11	0	9.4	2.5	30.7	0.15	11.056	0	0
FA12	0	9.0	1.2	24.7	0.15	1.112	0	0
FB01	20.8	12.3	1.7	40.7	0.43	3.759	0.16	1.422
FB02	18.4	17.9	4.9	79.2	0.37	2.591	0.19	1.325
FB0301	19.9	15.9	6.0	74.0	0.41	6.697	0.19	3.061
FB04	18.2	14.1	3.0	55.2	0.37	2.489	0.19	1.276
FB05	24.5	16.5	2.5	35.8	0.54	5.512	0.25	2.555
FB06	23.2	18.0	4.6	73.1	0.50	14.612	0.25	7.289
FB07	15.5	17.9	3.1	60.5	0.31	0.038	0.16	0.019
FB0701	21.8	17.8	3.9	62.3	0.46	17.251	0.23	8.640
FB0702	21.6	19.8	5.4	58.4	0.46	1.100	0.25	0.601
FB08	22.9	20.3	4.9	56.1	0.50	2.443	0.27	1.334
FC0101	16.2	16.3	4.9	64.3	0.32	7.906	0.15	3.621
FC0102	16.9	23.2	12.1	76.6	0.36	0.233	0.23	0.148
FC0103	9.2	21.4	17.8	37.6	0.26	1.385	0.12	0.625
FC0104	10.7	17.0	7.3	66.5	0.23	0.686	0.09	0.263
FC0105	10.7	23.4	13.7	75.7	0.25	2.276	0.15	1.381
FC0106	18.6	26.4	16.4	85.0	0.42	10.949	0.28	7.364
FC0201	17.5	17.4	5.2	69.6	0.35	6.033	0.18	2.995
FC0203	27.3	19.0	8.7	89.2	0.65	0.452	0.31	0.217
FC0301	17.3	21.0	6.9	80.9	0.35	18.261	0.21	10.882
FC0302	10.6	24.9	16.6	83.4	0.27	0.222	0.17	0.140
FC0401	29.7	21.9	8.9	79.0	0.74	2.447	0.37	1.228
FC0402	27.2	20.8	8.8	55.2	0.65	3.452	0.33	1.758
FC05	28.1	19.8	7.4	78.8	0.68	3.525	0.33	1.721
FC0601	16.3	23.9	16.0	82.4	0.36	20.782	0.23	12.992
FC07	25.5	20.2	9.0	93.0	0.59	10.283	0.30	5.285
FC08	12.4	37.9	5.6	85.7	0.25	2.156	0.32	2.750
FC09	12.4	16.8	5.8	60.0	0.26	2.165	0.11	0.907
FC10	11.7	17.2	5.8	61.2	0.24	4.271	0.10	1.800
FC11	14.0	20.1	7.3	77.0	0.29	5.589	0.16	3.135
FC12	16.3	26.1	13.0	87.2	0.35	4.854	0.25	3.469
FC1301	10.5	17.0	7.1	68.1	0.23	1.801	0.09	0.674

Table A-4 Cont'd

Watershed	Clay In Surf Soil	Manure and Fert. P Applied	% Of Farm Area In Row Crop	†% Of Total Area In Farms	Total Phosphorus Unit Area Load	Total Phosphorus Total Loading	Total Dissolved P Unit Area Load	Total Dissolved P Total Loading
	%	Kg/ha/yr	%	%	Kg/ha/yr	Tonnes	Kg/ha/yr	Tonnes
FD01	20.8	22.1	12.8	49.9	0.46	9.019	0.26	5.193
FD02	24.5	25.2	19.7	74.2	0.60	9.917	0.34	5.599
FD03	29.6	27.4	24.4	73.8	0.82	14.260	0.43	7.412
FD04	26.3	23.5	21.3	78.1	0.68	5.549	0.35	2.843
FD05	24.9	23.4	26.2	70.9	0.67	9.265	0.33	4.555
FD06	14.6	20.8	20.1	87.7	0.35	7.693	0.18	3.802
FD07	20.0	25.7	33.6	58.6	0.59	5.316	0.29	2.615
FE01	21.1	24.6	29.0	75.9	0.58	6.723	0.29	3.420
FE0101	16.2	22.4	13.1	91.7	0.35	17.208	0.21	10.423
FE0102	10.2	21.2	10.0	83.0	0.23	1.065	0.13	0.576
FE0103	16.5	23.1	24.7	84.4	0.43	17.806	0.22	9.272
FE02	17.5	23.2	16.7	93.1	0.39	0.327	0.24	0.195
FE03	24.0	26.3	28.5	91.5	0.66	24.632	0.35	12.989
FE04	23.2	26.6	1.7	91.9	0.50	30.208	0.34	20.469
FE05	18.8	23.3	15.7	93.6	0.42	15.180	0.25	9.117
FF01	30.0	22.6	44.4	53.6	1.06	57.883	0.38	20.899
FF02	20.4	24.2	38.2	66.5	0.66	8.830	0.28	3.766
FF03	27.2	23.4	33.3	87.5	0.81	79.271	0.36	34.666
FF04	23.3	19.7	26.0	86.8	.61	13.276	0.27	5.836
FF0501	30.6	32.0	43.5	97.3	1.06	6.068	0.49	2.759
FF0502	30.3	24.4	32.9	96.1	0.93	10.078	0.40	4.397
FF06	23.4	23.9	32.6	74.6	0.68	12.814	0.31	5.930
FF0701	27.3	29.9	33.6	90.9	0.82	16.551	0.42	8.561
FF0702	22.1	22.7	26.3	84.6	0.58	4.583	0.29	2.260
FF08	27.1	26.2	34.4	96.2	0.82	16.472	0.38	7.687
Total for Lake Huron						596.6		296.4

