AGRICULTURAL WATERSHED STUDIES

Task Group C - Activity 1

International Reference Group on Great Lakes

Pollution from Land Use Activity

Report on Project #18

CONTRIBUTION OF PHOSPHORUS FROM AGRICULTURAL LAND TO STREAMS BY SURFACE RUNOFF

A. Spires and M.H. Miller

Department of Land Resource Science

University of Guelph

Guelph, Ontario.

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DISCLAIMER

The study discussed in this report was carried out as 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. Results and conclusions are those of the authors and do not necessarily reflect the views of the Reference Group or its recommendations to the Commission.

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1.0 SUMMARY REPORT

1.1 Study Objectives and Approach

The objective of this study was to develop a capability for prediction of the amount of phosphorus carried to streams by surface runoff from agricultural cropland in Ontario.

The quantity of P lost from cropland on mineral soils to streams by surface runoff has been described by the following equation (Hagin and Amberger, 1974)

Amount of P lost in surface runoff	=	Total amount of sediment in surface runoff	x	P content of the surface soil	x	P enrichment ratio	(1)

This relationship is the basis of the predictive capacity developed in this study.

Gross erosion estimated from the universal soil loss equation by van Vliet and Wall (PLUARG Technical Report Project No. 16) in association with sediment delivery ratios estimated by Dickinson (PLUARG Technical Report Project No. 17) formed the basis for estimation of the total amount of sediment in surface runoff.

The total P content of 248 Ontario soils was related by regression analysis to the soil texture, drainage, organic matter content, pH and $NaHCO_3$ extractable phosphorus. The soils used were primarily surface soils collected from farm fields in watersheds No. 4 and 5 with some additional samples taken from other areas in Ontario to provide a wider range of soil types.

To determine the value of the P enrichment ratio, the P content of sediment obtained from a number of runoff samples collected from watershed No. 4 and 5 was related to the P content of the original soil.

The value of the P enrichment ratio was then related by regression analysis to soil and runoff characteristics to obtain a prediction equation for extrapolation to other watersheds.

1.2 Experimental Results

Prediction of Sediment Load. Attempts were made to calculate sediment loadings at the mouth of each watershed using the following relationship:

$$\text{Sediment Load} = \left[\begin{array}{l}\text{Potential Sheet} \\ \text{and Rill Erosion}\end{array} \times \text{Delivery Ratio}\right] + \begin{array}{l}\text{Streambank} \\ \text{Erosion}\end{array}$$

Although estimates were possible for both potential sheet and rill erosion and streambank erosion, prediction of the delivery ratio proved to be less reliable. Because of this, measured sediment loads were used to compute the phosphorus load.

Prediction of Soil P Content. Stepwise multiple regression analyses were conducted to relate measured total P to the chemical and physical properties of the soils. The total P values for 248 soils were compared to the following independent variables:

1. Extractable P (µg g^{-1})
2. pH
3. Estimated Clay Content (%)
4. Drainage
5. Organic Matter Content (%)
6. $(\text{Extractable P})^2$
7. $(\text{Drainage})^2$
8. $(\text{Organic Matter})^2$
9. Extractable P x pH
10. Organic matter x clay content
11. Organic matter x drainage
12. % Sand |
13. % Silt |➔ as indicators of texture
14. % Clay |
15. Organic matter x sand
16. Organic matter x silt

The best equation for the prediction of total P in the soil was as follows:

$$P = 177.7 + 92.4(OM) + 12.9(AP) - 0.15(AP^2) - 2.93(OM^2) \qquad R^2 = 0.32$$

where P = Total P content of the surface soil, µg g^{-1}

OM = organic matter content,

AP = $NaHCO_3$ extractable P (Ontario Soil Test), µg g^{-1}

The R squared value obtained (0.32), although statistically significant, was very low. This was partly due to the limited range of total P values obtained from the soils collected (Mean total P = 733 ppm, S.D. ± 150). Because of the narrow range of total P, the mean value was used in the predictive model to calculate P loads.

Prediction of Phosphorus Enrichment Ratio. Phosphorus enrichment of the sediment was directly related to clay enrichment:

$$PER = 0.8632\ e^{0.3022(CER)} \qquad R^2 = 0.93$$

where PER = phosphorus enrichment ratio

CER = 'clay' enrichment ratio. ('clay' = particles <5µ diam.)

This suggested that phosphorus enrichment was due to the more selective erosion of the finer particles which contained more phosphorus than coarse particles.

The phosphorus enrichment ratios calculated from runoff samples collected from the field varied from below 1.0 to 6.0. The highest values were associated with either ponding or low sediment concentrations. The phosphorus enrichment ratios of samples which were not ponded on the field were related to sediment concentration and the sand and clay content of the surface soil.

$$PER = 5.547 - 0.0202(SD \times CL_2) + 0.00128(CL_2^{\,2}) + 0.004(S_{50}^{\,2}) + 0.455\,(SD^2) - 2.674(SD) \qquad R^2 = 0.69$$

where PER = Phosphorus Enrichment Ratio

SD = Sediment Concentration (log.), mg L^{-1}

S_{50} = Sand content of surface soil, % (particles >50µ)

CL_2 = Clay content of surface soil, % (particles <2µ)

This predictive equation is valid within the following limits:

Particles >50µ diam.:	15-35%
Particles <2µ diam.:	5-35%

Prediction of Dissolved Reactive P. Dissolved Reactive P was related to both the equilibrium phosphorus concentration and the $NaHCO_3$-extractable P content of the sediment. However, due to the influence of surface applied manure and other variations in the soil surface, prediction of dissolved reactive P from soil characteristics was not possible. Concentrations of dissolved reactive P were greater in runoff from fields with manure present on the surface (mean 0.69 mg/L, range 0.19 - 1.42 mg/L) than from fields with no surface manure (mean 0.08 mg/L, range 0.01 - 0.21 mg/L).

Phosphorus Delivery Ratio. Samples taken from both runoff in the field and from a stream indicated that the ratio of phosphorus delivered to the stream from a field was greater than the corresponding delivery ratio for sediment although estimations of this factor were not possible in this present study.

1.3 Applications of Relationship to other Watersheds

Predictions of the amounts of sediment associated P lost from streambank erosion for eleven agricultural watersheds ranged from 0.003 to 0.11 Kg ha^{-1}. Similar predictions for cropland ranged from 0 to 1.09 Kg ha^{-1}. Losses from unimproved land were estimated at 0.08 Kg P ha^{-1}.

Greatest sediment associated P losses from cropland were predicted from watersheds Ag 1 and 13. These were the most intensively cultivated areas. Streambank erosion was highest in watersheds Ag 1 and 4. The major part of sediment associated P loss occurred during February, March and April. Losses during these months accounted for an average of 88% of the total annual loss. Watershed Ag 5 was not included in this calculation due to exceptionally high losses during July and August caused by severe storms not representative of an average year.

1.4 Relationship to PLUARG Objectives

The objective of this project was to develop a capacity for prediction of the amount of phosphorus carried to streams by surface runoff from agricultural cropland in Ontario.

The project has succeeded in developing relationships for estimation of total phosphorus concentration in surface soils in Ontario and for prediction of the phosphorus enrichment ratio.

However, it has not been as successful in predicting the sediment load, the third parameter required for estimating the contribution of phosphorus. The difficulty in predicting the sediment load is due to difficulty in estimating the sediment delivery ratio.

Although sediment associated P loss could be estimated, it was not possible to develop a relationship to predict dissolved P concentrations in runoff.

The study has improved our understanding of the processes involved in phosphorus loss from cropland and its transport to streams. Although the development of the predictive capacity has not been fully realized, the understanding obtained will greatly assist in interpretation and extension of the monitoring data from the Agricultural Watersheds Study.

2.0 INTRODUCTION

2.1 Study Objectives and Approach

The objective of this study was to develop a capability for prediction of the amount of phosphorus carried to streams by surface runoff from agricultural cropland in Ontario. The quantity of P lost from cropland on mineral soils to streams by surface runoff has been described by the following relationship (Hagin and Amberger, 1974)

$$\text{Amount of P lost in surface runoff} = \text{Total amount of sediment in surface runoff} \times \text{P content of the surface soil} \times \text{P enrichment ratio} \quad (1)$$

This relationship is the basis of the predictive capacity developed in this study.

Gross erosion estimated from the universal soil loss equation by van Vliet and Wall (PLUARG Technical Report Project No. 16) in association with sediment delivery ratios estimated by Dickinson (PLUARG Technical Report Project No. 17) formed the basis for estimation of the total amount of sediment in surface runoff.

The total P content of soil is composed of a mixture of native inorganic P, of organic P, and of added fertilizer P at varying stages of reaction. The native inorganic P and the organic P should be related to properties of the soil, such as clay content, type of parent material, drainage, and pH. These factors are incorporated into the soil classification system and thus would be available for predictive purposes from the soils inventory. The added fertilizer P is independent of the soil classification system. However, the extractable P as determined by the sodium bicarbonate extraction used in the Ontario Soil Testing Service should be a reasonably reliable indicator of added P.

The total P content of 248 Ontario soils was related by regression analysis to the soil texture, drainage, organic matter content, pH and $NaHCO_3$ extractable phosphorus. The soils used were primarily surface soils collected from farm fields in watersheds No. 4 and 5 with some additional samples taken from other areas in Ontario to provide a wider range of soil types.

In addition to the phosphorus concentration in the original soil, it is necessary to be able to predict the enrichment ratio. The erosion process tends to be selective in that the organic matter and finer mineral particles are some susceptible than are the coarser particles. These finer fractions are usually higher in nutrient content. Hence the P content of the eroded material is usually higher than that of the original soil. The value of the enrichment factor depends on the properties of the soil, such as clay and organic matter content, and the management practices, such as manure application or surface application of fertilizer. It also depends upon the intensity of the runoff event. To determine the value of the P enrichment ratio, the P content of sediment obtained from a number of runoff samples collected from watershed No. 4 and 5 was related to the P content of the original soil. The value of the P enrichment ratio was then related by regression analysis to soil and runoff characteristics to obtain a prediction equation for the extrapolation to other watersheds.

The equation (1) makes no allowances for soluble P lost in surface runoff. The concentrations of soluble P should be related to soil properties, management practices, and sediment concentration in the runoff. From the runoff samples collected attempts were made to produce a model enabling a prediction of soluble P levels in the runoff for a particular area or rainfall event.

3.0 DATA COLLECTION METHODS

3.1 Location of Study Sites

The Lower Great Lakes Basin has been divided into twenty-one agricultural regions of similar soils, in the same climatic zone, and upon which an identifiable agricultural land use or combination of land uses existed (Coote, MacDonald and Wall, 1974). Representative watersheds for each of these regions were identified for more detailed study.