Table A-4 Cont'd

Watershed	Clay In Surf Soil	Manure and Fert. P Applied	% Of Farm Area In Row Crop	† % Of Total Area In Farms	Total Phosphorus Unit Area Load	Total Phosphorus Total Loading	Total Dissolved P Unit Area Load	Total Dissolved P Total Loading
	%	Kg/ha/yr	%	%	Kg/ha/yr	Tonnes	Kg/ha/yr	Tonnes
LAKE ERIE								
GA0101	20.2	13.6	3.7	72.8	0.42	3.732	0.17	1.516
GA0102	19.9	17.5	5.9	73.9	0.41	16.940	0.21	8.409
GA0103	20.6	22.9	14.2	82.1	0.46	5.057	0.27	2.974
GA0104	15.0	20.9	16.0	83.7	0.34	11.694	0.18	5.539
GA0105	12.6	33.3	27.9	96.5	0.38	3.264	0.28	2.407
GA0107	15.9	30.2	41.0	85.2	0.59	19.149	0.29	9.382
GA0108	16.1	25.0	29.3	67.3	0.46	2.018	0.24	1.046
GA0109	17.2	25.9	32.0	73.9	0.51	1.485	0.26	0.759
GA0110	15.7	31.0	56.2	70.1	0.82	1.264	0.29	0.451
GA0111	3.7	23.9	41.1	85.2	0.43	3.537	0.07	0.606
GA0201	30.1	25.9	13.3	90.8	0.77	22.645	0.42	12.236
GA0202	25.2	27.2	21.0	88.6	0.64	12.357	0.37	7.197
GA0205	23.0	31.3	38.4	84.7	0.73	7.039	0.39	3.699
GA0206	12.3	28.1	46.4	79.4	0.60	12.682	0.22	4.719
GA0209	15.7	24.2	37.4	74.1	0.54	3.817	0.41	2.923
GA0210	5.8	24.8	54.3	100.0	0.65	6.672	0.56	5.753
GA0301	5.8	14.0	8.9	51.7	0.18	0.300	0	0
GA0302	5.8	18.4	20.6	64.7	0.24	0.039	0.02	0.004
GA0303	5.8	18.5	17.1	63.8	0.22	0.058	0	0
GA0304	5.8	15.8	12.7	56.1	0.20	0.675	0	0
GA0401	13.1	24.0	19.1	70.9	0.32	1.297	0.13	0.521
GA0402	14.3	27.1	29.4	78.8	0.42	7.381	0.26	4.576
GA0406	8.0	20.6	27.6	67.3	0.31	0.883	0.09	0.260
GA0407	12.8	25.6	33.3	66.1	0.44	0.351	0.20	0.163
GA0408	9.6	26.3	40.4	78.9	0.47	5.119	0.17	1.848
GA05	9.2	18.9	14.8	64.0	0.24	4.072	0.09	1.533
GA0601	24.0	15.0	5.0	79.9	0.53	11.735	0.23	5.092
GA0602	28.4	29.3	14.9	87.2	0.71	17.937	0.43	10.844
GA0603	28.0	26.1	13.1	92.9	0.69	13.467	0.39	7.675
GA0604	19.4	27.9	32.3	94.9	0.56	2.979	0.31	1.623
GB0101	11.4	23.4	48.2	63.3	0.61	2.808	0.16	0.751
GB0102	27.2	16.6	18.3	78.2	0.69	24.937	0.29	10.364
GB0103	28.5	13.9	13.7	44.2	0.71	7.816	0.27	3.007
GB0201	18.0	20.5	35.6	77.1	0.57	8.857	0.21	3.340
GB0202	26.0	21.7	27.8	91.2	0.72	15.093	0.32	6.808
GB03	24.0	25.3	28.3	80.2	0.66	9.078	0.34	4.660
GB04	20.8	20.8	30.4	76.8	0.58	18.252	0.25	7.861
GB0501	15.3	27.7	37.7	85.6	0.53	17.386	0.25	8.308
GB0502	6.3	26.8	51.0	94.2	0.60	1.481	0.14	0.337
GC01	8.4	25.4	59.0	80.1	0.76	7.686	0.15	1.493
GC02	23.7	30.5	45.6	92.3	0.85	37.135	0.39	16.791
GC0301	23.9	25.1	45.8	78.9	0.86	23.573	0.33	9.110
GC0302	7.2	22.3	52.8	73.6	0.63	3.713	0.10	0.590
GC0401	18.6	28.0	54.7	91.4	0.86	30.082	0.30	10.410
GC0402	10.1	19.8	43.4	87.5	0.52	13.537	0.11	2.852
GC0403	6.5	19.7	45.1	83.3	0.51	1.080	0.06	0.139

Table A-4 Cont'd

Watershed	Clay In Surf Soil	Manure and Fert. P Applied	% Of Farm Area In Row Crop	† % Of Total Area In Farms	Total Phosphorus Unit Area Load	Total Phosphorus Total Loading	Total Dissolved P Unit Area Load	Total Dissolved P Total Loading
	%	Kg/ha/yr	%	%	Kg/ha/yr	Tonnes	Kg/ha/yr	Tonnes
GC05	8.1	18.2	39.5	73.5	0.45	7.550	0.07	1.183
GC06	19.4	36.0	87.8	3.8	1.64	1.352	0.39	0.321
GC07	10.9	18.9	36.4	57.1	0.44	8.427	0.11	2.123
GC08	9.9	26.1	42.5	80.2	0.51	5.970	0.17	2.040
GC0801	7.6	14.0	33.6	88.9	0.37	2.547	0.02	0.140
GC0802	7.4	18.4	38.7	87.9	0.43	18.095	0.06	2.641
GC09	14.8	23.7	39.5	84.7	0.55	12.905	0.21	4.920
GC10	30.3	14.0	13.7	45.0	0.78	7.074	0.30	2.692
GC11	20.8	25.1	36.9	76.3	0.65	9.753	0.30	4.417
GC12	30.0	15.6	12.0	72.3	0.76	12.028	0.31	4.894
GC13	27.9	14.5	7.9	76.5	0.67	6.906	0.27	2.812
GD01	18.8	31.9	40.8	86.7	0.65	43.921	0.34	23.060
GD02	19.6	27.4	36.1	83.6	0.61	5.410	0.30	2.691
GD0301	18.6	26.1	42.2	82.2	0.66	1.570	0.28	0.659
GD0302	19.4	27.3	38.9	85.5	0.64	15.954	0.30	7.486
GD04	25.2	30.0	47.1	86.4	0.92	12.355	0.40	5.343
GD05	26.3	29.0	33.2	91.7	0.78	53.845	0.40	25.796
GD06	22.9	25.4	35.8	86.3	0.70	12.069	0.32	5.583
GD07	27.5	30.9	40.4	88.8	0.91	11.926	0.44	5.732
GD08	27.4	26.8	28.5	81.6	0.77	10.908	0.39	5.558
GD09	27.8	29.4	25.2	92.6	0.76	10.406	0.42	5.832
GD10	26.3	25.3	18.3	86.0	0.66	7.492	0.36	4.159
GD11	31.3	29.6	28.0	92.2	0.92	11.708	0.47	5.996
GE01	21.6	25.9	64.4	82.0	1.13	35.187	0.31	9.802
GE0201	33.7	21.8	65.5	98.1	1.59	9.006	0.42	2.378
GE0202	33.8	21.8	68.6	87.9	1.66	39.747	0.42	10.068
GE03	32.5	25.8	70.7	85.5	1.65	44.753	0.45	12.069
GE04	19.7	26.9	64.9	88.9	1.08	36.286	0.30	10.048
GE05	16.7	20.6	47.3	81.0	0.69	63.497	0.20	13.235
GE06	23.8	38.4	42.3	77.6	0.81	10.297	0.47	5.959
GE07	20.7	22.3	36.3	83.9	0.64	5.253	0.27	2.169
GF01	25.6	21.3	68.6	68.3	1.34	12.362	0.31	2.901
GF02	18.0	26.4	68.0	61.1	1.11	12.649	0.27	3.122
GF03	25.5	23.1	67.5	70.3	1.31	9.176	0.33	2.318
GF04	9.1	22.8	60.3	74.1	0.79	15.126	0.13	2.462
GF05	14.8	23.5	53.7	77.7	0.76	4.581	0.21	1.238
GF06	10.4	22.1	51.8	79.7	0.65	11.425	0.14	2.405
GG01*	32.4	18.4	38.7	76.2	1.08	18.435	0.37	6.316
GG02*	20.7	23.4	67.7	73.1	1.17	44.572	0.28	10.667
GG03	26.9	28.2	77.2	84.4	1.59	25.853	0.40	6.537
GG04	17.5	29.2	71.9	98.6	1.19	28.080	0.30	7.043
GG05	22.6	23.3	47.0	87.2	0.84	111.418	0.30	39.495
GG06	34.1	17.6	42.4	84.6	1.20	62.158	0.38	19.663
GG07	32.2	18.6	35.6	87.6	1.03	58.852	0.37	20.922

Table A-4 Cont'd

Watershed	Clay In Surf Soil	Manure and Fert. P Applied	% Of Farm Area In Row Crop	† % Of Total Area In Farms	Total Phosphorus Unit Area Load	Total Phosphorus Total Loading	Total Dissolved P Unit Area Load	Total Dissolved P Total Loading
	%	Kg/ha/yr	%	%	Kg/ha/yr	Tonnes	Kg/ha/yr	Tonnes
GH01*	32.1	32.1	63.0	66.1	1.47	60.199	0.51	20.885
GH02	30.0	24.0	63.4	82.3	1.39	26.241	0.40	7.475
GH03	33.1	24.8	59.5	79.5	1.44	16.840	0.44	5.168
GH04*	19.4	105.2	63.5	33.9	1.05	5.121	1.10	5.364
GH05	32.8	20.9	59.1	83.3	1.42	34.192	0.40	9.595
GH06	31.1	24.3	62.2	39.8	1.41	17.691	0.41	5.184
GH07	21.5	28.7	58.9	36.2	1.01	20.220	0.34	6.790
GH08	20.2	34.7	68.8	23.3	1.18	4.457	0.39	1.459
GH0901	9.2	39.3	66.1	86.7	0.91	2.067	0.30	0.679
GH0902	19.9	29.9	71.9	73.4	1.25	14.614	0.33	3.910
GH10	34.4	16.8	66.2	3.6	1.63	4.061	0.38	0.934
GH11*	14.0	50.5	65.8	35.8	0.98	1.662	0.47	0.797
Total For Lake Erie						1578.4		580.7