Two of these representative watersheds, Ag #4 (Canagagigue Creek) and Ag #5 (Holiday Creek, Embro), were selected for the present study as well as for those of other related projects at the University of Guelph. Both soil type and management practices within these watersheds were thought to be sufficiently diverse to obtain information which could be applied to much larger areas. This factor, coupled with the close proximity to Guelph, accounted for this choice.

As the project progressed it became apparent that data from a wider range of soil types should be obtained. Thus during the latter part of the study, emphasis was shifted to different watersheds within the Lower Great Lakes Basin. Ag #1 (Big Creek) was selected as an example of a watershed with a finer textured soil type and Ag #13 (Hillman Creek) as a watershed with a coarser textured soil type.

The locations of these various watersheds and the approximate areas that they represent are shown in Figure 1.

Details of soil properties and land use practices are given in Table 1. The soils of watershed Ag #1 are predominantly clay loam texture, whilst those of Ag #4 and 5 are predominantly sil loams although Ag #4 soils have a slightly higher clay content than Ag #5. Soils in Ag #13 are coarser textured with an average of 75% sand.

Soils from watersheds 1 and 13 contain larger amounts of extractable P than those from watersheds 4 and 5 due at least in part to higher fertilizer P addition associated with the higher percentage of row crops in these watersheds. Watersheds 1 and 13 also have lower livestock production as reflected by the numbers animal units per hectare and the amounts of P added as manure.

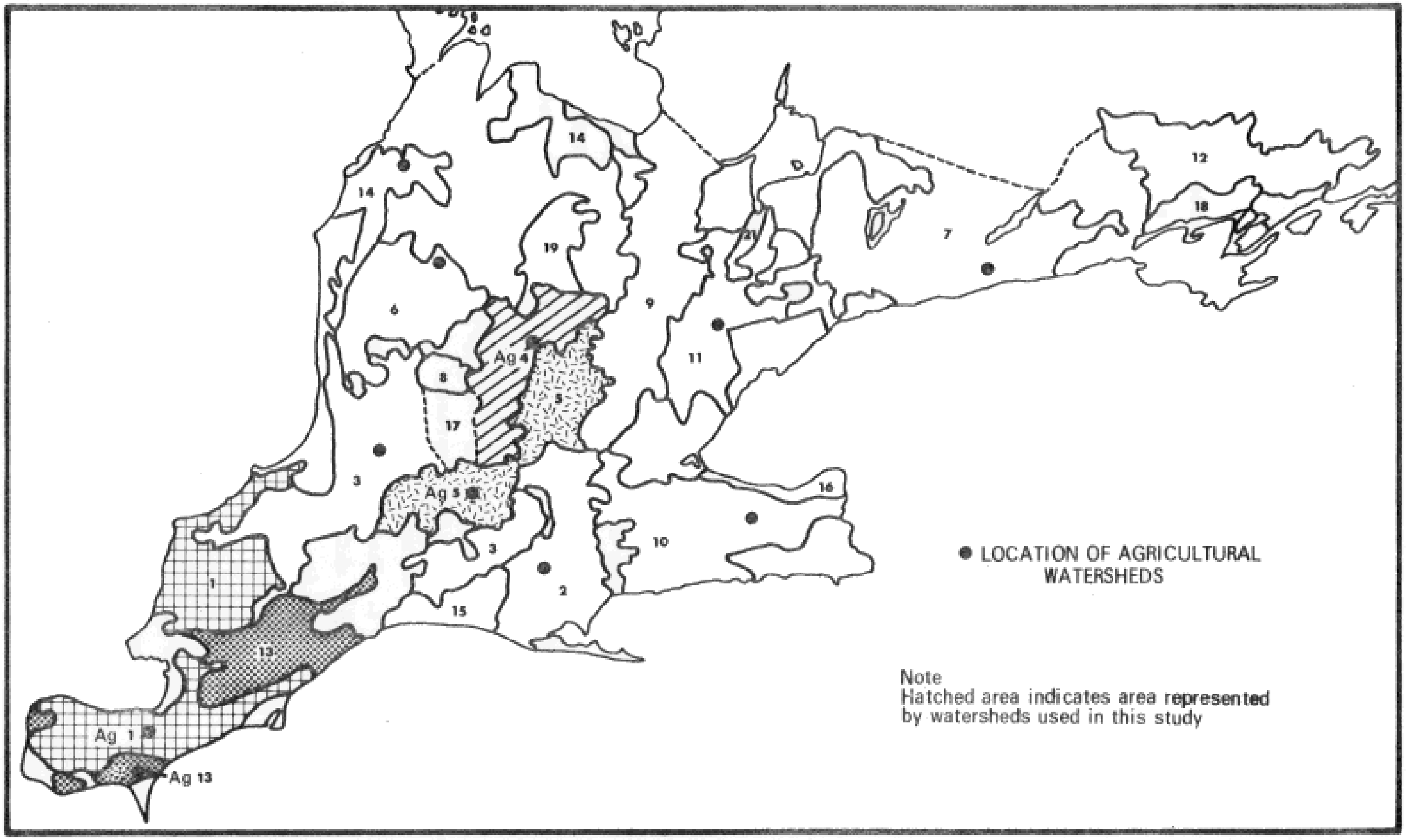


Figure 1: Agricultural Watersheds.

Table 1: Characteristics of the Four Agricultural Watersheds used in Study.

	AG 1	AG 4	AG 5	AG 13
Area, ha	5080	1860	3000	1990
Surface Soil % Sand	35	22	26	75
Surface Soil % Clay	35	23	13	11
Predominant Texture	Clay loam	Silt loam	Silt loam	Sandy loam
Extractable Phosphorus µg g^{-1}	31.4	13.8	19.3	41.2
Fertilizer Phosphorus added Kg ha^{-1}	18.9	10.1	16.8	40.5
Manure Phosphorus added Kg ha^{-1}	1.0	14.5	10.0	0.3
% Pasture and Hay	1.7	37.2	22.8	0
% Orchard	0	0	0	3.8
% Woodland and Unimproved	3.9	6.9	15.4	7.0
% Non Agriculture	5.1	2.0	3.7	16.9
% Row Crops	62.2	18.7	45.9	63.5
% Corn	23.0	18.7	42.3	22.8
% Soybeans and White Beans	37.4	0	0	7.9
% Tobacco	0	0	0	5.0
% Vegetables	1.8	0	3.6	27.8
% Cereal	27.1	35.3	12.2	8.9
Animal Units ha^{-1}	0.08	0.75	0.61	0.01
Rural Residences, houses Km^{-2}	4.1	3.8	1.4	17.3
Exposed Streambank, %	21	31	6	7

The amounts of exposed streambank vary considerably among the four watersheds. Ag #1 and Ag #4 would appear to be the most liable to streambank erosion due to the larger proportion of streambank exposed in each watershed.

A further difference between these watersheds exists in terms of rural residences, with watershed 13 having a much greater density of houses than any of the other watersheds.

3.2 Sampling Procedures

Collection of Field Runoff. Any field under agricultural usage in or from which water was flowing on the surface was considered a potential site although practical considerations of transportation of 20 L samples influenced specific site locations.

A total of forty-five individual field runoff events were sampled in 1975, of which twenty-four were from Ag #4-Canagagigue (Figure 2), fifteen from Ag #5-Holiday (Figure 3) and six additional samples from sites to the north of Guelph. In 1977, three runoff samples were collected, one from each of Ag #1-Big Creek, Ag #13-Hillman Creek and Ag #5-Holiday Creek.

Samples were collected from a point in the field where there was a natural concentration of the runoff water. The runoff was collected in a pail[1] and transferred to a 20 L nalgene jerrican with the aid of a funnel. Care was necessary to avoid the inclusion of soil from the rivulet walls or bottom yet still obtaining a representative sample.

As soon as possible after collection, approximately a 125-ml aliquot of the runoff sample was filtered, under vacuum, through a 0.45µ Gelman millipore filter[2] using a Sartorius millipore filter apparatus. When completed the filtrate was transferred to a 125-ml polyethylene bottle.

NOTES: [1] All equipment used throughout this project was acid washed and rinsed thoroughly with distilled water with the exception of those analyses not involving the determination of phosphorus.

[2] Gelman filters were used since Sartorius filters were found to contain phosphorus.

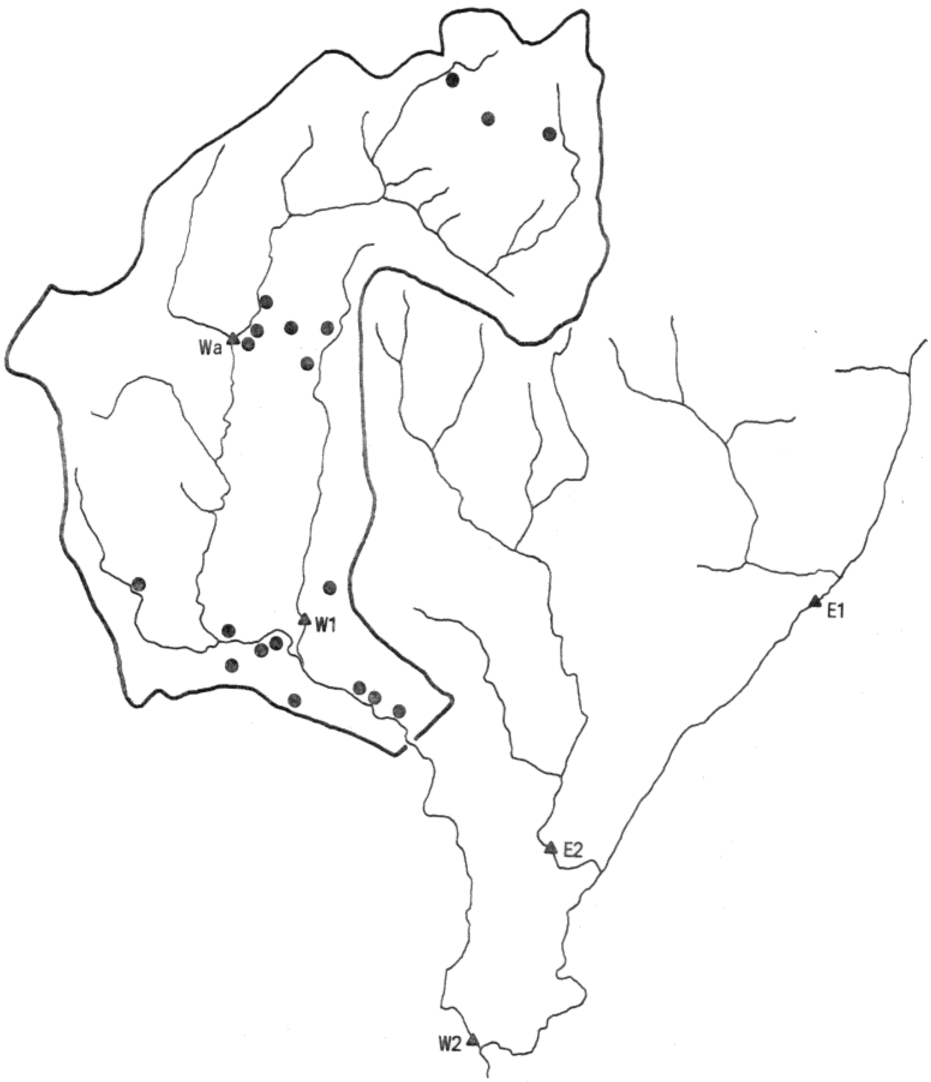


Figure 2: Ag 4 Canagagigue Creek - Location of field runoff (0) and stream sampling sites (A)

Note: More than one sample was collected from some field sites.