Table A-4 Cont'd

Watershed	Clay In Surf Soil	Manure and Fert. P Applied	% Of Farm Area In Row Crop	† % Of Total Area In Farms	Total Phosphorus: Unit Area Load	Total Phosphorus: Total Loading	Total Dissolved P: Unit Area Load	Total Dissolved P: Total Loading
	%	Kg/ha/yr	%	%	Kg/ha/yr	Tonnes	Kg/ha/yr	Tonnes
				LAKE ONTARIO				
HA01	28.7	15.7	7.2	68.0	0.70	14.942	0.29	6.314
HA0201	36.8	23.0	14.9	78.3	1.07	2.316	0.47	1.014
HA0202	34.7	29.2	20.6	79.1	1.01	22.720	0.51	11.444
HA03	32.2	16.5	13.6	68.9	0.86	7.806	0.35	3.148
HA04	28.2	18.1	11.1	45.9	0.69	3.756	0.31	1.707
HA05*	30.3	16.8	12.6	23.9	0.78	2.408	0.33	1.018
HA06	25.0	16.0	3.7	46.0	0.56	5.022	0.25	2.267
HA07	32.1	19.0	16.5	66.9	0.87	61.018	0.37	26.034
HA08*	33.8	18.4	27.4	14.8	1.02	3.089	0.38	1.151
HA09*	27.8	21.3	23.0	25.8	0.74	6.732	0.34	3.093
HB0201	10.9	18.0	9.1	60.5	0.24	1.535	0.10	0.646
HB0202	18.4	16.5	10.9	54.6	0.39	16.299	0.18	7.412
HB03*	25.2	20.8	15.1	54.2	0.60	15.679	0.30	7.840
HB0401	21.8	26.0	24.6	51.3	0.56	8.860	0.32	5.027
HB05	21.3	47.0	50.8	64.5	0.86	4.821	0.53	2.938
HB07	19.3	21.0	25.8	56.6	0.50	7.949	0.24	3.732
HC01	36.6	19.2	16.3	83.2	1.07	21.995	0.43	8.839
HC02**	13.0	15.5	5.3	42.2	0.26	--	0.10	--
HC0301	29.8	21.5	22.3	78.0	0.81	1.727	0.36	0.785
HC0302	34.8	17.7	13.8	76.1	0.97	11.953	0.39	4.792
HC0401	18.2	16.0	11.5	51.8	0.39	6.775	0.17	2.975
HC0402*	7.0	17.4	19.1	67.3	0.24	2.692	0.05	0.561
HC05	30.1	12.2	9.5	61.5	0.76	9.661	0.28	3.518
HC0702	11.0	17.2	22.9	40.1	0.31	4.270	0.09	1.240
HC09	25.8	22.7	30.7	48.4	0.74	13.886	0.33	6.239
HC10*	18.9	20.2	14.5	46.7	0.42	5.564	0.22	2.914
HC11**	21.7	18.9	4.3	52.4	0.46	--	0.24	--
HD01	17.8	18.2	18.2	63.6	0.41	1.956	0.19	0.893
HD0201	5.0	44.6	26.7	66.7	0.28	1.111	0.30	1.201
HD0202	6.0	15.5	22.6	50.7	0.26	1.539	0.02	0.095
HD0203	3.0	15.9	26.3	47.3	0.27	0.149	0	0
HD03	18.9	21.4	16.8	80.3	0.43	9.254	0.23	4.950
HD0401	15.7	23.4	22.7	63.3	0.39	5.723	0.22	3.126
HD0501	16.1	19.7	19.0	61.4	0.38	2.151	0.18	1.041
HD0502	14.8	17.2	24.2	54.5	0.39	5.123	0.14	1.863
HD0601	13.8	14.5	17.0	63.1	0.32	5.121	0.10	1.604
HD07	11.0	13.6	14.9	68.9	0.26	2.303	0.06	0.502
HE01	19.8	15.6	19.1	57.1	0.46	1.439	0.18	0.572
HE02	19.3	12.9	17.1	64.4	0.44	4.010	0.15	1.377
HE03	17.1	9.6	9.6	60.4	0.36	3.146	0.09	0.800
HE04	8.0	15.2	15.2	75.9	0.23	4.018	0.04	0.652
HE05	0	24.5	13.0	61.1	0.18	1.911	0.04	0.384
HE06	17.4	8.3	8.3	49.2	0.36	1.391	0.08	0.312
HE07	0	10.9	10.7	45.1	0.17	0.857	0	0
HE08	20.0	14.3	13.0	22.8	0.44	1.898	0.17	0.755

Table A-4 Cont'd

Watershed	Clay In Surf Soil	Manure and Fert. P Applied	% Of Farm Area In Row Crop	† % Of Total Area In Farms	Total Phosphorus Unit Area Load	Total Phosphorus Total Loading	Total Dissolved P Unit Area Load	Total Dissolved P Total Loading
	%	Kg/ha/yr	%	%	Kg/ha/yr	Tonnes	Kg/ha/yr	Tonnes
HE09	0	24.0	26.7	15.4	0.26	2.211	0.03	0.251
HE10	0	15.6	19.4	27.1	0.21	1.402	0	0
HE11	0	7.1	5.7	10.7	0.15	0.736	0	0
HF01	11.0	10.1	4.0	73.0	0.23	2.167	0.02	0.199
HF02	5.0	10.8	4.5	68.2	0.17	2.393	0	0
HF03**	0	5.3	1.3	56.8	0.15	--	0	0
HF04**	0	4.5	1.0	56.8	0.15	--	0	0
HF05	0	1.8	0	5.9	0.15	0.995	0	0
HF06	0	5.0	1.0	31.9	0.15	1.765	0	0
HF08	0	0	0	9.1	0.15	0.126	0	0
HF09	0	0	0	7.5	0.15	0.072	0	0
HG02	17.0	18.7	14.3	59.1	0.37	7.618	0.18	3.758
HG03	17.8	20.6	14.4	65.4	0.39	4.429	0.21	2.417
HG04	29.7	16.5	10.6	71.2	0.74	1.926	0.32	0.816
HG05	30.7	20.1	13.9	84.5	0.80	14.744	0.36	6.730
HG06	18.2	18.1	16.4	66.7	0.41	3.544	0.19	1.658
HG07	29.8	16.0	9.2	81.3	0.74	5.801	0.31	2.426
HH01	17.6	14.2	13.2	59.8	0.38	6.947	0.14	2.628
HH02	12.0	13.3	9.3	61.0	0.26	8.486	0.07	2.190
HH03	16.0	12.4	5.3	69.6	0.32	8.332	0.11	2.739
HH04	21.4	10.8	7.7	44.8	0.46	8.291	0.16	2.814
HH05	21.6	13.9	7.2	61.5	0.46	4.525	0.19	1.854
HH06**	0	1.34	0	8.6	0.15	--	0	0
HH07**	0	0	0	7.2	0.15	--	0	0
HH08**	0	0	0	5.6	0.15	--	0	0
HH10**	0			56.9	0.15	--	0	0
HJ01	20.0	13.6	10.1	69.1	0.43	21.988	0.17	8.605
HJ02	17.7	12.6	11.6	62.4	0.38	9.252	0.13	3.171
HJ03	21.2	12.2	8.2	67.4	0.45	6.259	0.17	2.301
HJ04	19.1	12.8	9.5	60.0	0.40	7.200	0.15	2.650
HK01	16.0	13.0	11.4	71.5	0.34	14.948	0.11	4.955
HK02	6.0	14.6	20.5	63.6	0.24	4.292	0.01	0.113
HK03	13.9	13.7	17.1	72.5	0.32	2.209	0.09	0.639
HK04	10.7	12.0	10.4	62.5	0.24	3.339	0.04	0.512
HK05	23.5	9.6	6.2	76.8	0.52	7.440	0.17	2.422
HK06	19.6	10.8	6.0	76.9	0.41	5.554	0.13	1.821
HK07	12.0	6.2	2.2	28.6	0.24	5.129	0	0
HK08**	11.0	4.4	0.6	16.9	0.23	--	0	0
HK09	11.0	3.8	2.4	13.7	0.23	0.638	0	0
HK10	4.0	3.8	2.6	13.4	0.16	0.087	0	0
HL01	20.3	13.3	20.3	73.1	0.49	4.369	0.17	1.508
HL02	27.3	9.6	8.6	74.9	0.65	22.582	0.21	7.465
HL03	26.6	6.1	2.1	57.6	0.61	6.792	0.17	1.893
HL04	17.3	4.2	0.7	52.2	0.35	5.185	0.04	0.554
HL05	14.2	1.8	0.7	17.5	0.28	1.826	0	0
HL06	17.4	5.0	2.3	51.3	0.35	3.934	0.05	0.530
HL07	19.7	6.4	3.2	52.9	0.40	12.260	0.09	2.708
HM01	24.1	9.2	5.6	69.9	0.53	4.561	0.17	1.462
HM02	21.3	6.9	2.7	56.3	0.45	19.417	0.11	4.954

Table A-4 Cont'd

Watershed	Clay In Surf Soil	Manure and Fert. P Applied	% Of Farm Area In Row Crop	† % Of Total Area In Farms	Total Phosphorus: Unit Area Load	Total Phosphorus: Total Loading	Total Dissolved P: Unit Area Load	Total Dissolved P: Total Loading
	%	Kg/ha/yr	%	%	Kg/ha/yr	Tonnes	Kg/ha/yr	Tonnes
HM03	20.9	6.8	2.9	55.3	0.44	20.798	0.11	5.131
HM04	28.2	13.6	11.0	65.3	0.69	15.585	0.27	6.046
HM05	19.8	15.7	12.9	50.3	0.43	2.224	0.19	0.955
HM06	28.7	10.1	7.1	53.2	0.70	9.931	0.24	3.377
HM07	34.2	9.9	3.7	62.1	0.92	10.442	0.30	3.444
HM08**	36.3	10.2	10.9	39.7	1.03	--	0.33	
HM09	0	8.7	7.5	10.1	0.16	0.434	0	0
HM10	23.4	7.9	4.7	63.3	0.51	7.310	0.15	2.140
Total for Lake Ontario						639.1		236.6

* 50-70% of enumeration areas suppressed

** More than 70% of enumeration areas suppressed

† Since correlation could not be made accurately for urban land area in this subbasin, these values of % of total area in farm land may be high (by an average of > 3%). Data for individual watershed subbasins should be used with care if urban land is significant.

Appendix Table A-5. Remedial measure programs for Ag Watersheds 1, 3, 4 and 5 as examples of a suggested approach to remedial measure recommendations.

Watershed Ag-1 - Big Creek

Watershed description: Area - 5080 ha; soil - 35% to 40% clay; relief - level; stream length - 91 km; hydrologically active contribution area - 50%; land use - 62% row crops, 23% corn, 37% soybeans, 27% wheat, 1% hay; livestock - 0.08 animal units per ha.