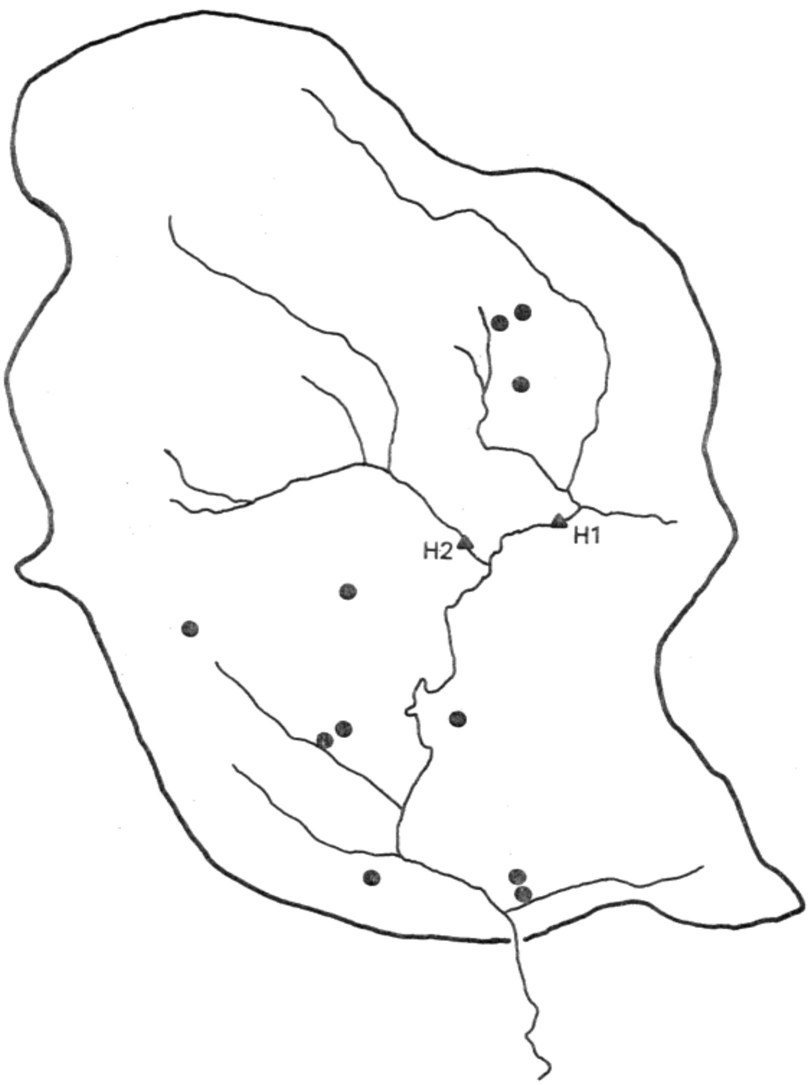


Figure 3: Ag 5 Holiday Creek - Location of field runoff (B) and stream sampling sites (A)
Note: More than one sample was collected from some field sites.

On returning to the laboratory the sediments contained in the 20 1 runoff samples were divided into coarse (50µ diam.), medium (5-50µ diam.) and fine (<5µ diam.) fractions whilst the filtrates were analyzed for dissolved reactive P, dissolved total P, NH_3-N and NO_3-N (Figure 4).

Due to the time factor involved, it was necessary to store these samples prior to analyses. The runoff samples were stored at 2ºC and the filtrates placed in a freezer until analyzed.

<u>Separation of Runoff Samples Into Aggregate Size Fractions.</u> The volume of each field runoff sample was determined to the nearest 0.5 L by comparison with a calibrated jerrican. The runoff was then passed through a 50µ nylon mesh, the filtrate being collected in a jerrican. The original jerrican was washed with sufficient filtrate to remove any settled particles. This coarse material on the mesh was transferred quantitatively to a Buchner funnel containing a prebaked, preweighed Whatman No. 42 filter paper and filtered under suction. The filter paper with the coarse fraction was placed on a watchglass, oven dried at 105ºC for 24 h and then weighed. This represented the coarse fraction with particle diameter greater than 50µ.

The remaining sediment was resuspended by shaking and, after allowing 2 hours to permit particles of 5µ or greater to settle beyond the 15 cm depth, the top 15 cm was siphoned off into the original sample jerrican. The sediment was again resuspended, allowed to stand for 2 hours and the supernatant siphoned off into the sample jerrican down to the 2 L level. The remaining suspension was transferred quantitatively to a 2 L cylinder, washing with siphoned supernatant. The suspension was made up to 2 L with siphoned supernatant, resuspended by gently using a plunger and allowed to settle for a calculated time (Table 2). The top 15 cm of suspension was siphoned off, the medium fraction resuspended and allowed to resettle. At the calculated time the supernatant was siphoned off down to the 200 ml level or to the lowest level possible such as not to disturb the sediment. The medium sized particles were then transferred to a Buchner funnel, filtered, oven dried and weighed as in the separation of the coarse material outlined above. This represented the medium sized fraction (5-50µ).

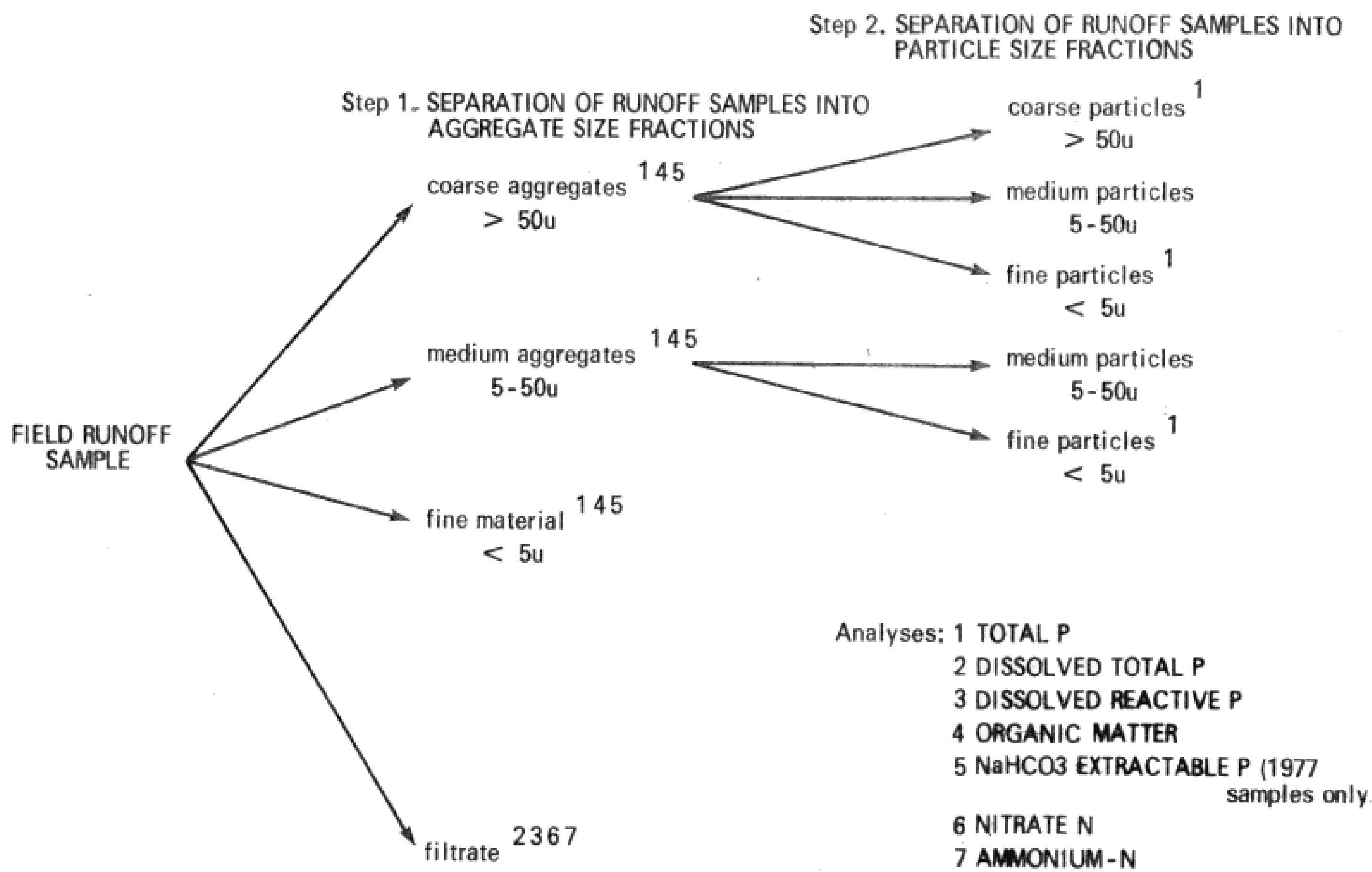


Figure 4: Treatment of Field Runoff Samples.

Table 2: Settling times (min.) for particles with diameter >5µ (medium size fraction).

Depth (cm)	Temperature ºC					
	20	21	22	23	24	25
5.0	37.5	36.5	35.5	34.5	34.0	33.0
6.0	44.5	43.5	42.5	41.5	40.5	39.5
7.0	52.0	51.0	49.5	48.5	47.5	46.5
8.0	59.5	58.0	57.0	55.5	54.0	53.0
9.0	67.0	65.5	64.0	62.5	61.0	59.5
10.0	74.5	72.5	71.0	69.5	68.0	66.0
11.0	82.0	80.0	78.0	76.5	74.5	73.0
12.0	89.5	87.5	85.0	83.0	81.5	79.5
13.0	97.0	94.5	92.5	90.0	88.0	86.0
14.0	104.5	102.0	99.5	97.0	95.0	92.5
15.0	112.0	109.0	106.5	104.0	101.5	99.5

The suspension of fine material in the jerrican was agitated and a representative sample of known volume (approximately 500 ml) was withdrawn. This sample was filtered through a pre-baked, pre-weighed 0.45µ Gelman millipore filter under suction. The filter plus the fine fraction was removed, oven dried (24 h, 105ºC) and weighed. This fraction contained particles with diameters between 0.45 and 5µ.

A 1-1 aliquot of the fine suspension was stored at 2ºC.

<u>Separation of the Coarse and Medium Fractions into Particle Size Fractions.</u> (Step 2, Figure 4). In the previous separation care was taken to avoid dispersion of the sediment into discrete particle sizes. During runoff it was expected that the finer particles would be preferentially transported. These finer particles, however, tended to form aggregates. To obtain information regarding the relative proportions of fine, medium and coarse material for each runoff event it was necessary to disperse these aggregates. Since 'Calgon' (sodium hexametaphosphate), the most commonly used dispersing agent, contains phosphorus, it could not be used in this instance.

A series of experiments was conducted to select a suitable dispersion method.

Sodium bicarbonate was found to be less effective as a dispersant than calgon and only slightly better than water (Figure 5).

Due to this apparent lack of a suitable chemical alternative to calgon, ultrasonic vibration was used to disperse the aggregates in the sediment fractions. However, flocculation of the suspension occurred very rapidly after sonification. This was in contrast to other reports in the literature (Vladimirov, 1968; Watson, 1971). Thus, in addition to ultrasonic vibration, chemical dispersants were used. Sodium bicarbonate produced more reliable results than sodium chloride although it had the disadvantage of extracting phosphorus from the dispersed material (Figure 6). However, at low concentrations the amount extracted was insignificant compared with the total amounts of P present and it was decided to use 0.04 M $NaHCO_3$ as the dispersing agent.

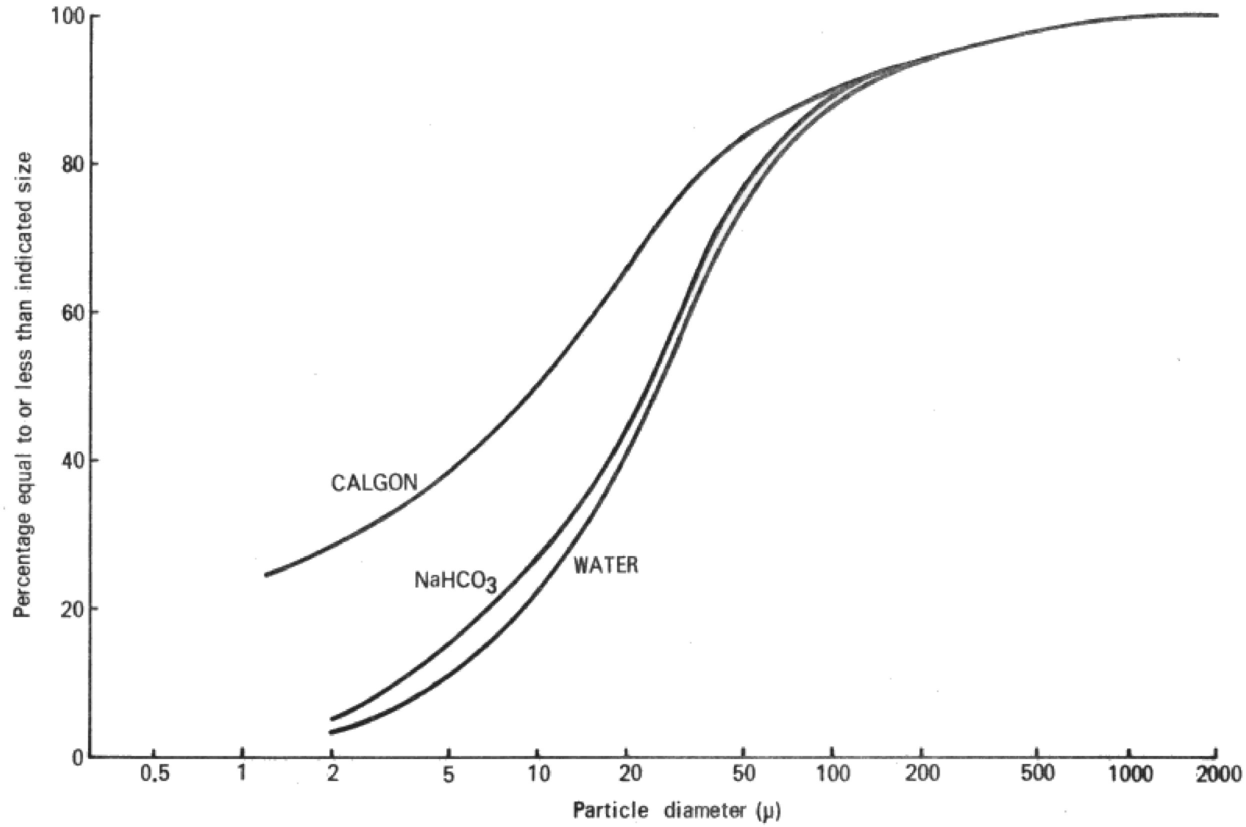
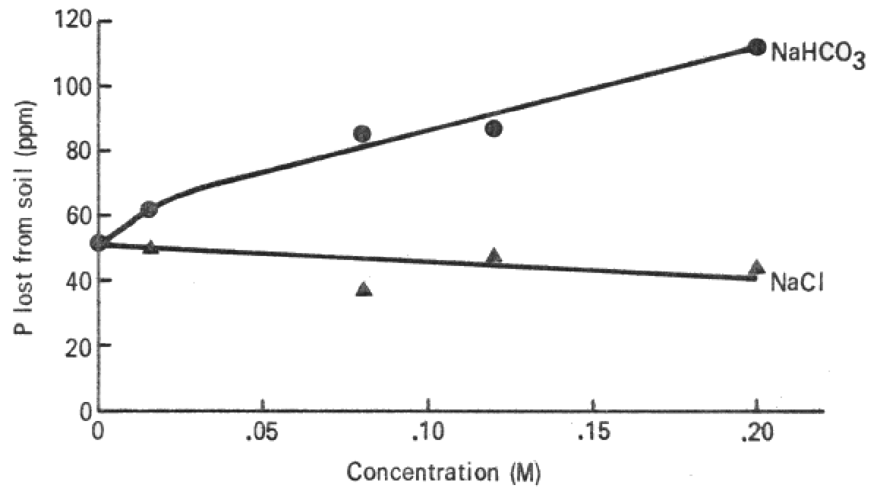


Figure 5: Effectiveness of Calgon, sodium bicarbonate and water on the dispersion of soil.



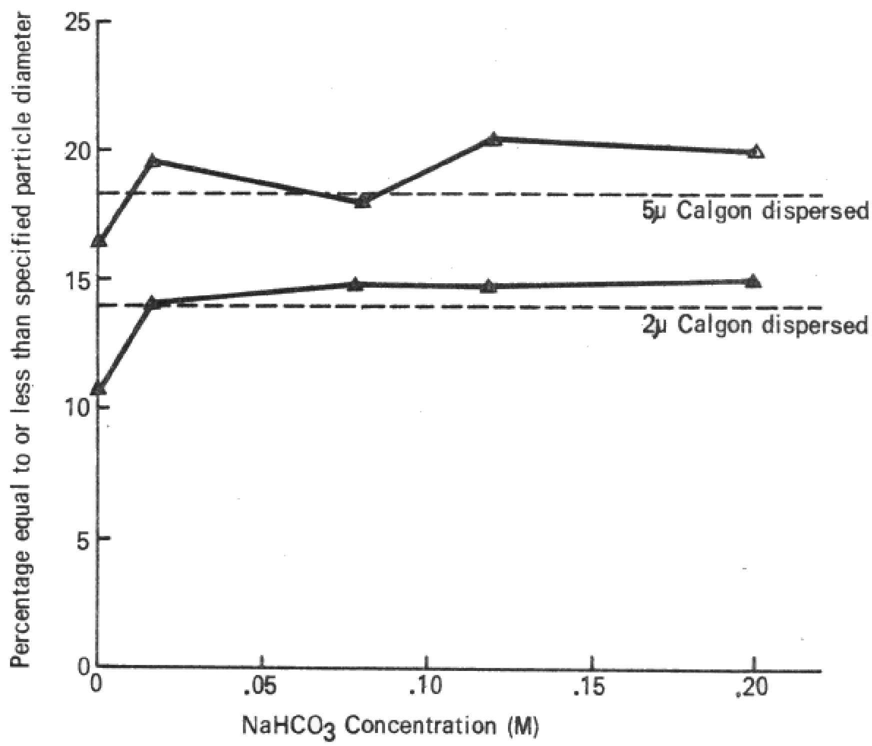


Figure 6a: Comparison between the amounts of P lost from soil using $NaHCO_3$ and NaCl as dispersing agents.

Figure 6b: Comparison between calgon dispersion of soil and ultrasonic disintegration using $NaHCO_3$.

Δ Ultrasonic disintegration + $NaHCO_3$, 5μ

▲ Ultrasonic disintegration + $NaHCO_3$, 2μ

Because of the necessity for reference back to Calgon dispersed soil samples, it was important that the recovery of the fine material (<5µ) represented approximately the same percentage as obtained by dispersion with Calgon. The method outlined below proved to be the most satisfactory (compare dispersion using Calgon and dispersion using ultrasonic vibration + 0.04 M $NaHCO_3$ in figure 6).

A 0.5 g sample of sediment in 160 ml of 0.04 M NaHCO3 was subjected to ultrasonic vibration (Labline Ultratip Labsonic System #9100, Probe depth 15 mm, Power 120) for 5 minutes. The suspension was cooled during operation by a water jacket to maintain a reasonably constant temperature. The suspension was then transferred quantitatively to a 250 ml graduated cylinder and made up to 250 ml with 0.04 M $NaHCO_3$. The cylinder was shaken thoroughly and allowed to stand such that particles of >5µ diameter had settled to a depth of at least 10 cm (exact sampling times given in table 2). A 50 ml sample was withdrawn by pipette and filtered through a pre-baked, pre-weighed Gelman 0.45µ millipore filter. This sample, containing the fine particles, plus the filter paper were oven dried (105ºC, 24 h) and weighed.