Pollutant loads:	Sediment (suspended solids)	Total phosphorus
Measured loading rates	900 (kg/ha/yr)	1.8 (kg/ha/yr)
Potential minimum - zero row crops[1]	260	0.8
Potential maximum reduction	640	1.0

Remedial Measure[2]	Effectiveness[2] Sediment % Reduction	Sediment Residual	Phosphorus % Reduction	Phosphorus Residual	Cost ($) Annual	Cost ($) Capital	Explanatory Note
1. Good management practices	5	850	5	1.70	0	0	3
2. Crop rotations (Corn-soybeans - wheat - hay)	10	765	10	1.50	130,000	0	4
3. Winter cover (oats) - shorter season corn	10	690	10	1.35	57,500	0	5
4. Stream channel buffer strips	15	590	10	1.25	61,820	0	6
5. Drainage engineering:	40	350	15	1.00			
a. Grading channel banks to 3:1 slopes					31,000	57,000	7, 8
b. Drop inlet structures						100,000	9
c. Amortization of capital costs					17,900		10
Total annual costs - $58/watershed ha.					298,200	157,000	

Explanatory Notes:

1. As computed by the following regression equations (row crops = 0) Sediment (kg/ha/yr) = -281 + 8.3 (% row crops) + 13.6 (% clay); Total phosphorus (kg/ha/yr) = $-0.0939 + 0.000846 (\% \text{ clay})^2 + 0.000212 (\% \text{ row crops})^2$.
2. Relative benefits obtained by each remedial measure (i.e. cost effectiveness) depends on the order in which they are implemented.
3. Good management practices include the following no cost items that are applicable to all agricultural land: - a. fertilize by soil test; b. retain surface residues over winter; c. minimum tillage for optimum yield; d. manure incorporation and restricted use near streams; e. residue management for soil organic matter maintenance; f. cross slope farming.
4. Assumed costs and returns for cropping practices:

	Corn and Soybeans	Cereal Grains	Hay
Returns	300 bu/ha @ $2.50/bu = $750/ha	150 bu/ha @ $2.0/bu = $300/ha	25 bu/ha increase in subsequent corn yield = $60/ha. Nitrogen added @ 114 kg/ha @ 44¢ = $50/ha $80/ha (assumed equal to costs since no market)
Costs	$300/ha	$100/ha	$80/ha
Net	$450/ha	$200/ha	$110/ha

Revenue Lost by Crop Conversions
Corn or soybeans to hay - $340/ha
Corn or soybeans to grains - $250/ha
Grains to hay - $90/ha

2500 ha in contributing area (currently 500 ha corn, 1000 ha soybenas, 750 ha wheat, 50 ha hay, 200 ha other improved) is changed to meet rotation requirements (575 ha corn, 575 ha soybeans, 575 ha wheat, 575 ha hay) requiring 350 ha of corn or soybeans and 125 ha of wheat to be converted to hay.

5. 575 ha corn with 25 bu/ha yield reduction ($60/ha) and cost of $40/ha for oats establishment.
6. 182 ha in contributing area lost from production (110 ha corn and soybeans and 55 ha wheat to uncut hay) for $60,000; buffer strip maintenance @ $10/ha.
7. Lost from production by grading channels to 3:1 bank slopes - 10 m X 91 km = 91 ha (55 ha corn or soybeans and 30 ha wheat)
8. Grading costs @ $600/km for 91 km of channel
9. Drop inlet structures @ 4/km^2 @ $500/structure
10. Amortization over 20 years @ 10%

Watershed Ag-3 - Little Ausable River

Watershed description: Area - 6200 ha; soil - 25% to 30% clay; relief - gently sloping; stream length - 40 km; hydrologically active contributing area - 25%; land use - 45% row crops, 32% corn, 12% beans, 22% small grains, 5% wheat, 10% hay; livestock - 0.48 animal units per ha.

Pollutant loads:	Sediment (suspended solids)	Total phosphorus
Measured loading rates	260 (kg/ha/yr)	1.1 (kg/ha/yr)
Potential minimum - zero row crops[1]	60	0.4
Potential maximum reduction	200	0.7

Remedial Measure[2]	Effectiveness[2] Sediment % Reduction	Sediment Residual	Phosphorus % Reduction	Phosphorus Residual	Cost ($) Annual	Cost ($) Capital	Explanatory Note
1. Good management practices	10	230	10	1.00	0	0	3
2. Strip cropping	5	220	5	0.95	2,900	1,000	4
3. Crop rotations (corn - corn - grain - hay - hay)	10	200	10	0.85	25,000	0	5
4. Winter cover (oats) - shorter season corn	10	180	10	0.75	42,000	0	6
5. Stream channel buffer strips (20 m width)	15	150	10	0.70	18,000	0	7
6. Drainage engineering:	10	135	0	0.70			
a. Tile outlet stabilization						15,000	8
b. Bank stabilization on 13 ha						5,200	9
c. Amortization of capital costs					2,500		10
Total annual costs - $15/watershed ha.					90,400	21,200	

Explanatory notes:

1, 2, and 3 - see notes for Watershed Ag-1 (Note 1 includes 0.1 kg P/ha/yr subjective reduction estimate for applying remedial measures)

4. Strip cropping on 75% of the "C" slopes in the contributing area (290 ha) @ $10/ha plus a capital cost of $1,000 for some tree and fence-row removal.