To separate the coarse particles the remaining solution was passed through a 50µ nylon mesh screen. These particles were collected on a Gelman 0.45µ filter paper, oven dried and weighed.

No attempt was made to collect the medium sized particles. Both the coarse and the fine particle fractions were analyzed for total P.

<u>Collection of Stream Samples.</u> Much of the sediment in runoff occurring within a field may never reach a water course. To elucidate the relationship between the sediment concentration in the field and that in the stream, a number of streams were sampled during 1976 and 1977.

Depth integrated 1 L samples were collected weekly and on an event oriented basis from seven sites either within or in close proximity to watershed Ag #4-Canagagigue Creek and Ag #5-Holiday Creek (for site locations see Figures 2 and 3). The samples were filtered using a Gelman 0.45µ millipore filter as soon as possible after collection. The sediments plus the filter papers were oven dried, weighed and analyzed for total P. Dissolved total P and dissolved reactive P were determined on the filtrates.

Additional stream samples were obtained from a stream in watershed Ag #13-Hillman Creek. This stream appeared to have an unusually high phosphorus load. The source was considered to be either a large mushroom operation or malfunctioning septic systems from a housing community further upstream. To clarify the situation, a number of stream samples were taken both upstream and downstream of the mushroom farm and were treated in a similar manner to the 1 L samples above.

Changes in both sediment and phosphorus status during transport to and transport in the stream were studied during spring runoff events in 1977. Streams were located such that a major input of sediment occurred at one point but with no other inputs downstream of that point. Runoff in the field together with stream samples were taken at various points along these selected lengths. Depth integrated 20-L stream samples were collected, using a peristaltic pump, from three watersheds - Ag #1, Ag #5, and Ag #13.

These samples were separated into coarse, medium and fine aggregates and particles and analyzed in a similar way to the field runoff samples discussed previously.

Collection of Soil Samples. Soils within watersheds Ag #4 and Ag #5 were sampled intensively at two depths, 0-15 cm and 15-30 cm, using a soil probe (Figures 7 and 8). The samples were dried in paper bags at 60ºC for approximately three weeks and passed through a 2 mm sieve. Duplicate soil samples were taken from all fields in which runoff had been collected previously (including sites outside of watersheds Ag #4 and Ag #5). All soils were analyzed for total P, $NaHCO_3$ extractable P, and pH. In addition organic matter content was determined for surface samples (0-15 cm). Particle size distribution was determined, using the Bouyoucos hydrometer method with Calgon as the iispersing agent (Bouyoucos, 1951), for those soils collected from runoff sites. Total phosphorus contents of individual size fractions were determined on selected, water dispersed samples.

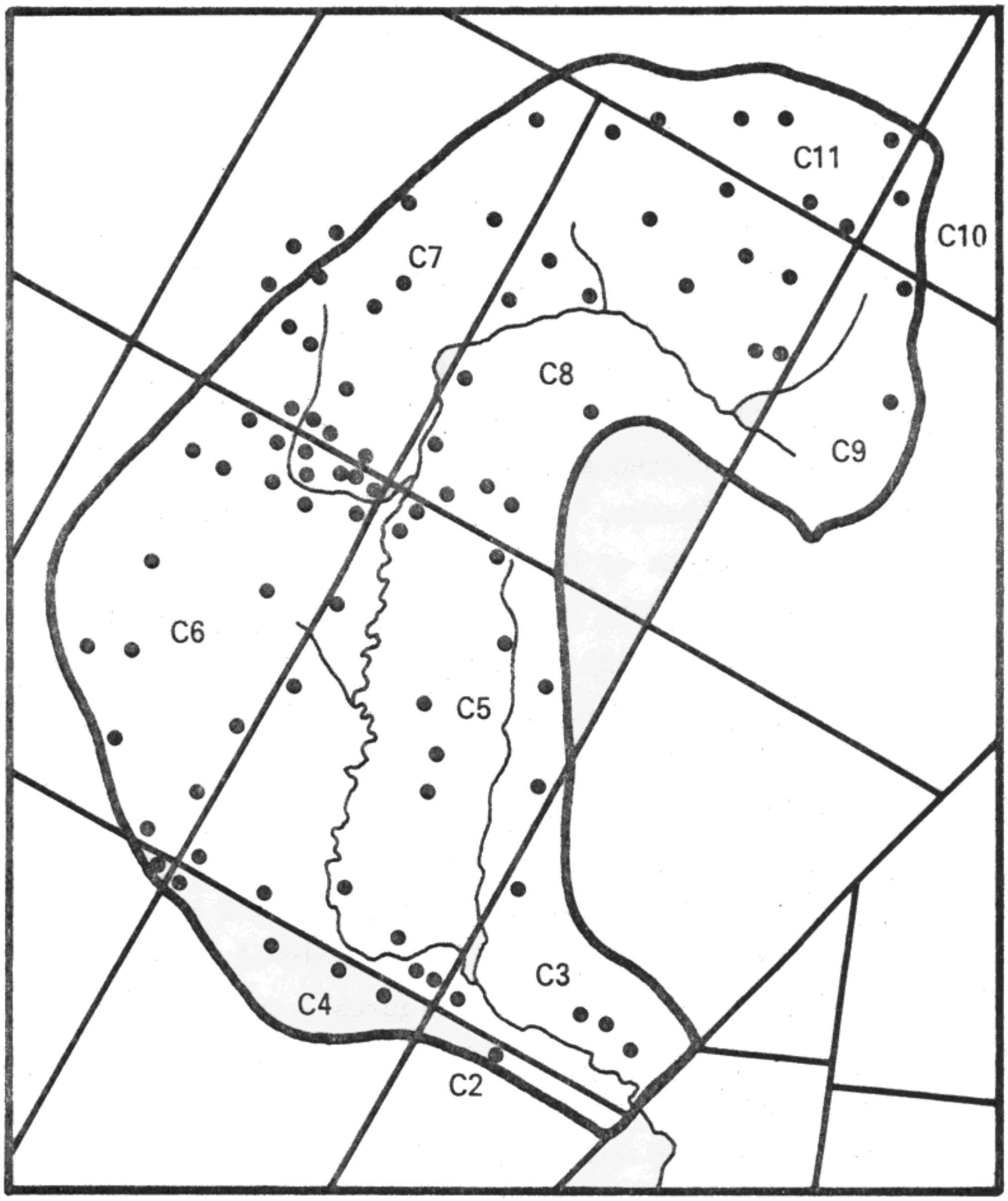


Figure 7: Location of soil sampling sites - Ag 4 Canagagigue Creek.

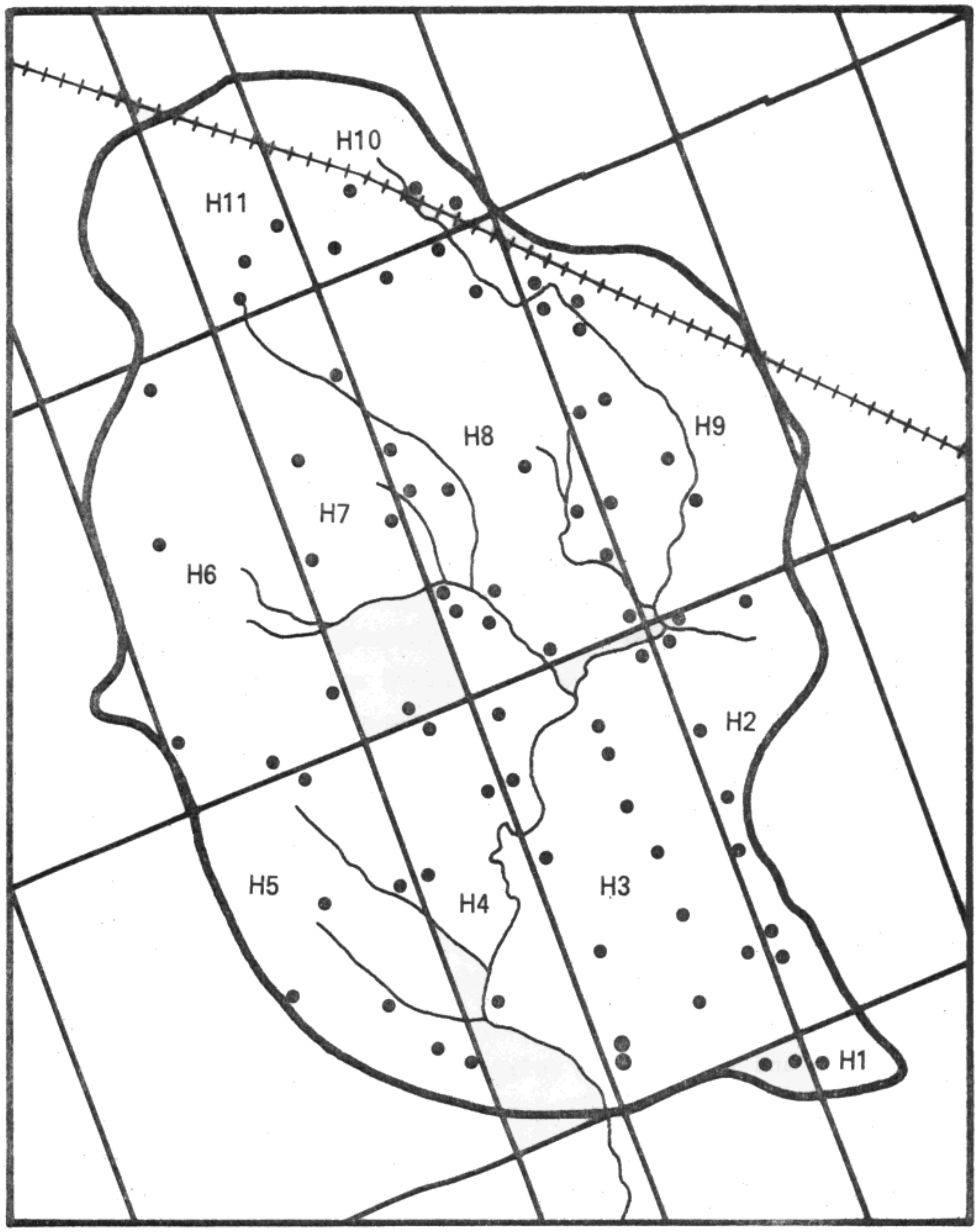


Figure 8: Location of soil sampling sites - Ag 5 Holiday Creek.

Management histories were obtained from the farmers which gave details of cropping and cultivation practices as well as manure and fertilizer applications over the previous three years.

Additional information on slope, drainage and textural class were obtained from soil survey maps (Acton et al, PLUARG Technical Report, Project 7).

3.3 Chemical Analyses

Total Phosphorus. The H_2SO_4-H_2O_2 digestion technique used was adapted from that used for plant material by Thomas, Sheard and Moyer (1967).

All material to be digested, with exception of that on 0.45µ filter papers, was pulverized using a mortar and pestel. Approximately 0.1 g was weighed out accurately and placed in 75-ml digestion tubes. Samples on filter papers were weighed and both filter paper and sample placed in digestion tubes. A 4-ml aliquot of concentrated H_2SO_4, 5 glass beads and 4 drops of 30% H_2O_2 (reagent grade) were added to each tube and the tubes allowed to stand overnight. The tubes were placed in a Technicon BD 40 automatic block digestor, heated for 45 min. at 110ºC and then approximately 1 hour at 225ºC until fuming commenced. The solutions were allowed to cool for 10 minutes, 4 drops of H_2O_2 added, swirled, and the tubes returned to that heat for 10 minutes. Additions of H_2O_2 were repeated until the solutions became clear. The samples cooled slightly, brought up to volume with deionized-distilled water, covered with plastic stoppers, inverted to mix and allowed to cool for at least 4 hours. After cooling the samples were brought up to volume again, mixed and allowed to settle for 24 hours. An aliquot was placed in a test tube, covered with parafilm and stored in a refrigerator for analysis (0-7 days).

The SnCl-ammonium molybdate method was used to determine the concentration of phosphorus in the solution on a Technicon Auto-Analyzer I system (Range 0-8.0 $\mu g\ ml^{-1}$).

Total Dissolved Phosphorus. A 5-ml aliquot of the sample to be analyzed was pipetted into a 18 mm x 150 mm test tube, 0.2 ml of perchloric acid added and the solution heated until white fumes appeared. The tubes were then capped with a glass marble and the heating continued until the $HClO_4$ reflux line was about 2.5 cm from the bottom of the tube. The tubes were removed, allowed to cool, and diluted with 5 ml of distilled-deionized water. After being mixed, the solutions were analyzed on the Auto-Analyzer (Range 0-0.250 $\mu g\ ml^{-1}$).

Dissolved Reactive Phosphorus, Extractable P, pH and Organic Matter Content. Dissolved reactive P content was measured directly on the auto-analyzer (Range 0-0.250 $\mu g\ ml^{-1}$).

Extractable P content and pH of soils were analyzed by the Ontario Soil Test Laboratory, Guelph. The extracting solution used was 0.5 M $NaHCO_3$. The pH was determined in a water paste.

Organic matter contents of soils and sediments were obtained by the Walkley-Black method (Allison, 1965).

4.0 EXPERIMENTAL RESULTS

4.1 Development of Relationship for Prediction of Loss of Sediment—Associated Phosphorus from Cropland

The relationship developed for prediction of sediment-associated P lost from cropland on mineral soils by surface runoff is as follows:

Monthly Total P (Kg ha^{-1}) from cropland	=	Monthly Sediment Load from cropland	x	Soil P Content	x	P Enrichment Ratio

where P Enrichment Ratio = $\dfrac{\text{Total P Concentration in sediment}}{\text{Total P Concentration in soil}}$

Prediction of the Sediment Load. The potential sheet and rill erosion was calculated from a knowledge of the crop grown and rainfall data (Van Vliet and Wall, PLUARG Technical Report, Project 16). Much of the sediment from this source would never reach the stream and would therefore not be included in the sediment load leaving the watershed. This has been accounted for by use of a delivery ratio factor applied to the potential erosion:

Sediment Load	=	Potential Sheet and Rill Erosion	x	Delivery Ratio	+	Streambank Erosion

However, delivery ratio estimates based on drainage basin size were considerably greater than actual measured delivery ratios[1] for each of the watersheds (vanVliet and Wall, PLUARG Technical Report, Project 16).

Because reliable independent estimates of the delivery ratio were not available, accurate prediction of the sediment load was not possible. To calculate phosphorus loadings, therefore, measured sediment loadings were used. It should be noted that predictions of P losses from cropland were based on measured values of sediment load and were not independent estimates.

Prediction of the Soil P Content. Results of analysis of soils used in this study are presented in Appendix - Tables A1, A2, and A3.

Stepwise multiple regression analyses were conducted to relate the measured total P to the chemical and physical properties of the soils. The total P values for 248 soils were compared to the following independent variables:

1. Extractable P
2. pH
3. Estimated Clay Content (%)
4. Drainage
5. Organic matter content (%)
6. $(\text{Extractable P})^2$
7. $(\text{Drainage})^2$
8. $(\text{Organic matter})^2$
9. Extractable P x pH
10. Organic matter x clay content
11. Organic matter x drainage
12. % Sand |
13. % Silt |➜ as indicators of texture
14. % Clay |
15. Organic matter x sand
16. Organic matter x silt

The analysis showed that organic matter and extractable P were the factors most related to total P. The R squared values obtained, although statistically significant, were low ($r^2 = 0.32$). The range of total P in the soils tested was not great even though the regression included soils collected throughout Ontario (Mean total P = 732.8 ppm, S.D. ± 150.4).

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[1]

$$\text{Actual Delivery Ratio} = \frac{\text{Measured Total Sediment Load} - \text{Sediment load due to Streambank Erosion}}{\text{Estimated potential sheet and rill erosion}}$$

It would be possible, using the regression analysis, to predict levels of total P for different areas in Ontario, the soil parameters necessary for such predictions being organic matter content, and extractable P. Alternatively these parameters were not readily obtainable, the mean total P value could be used in the predictive model of P losses due to surface runoff. Because of the narrow range of total P, using t, mean value would not cause major errors in prediction.

The equation for the prediction of total P in the soil as follows:

$$P = 177.7 + 92.4(OM) + 12.9(AP) - 0.15(AP^2) - 2.93(OM^2) \qquad R^2 = 0.32$$

where P = Total P content of soil, $\mu g\ g^{-1}$
OM = organic matter content,
AP = $NaHCO_3$ extractable P (Ontario Soil Test), $\mu g\ g^{-1}$

Prediction of the P enrichment ratio. The P enrichment ratio is the relationship between the P content of the eroded material and that of the surface soil.

Soil P enrichment ratios calculated from the runoff samples from watersheds Ag #4 and Ag #5 ranged from below 1.0 to 6.0. The highest values were thought to be associated with either ponding or low sediment load in the runoff sample.

Detailed Analyses of the sediment are given in the Appendix - Tables A4 and A5. Clay (<5µ) enrichment ratio values obtained from ultrasonic dispersion of the sediments and calgon dispersed mechanical analyses of the corresponding soils were closely related to the P enrichment ratios (Figure 9). This suggested that P enrichment was due to the greater erosion of finer particles with a higher P content. Various size fractions of four different soils from runoff sites in each watershed were analysed for total P. From these values P enrichment ratios were calculated assuming that only particles less than the specified size were included. The enrichment ratios increased as the proportion of finer particles in suspension increased (Figure 10). The finer particles in soils from Ag #5 appeared to have greater enrichment of phosphorus than those in Ag #4.

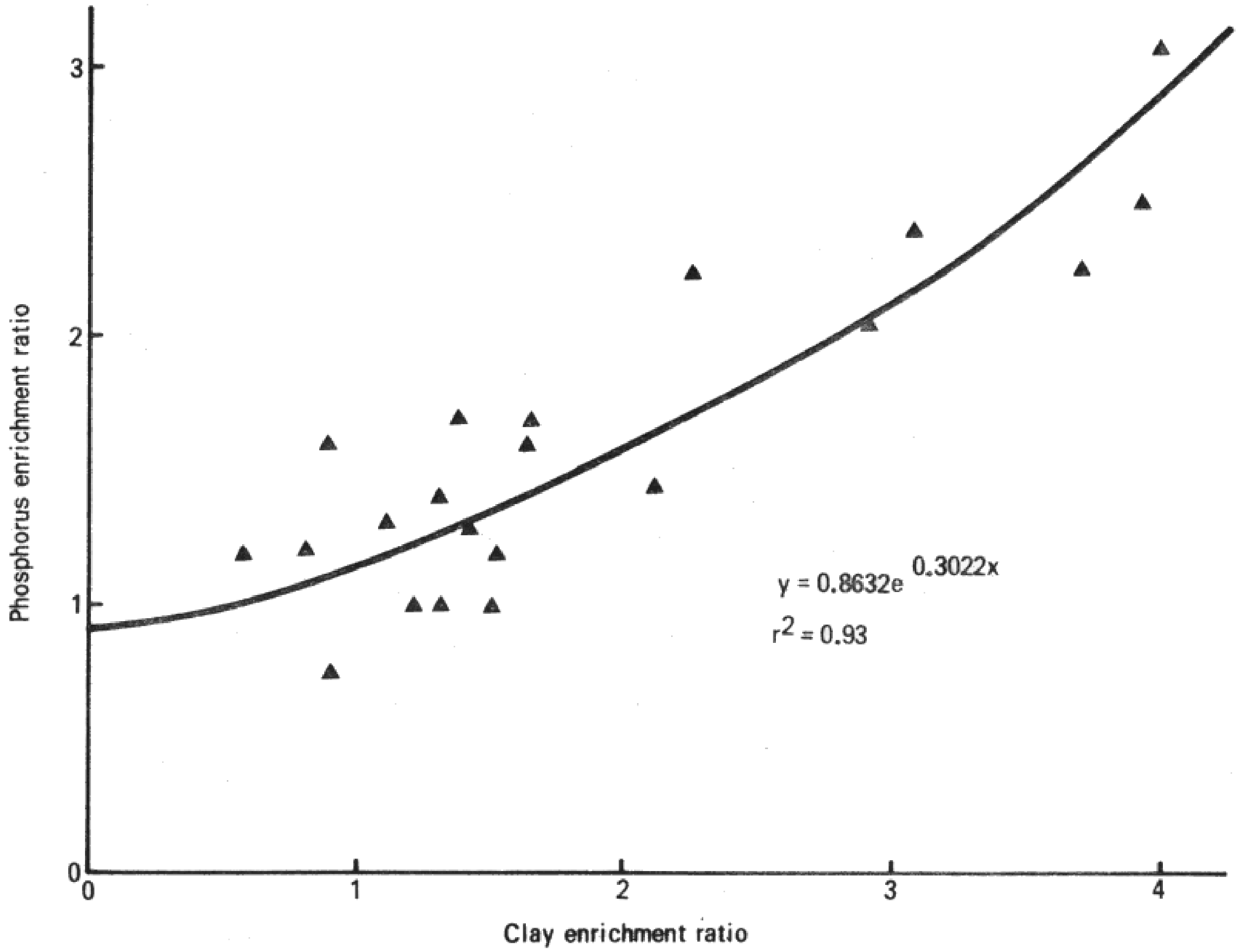

Figure 9: Phosphorus Enrichment Ratio vs. Clay Enrichment Ratio for Runoff Samples from Ag 4 and Ag 5.