5. Assumed costs and returns for cropping practices:

	Corn (net same for soybeans)	Cereal grains	Hay	Revenue Lost by Crop Conversions
Returns	250 bu/ha @ $2.50/bu = $600/ha	150 bu/ha @ $2.00/bu = $300/ha	25 bu/ha increase in subsequent corn yield = $60/ha/2 yrs 114 kg/ha N added @ 44¢ = $50/ha/2 yrs 7.5 tonnes/ha hay @ $30/t = $225/ha	Corn or soybeans to hay - $100/ha Corn or soybeans to grains - $100/ha Grains to hay - nil
Costs	$300/ha	$100/ha	$80/ha	
Net	$300/ha	$200/ha	$200/ha	

1550 ha in contributing area (currently 700 ha corn/beans, 340 ha grain, 280 ha hay) is changed to meet rotation requirements (525 ha corn/beans, 265 ha grains, 525 ha hay) requiring 175 ha of corn/beans and 75 ha small grains to be converted to hay.

6. 420 ha corn with a 25 bu/ha yield reduction ($60/ha) and cost of $40/ha for oats established.

7. 80 ha in contributing area lost from production (36 ha corn/beans @ $300/ha, 18 ha grains @ $200/ha, 14 ha hay @ $200/ha): buffer strip maintenance @ $10/ha.

8. 150 drain outlets @ $100/outlet.

9. 13 ha of eroding banks stabilized @ $400/ha.

10. Amortization over 20 years @ 10%.

Watershed Ag-4 - Canagagigue Creek

Watershed description: Area - 1860 ha; soil - 25% clay; relief - gently sloping; stream length - 20 km; hydrologically contributing area - 25%; land use - 20% row crop (all corn), 32% small grains, 38% hay/pasture; livestock - 0.75 animal units per ha.

Pollutant loads:	Sediment (suspended solids)	Total phosphorus
Measured loading rates	425 (kg/ha/yr)	0.75 (kg/ha/yr)
Potential minimum - zero row crops[1]	75	0.30
Potential maximum reduction	350	0.45

Remedial Measure[2]	Effectiveness[2] Sediment % Reduction	Sediment Residual	Phosphorus % Reduction	Phosphorus Residual	Costs ($) Annual	Capital	Explanatory Note
1. Good management practices	10	380	10	0.67	0	0	3
2. Strip cropping	15	325	10	0.60	1,400	500	4
3. Crop rotation (corn - grain - grain - hay - hay)		-	-	-		-	5
4. Spring plowing (corn and hay)	5	310	5	0.57	12,000	0	6
5. Stream channel buffer strips (20 m); grassed waterways	40	185	25	0.43	18,400	0	7
6. Drainage engineering:	10	165	0	0.43			
a. Tile outlet stabilization						5,000	8
b. Stream bank stabilization						1,200	9
c. Amortization of capital costs					800		10
Total annual cost - $18/watershed ha.					32,600	6,700	

Explanatory notes:

1, 2, and 3 - see notes for Watershed Ag-1 (Addition to Note 1. - includes subjective 0.1 kg/ha/yr livestock input reduction assumed to result from the implementation of the remedial measures listed.)

4. Strip cropping on 75% of the "C" slopes in the contributing area (140 ha) @ $10/ha, plus $500 capital costs for fence row removal.

5. Crop rotation is not applicable as a new remedial measure, since, in this watershed, they are already generally practiced.

6. To avoid fields in the contributing area being left bare over the winter period, either plow in the spring, or use cover crop over winter; - 100 ha corn with expected yield loss of 25 bu/ha @ $2.50/bu = $6,000 and 200 ha grain @ a loss of $30/ha = 6,000 - total $12,000/yr.

7. 40 ha to buffer strips and lost from production (8 ha corn @ $300/ha, 16 ha grain @ $200/ha, 16 ha hay @ $200/ha = $8,800); grassed waterways established on an equal land area with the same costs. Assumed that the buffer strips and waterways are clipped and not harvested for hay - maintenance costs @ $10/ha = $800. Total cost $18,400.

8. 50 tile outlets stabilized @$100/outlet.

9. 3 ha of eroding streambanks stabilized @ $400/ha.

10. Amortization of capital costs at 10% for 20 years.

Watershed Ag-5 - Holiday Creek

Watershed description: Area - 3000 ha; soil - 20% clay; relief - gently sloping; stream length - 22 km; hydrologically active contribution area - 25%; land use - 48% row crops (all corn), 13% small grains, 25% hay; livestock - 0.61 animal units/ha.	Pollutant loads:	Sediment (suspended solids)	Total phosphorus
	Measured loading rates	250 (kg/ha/yr)	1.00 (kg/ha/yr)
	Potential minimum - zero row crops[1]	25	0.15
	Potential maximum reduction	225	0.85