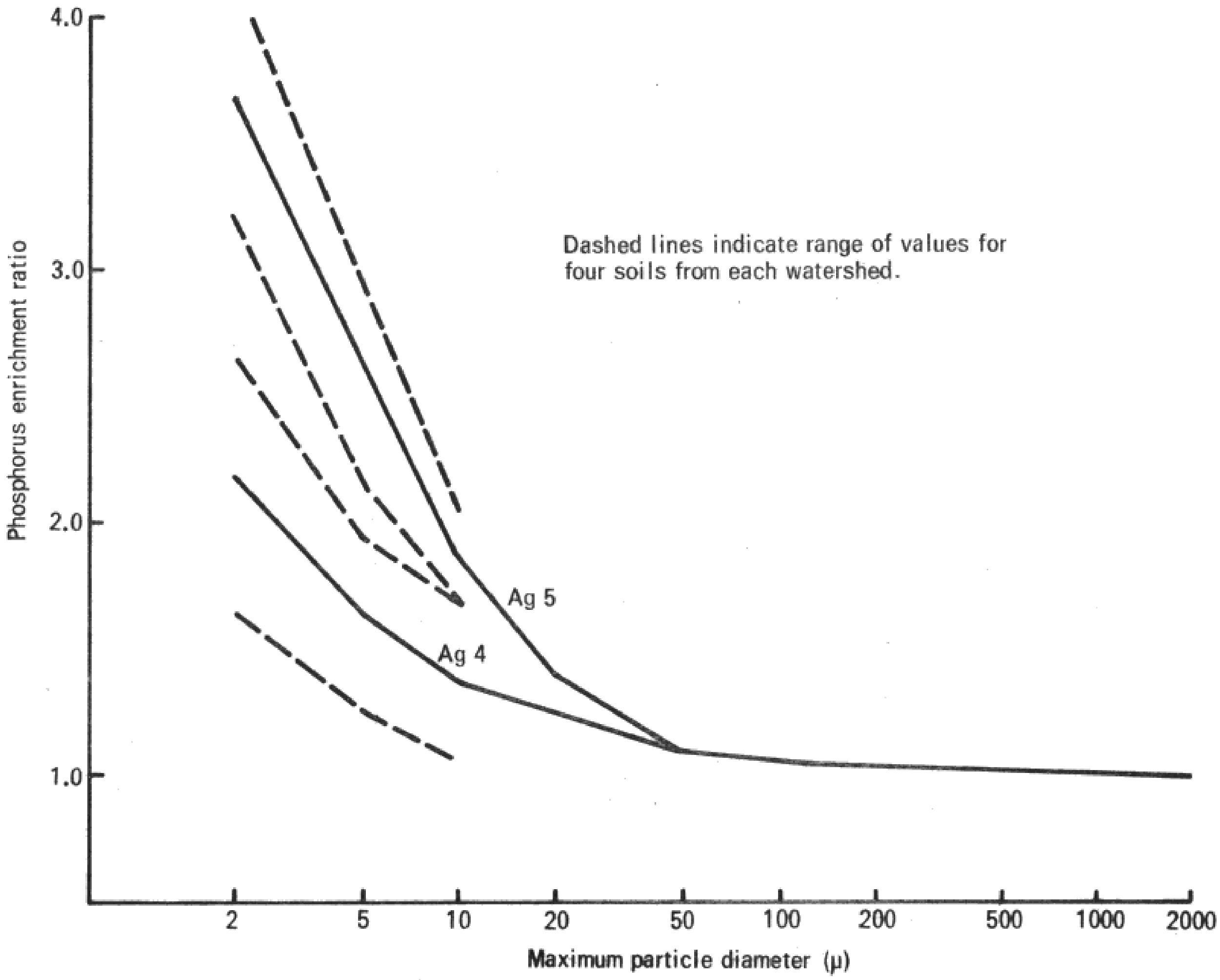

Figure 10: Particle diameter and Phosphorus Enrichment Ratio for soils from Ag 4 and Ag 5.

This was possibly due to the lower number of available sites for anion adsorption caused by the lower clay content of soils in Ag #5 and thus increased concentrations of phosphorus in these finer particles. It might also have been related to the higher applications of fertilizer P in Ag #5. Although total P applications were similar for Ag #4 and 5, a higher proportion was added in the form of manure in Ag #4.

The P Enrichment Ratio in the field runoff samples was related to sediment concentration, clay content and sand content. Samples which were ponded on the fields (ie. those not flowing across the fields) had higher than expected enrichment ratios due to the greater fine particle enrichment caused by the settling out of the coarser fractions. Thus these samples were removed from the regression analyses. Using the remaining samples (n = 39) the following relationships were developed:

A. $$PER = 5.394 - 0.0158(SD \times CL_5) + 0.000606(CL_5^2) + 0.000342\,(S_{50}^2) + 0.439(SD^2) - 2.496(SD)$$

$R^2 = 0.69$

B. $$PER = 5.547 - 0.0202(SD \times CL_2) + 0.00128(CL_2^2) + 0.0004\,(S_{50}^2) + 0.455(SD^2) - 2.674(SD)$$

$R^2 = 0.69$

C. $$PER = 4.112 - 0.0174(SD \times CL_2) + 0.00193(CL_2^2) + 0.00041\,(S_{20}^2) + 0.389(SD^2) - 2.343(SD)$$

$R^2 =-0.72$

where PER = Phosphorus Enrichment Ratio

SD = Sediment Concentration (log), mg L^{-1}

S_{50} = Sand content of surface soil, % (particles >50μ)

S_{20} = Sand content of surface soil, % (particles >20μ)

CL_5 = Clay content of surface soil, % (particles <5μ)

CL_2 = Clay content of surface soil, % (particles <2μ)

These predictive equations are valid within the following limits:

Particles >50µ diam.: 15-35%
Particles >20µ diam.: 25-60%
Particles <5µ diam.: 15-50%
Particles <2µ diam.: 5-35%

Three equations were developed to account for the different classification of soil particle sizes in use at present. Equation A, (sand >50µ and 'clay' <5µ), conformed to the particle size distribution adopted for the purposes of this study, whilst equations B and C conformed to the North American and the International systems respectively.

These equations approximate each other closely indicating that the limits used for separation are not critical. Increases in either % sand or % clay in the surface soil tend to produce higher estimates of the enrichment ratio (Figure 11, I v II, I v III). The higher clay content would produce higher enrichments due to the selectivity of the erosion process. The increase in enrichment caused by a higher sand content, would possibly be an indirect effect, the increase in sand content being associated with a corresponding decrease in clay but with the clay containing much higher concentrations of phosphorus.

The relationships developed for watersheds Ag #4 and Ag #5 are presented in Figure 12.

4.2 Dissolved Nutrients in Runoff

Dissolved Reactive P. In the initial phases of this project, phosphorus associated with sediment was considered to be the main source of phosphorus in runoff. During the course of the study it became increasingly apparent that losses of phosphorus in the soluble form were also of importance particularly when the sediment concentration in the runoff was less than 1000 mg L^{-1}. As much as 90% of the total P in runoff was in solution at sediment concentrations below 100 mg L^{-1} (Figure 13).

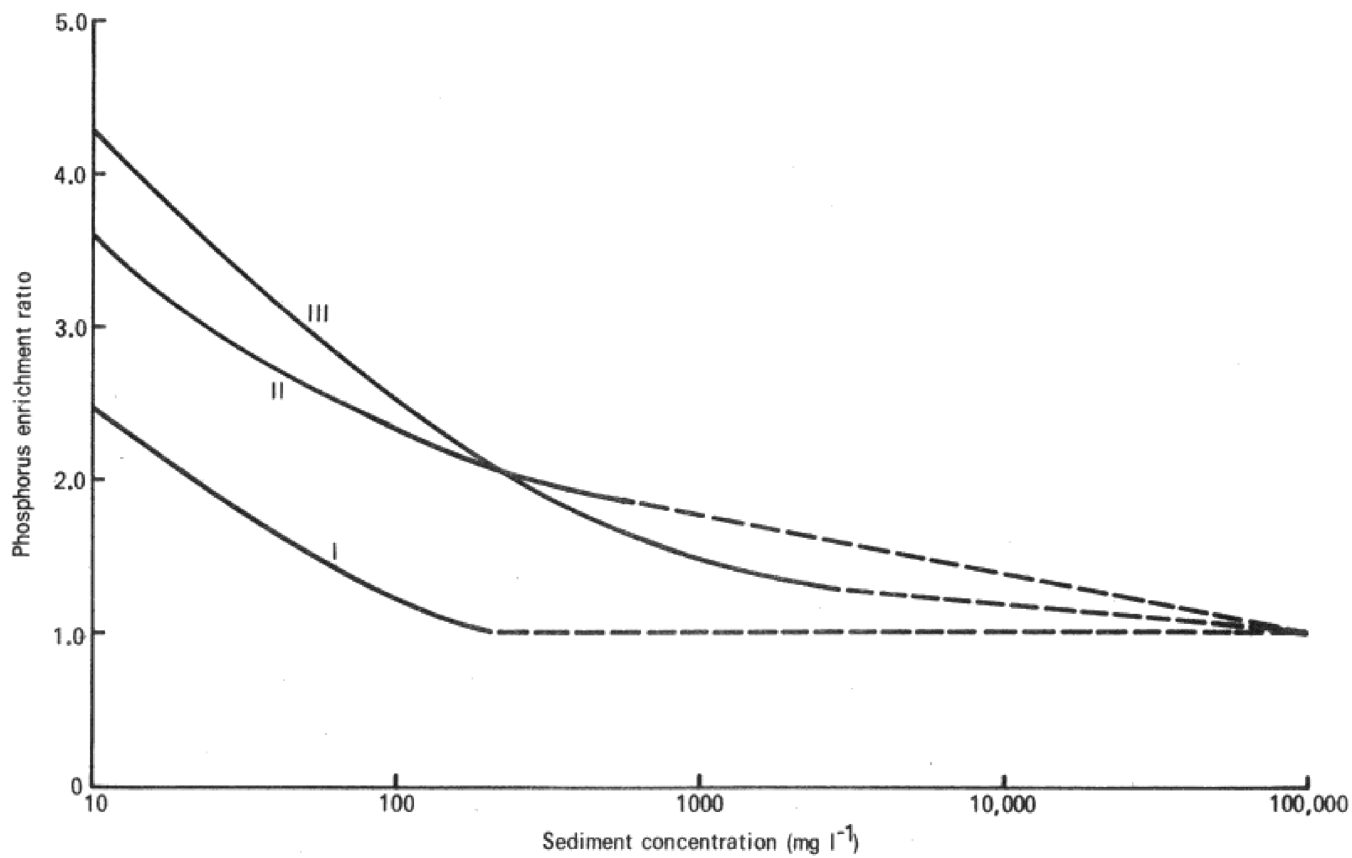

Figure 11: The effect of soil texture on the relationship between phosphorus enrichment ratio and sediment concentration.