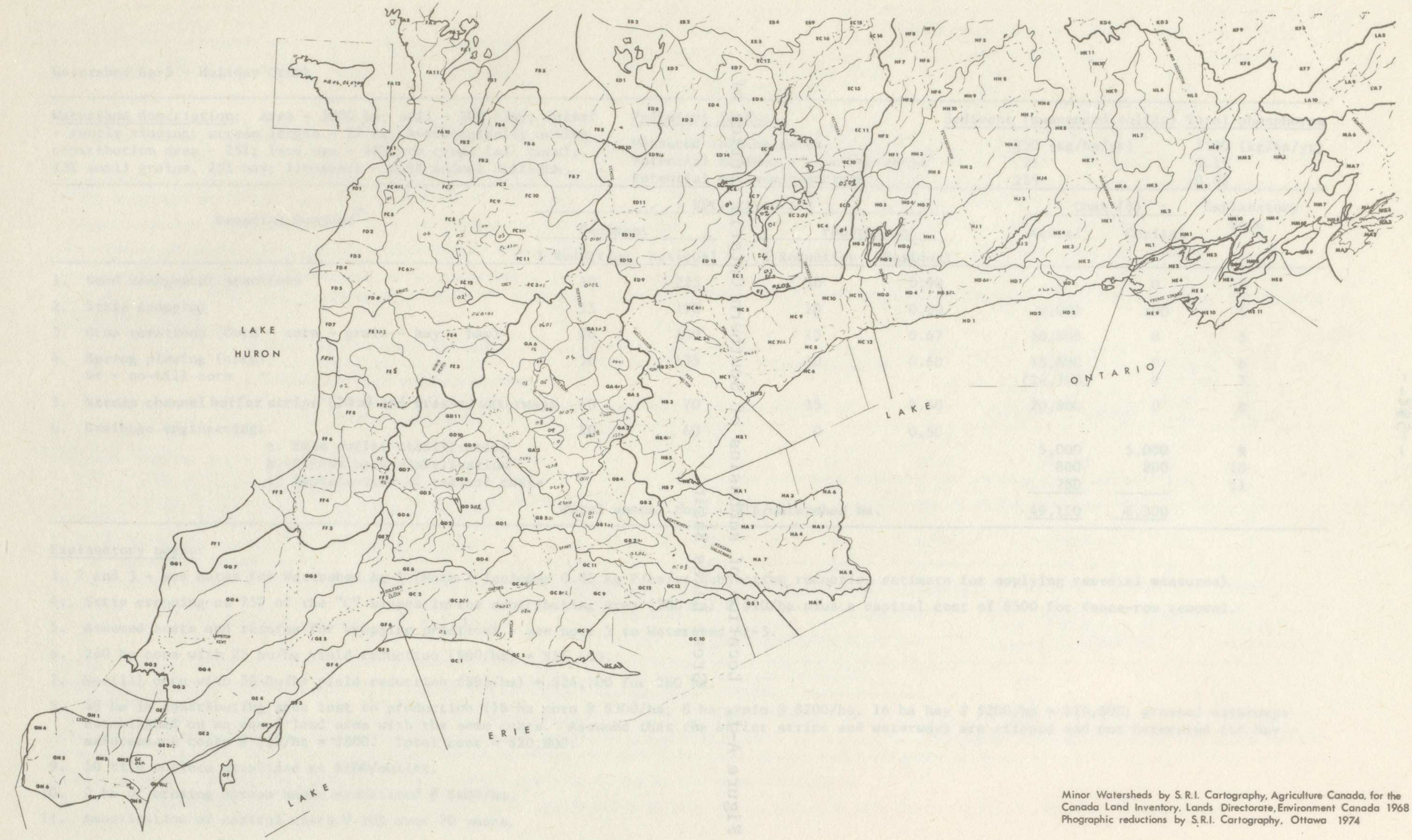
Remedial Measure[2]	Effectiveness[2]: Sediment % Reduction	Sediment Residual	Phosphorus % Reduction	Phosphorus Residual	Cost ($) Annual	Cost ($) Capital	Explanatory Note
1. Good management practices	10	225	10	0.90	0	0	3
2. Strip cropping	15	190	10	0.80	2,000	500	4
3. Crop rotations (Corn - corn - grain - hay - hay)	20	150	15	0.67	10,000	0	5
4. Spring plowing (corn)	10	135	10	0.60	15,600	0	6
or - no-till corn					(24,700)	0	7
5. Stream channel buffer strips (20 m) and grassed waterways	40	70	15	0.50	20,800	0	8
6. Drainage engineering:	10	60	0	0.50			
a. Tile outlet stabilization					5,000	5,000	9
b. Stream bank stabilization					800	800	10
c. Amortization of capital costs					750		11
Total annual cost - $16/watershed ha.					49,150	6,300	

Explanatory notes:

1, 2 and 3 - see notes for Watershed Ag-1 (Note 1 includes 0.05 kg P/ha/yr subjective reduction estimate for applying remedial measures)

4. Strip cropping on 75% of the "C" slopes in the contributing area (200 ha) @ $10/ha plus a capital cost of $500 for fence-row removal.
5. Assumed costs and returns for cropping practices - see note 5 to Watershed Ag-3.
6. 260 ha corn with 25 bu/ha yield reduction ($60/ha) = $15,600.
7. No-till corn with 35 bu/ha yield reduction ($95/ha) = $24,700 for 260 ha.
8. 40 ha in contributing area lost to production (16 ha corn @ $300/ha, 8 ha grain @ $200/ha, 16 ha hay @ $200/ha = $10,000; grassed waterways established on an equal land area with the same costs. Assumed that the buffer strips and waterways are clipped and not harvested for hay - maintenance costs @ $10/ha = $800. Total cost = $20,800.
9. 50 tile outlets stablized at $100/outlet.
10. 2 ha of eroding stream banks stabilized @ $400/ha.
11. Amortization of capital costs @ 10% over 20 years.

Figure A-1. Location of subbasins of Southern Ontario portion of Great Lakes Basin.



Minor Watersheds by S.R.I. Cartography, Agriculture Canada, for the
Canada Land Inventory, Lands Directorate, Environment Canada 1968
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