Curve I: Sand 30%, Clay 5% Curve II: Sand 60%, Clay 5% Curve III: Sand 30%, Clay 35%

$$PER = 4.112 - 0.0174(SD \times CL_2) + 0.00193(CL_2^2) + 0.00041(S_{20}^2) + 0.389(SD^2) - 2.343(SD) \qquad R^2 = 0.72$$

PER = Phosphorus Enrichment Ratio

SD = Sediment Concentration (log), mg L^{-1}

CL_2 = Clay content of surface soil (<2µ), %

S_{20} = Sand content of surface soil (>20µ), %

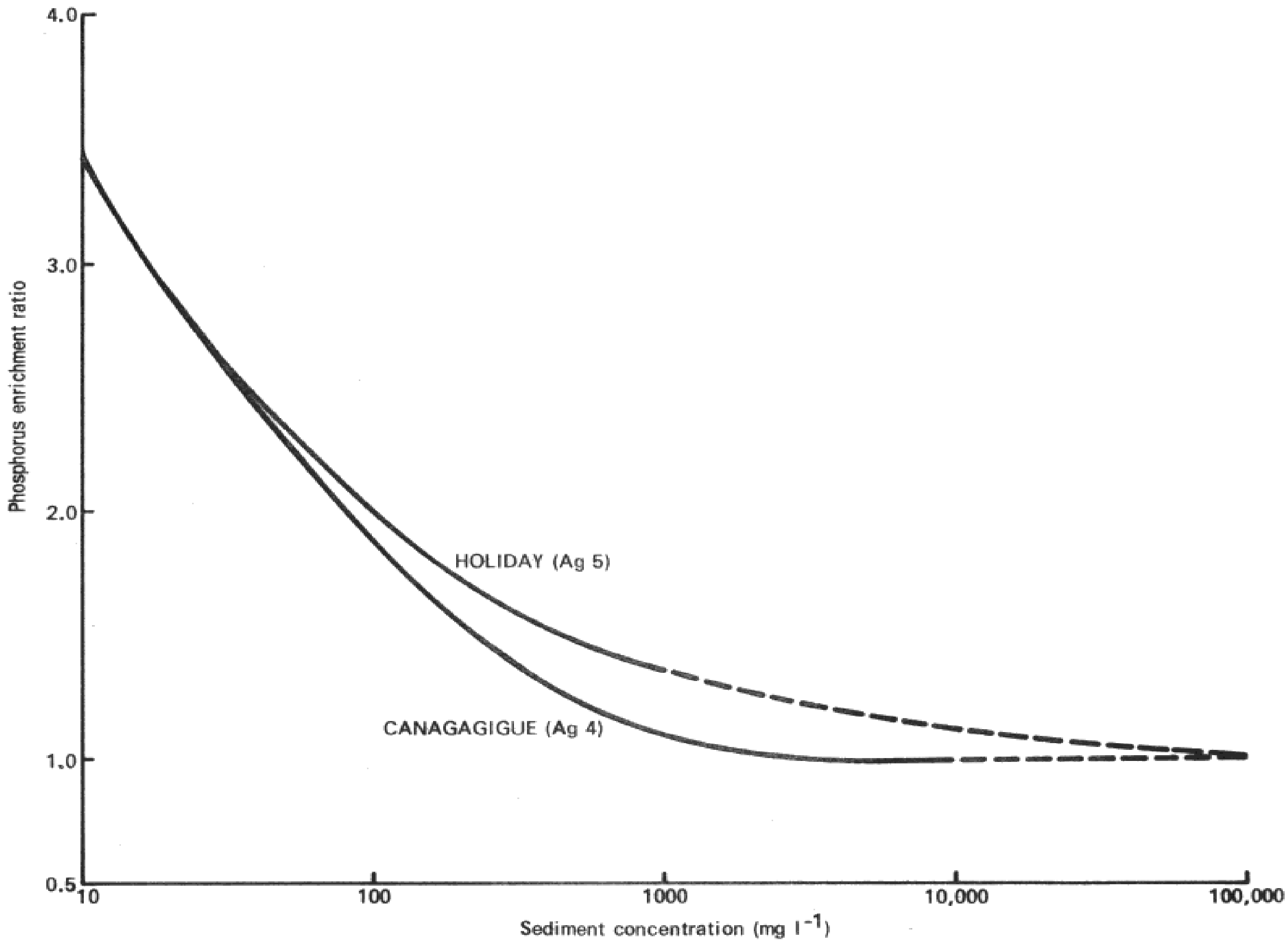

Figure 12: Phosphorus Enrichment Ratio vs. Sediment Concentration for Runoff Samples from Ag 4 and 5.

$$PER = 4.112 - 0.0174\,(SD \times CL_2) + 0.00193(CL_2^2) + 0.00041\,(S_{20}^2) + 0.389\,(SD^2) - 2.343\,(SD) \qquad R^2 = 0.72$$

PER = Phosphorus Enrichment Ratio

SD = Sediment Concentration (log), mg L^{-1}

CL_2 = Clay content of surface soil (<2µ), %

S_{20} = Sand content of surface soil (>20µ), %

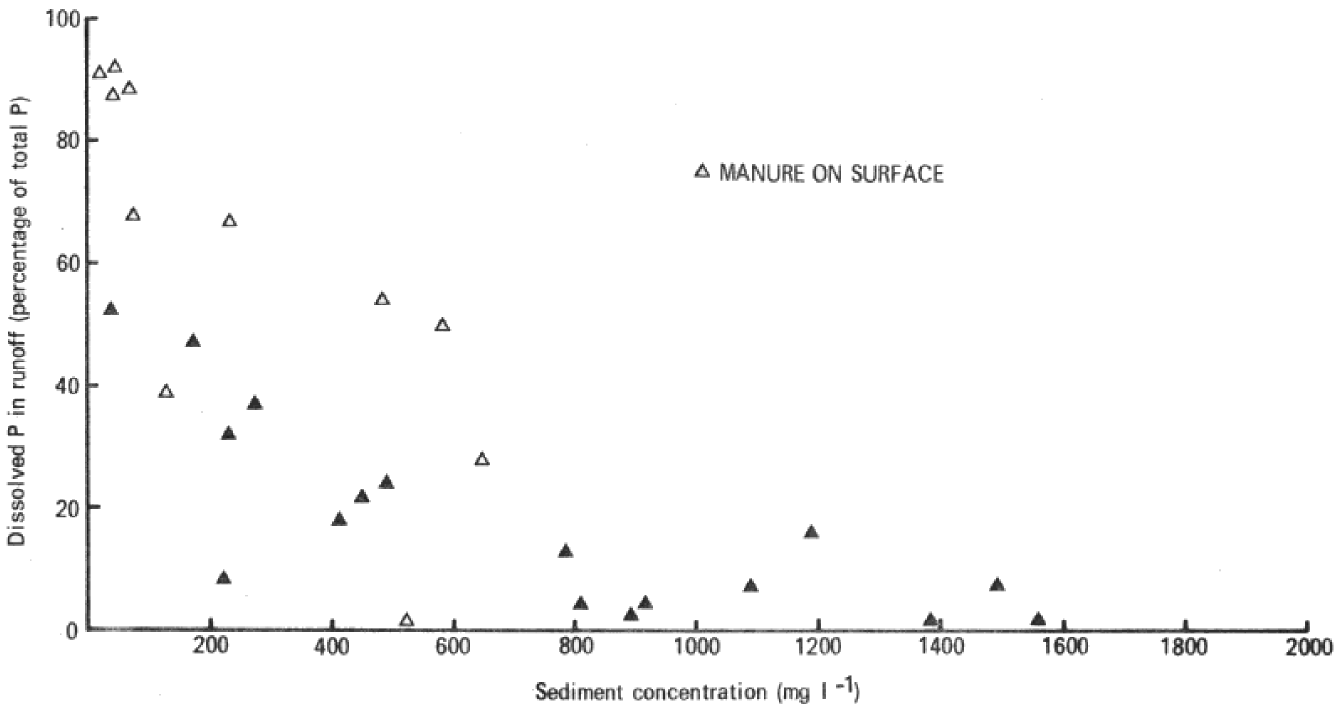

Figure 13: Dissolved reactive-P in runoff as proportion of total P at sediment loads less than 2000 mg per litre of runoff.

Using data obtained from the experimental plots in Guelph the concentrations of dissolved reactive P in the runoff were related by stepwise multiple regression to the following runoff and sediment characteristics: total amount of runoff, sediment concentration of runoff, and sediment total P, $NaHCO_3$ extractable P, equilibrium P concentration[1], pH, clay content and organic matter content.

For treatments in which manure was present on the surface, the dissolved reactive P was not significantly correlated with any of the runoff or sediment characteristics. It was felt that the amount of residual manure present at the surface and its rate of mineralization at the time of the runoff event largely determined the amount of dissolved reactive P in surface runoff and it was concluded that prediction of dissolved reactive P when manure was present on the soil surface was not feasible from sediment or runoff characteristics.

Data from both no tillage plots and plots in which manure was added but ploughed under were combined and predictive equations developed. The dissolved reactive P was significantly correlated with both the equilibrium P concentration and the extractable P content of the sediment (Figures 14 and 15).

Since sediment samples would be available only after the occurrence of the runoff event, it would not be possible to use sediment equilibrium P concentration or sediment extractable P directly to predict the dissolved reactive P content of the runoff. However, attempts to relate the sediment characteristics with soil properties met with limited success.

Although the extractable P enrichment ratio[2] was related to both organic matter enrichment and clay enrichment as well as being influenced by management practices, it could not be predicted from soil parameters. (Bhatnagar, 1977).

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1 The equilibrium P concentration was determined on a 0.5 g sample by equilibrating for 24 h in 25-ml aliquots of 0.1 N NaCl containing 0, 0.25, 0.50, 2.0, 4.0, 6.0, 8.0, 10.0 and 12.0 µg P/ml as KH_2PO_4. The equilibrium P concentration is that concentration at which no net adsorption or desorption of P occurs.

2 Ratio of $NaHCO_3$-extractable P content of eroded material to that of the surface soil.

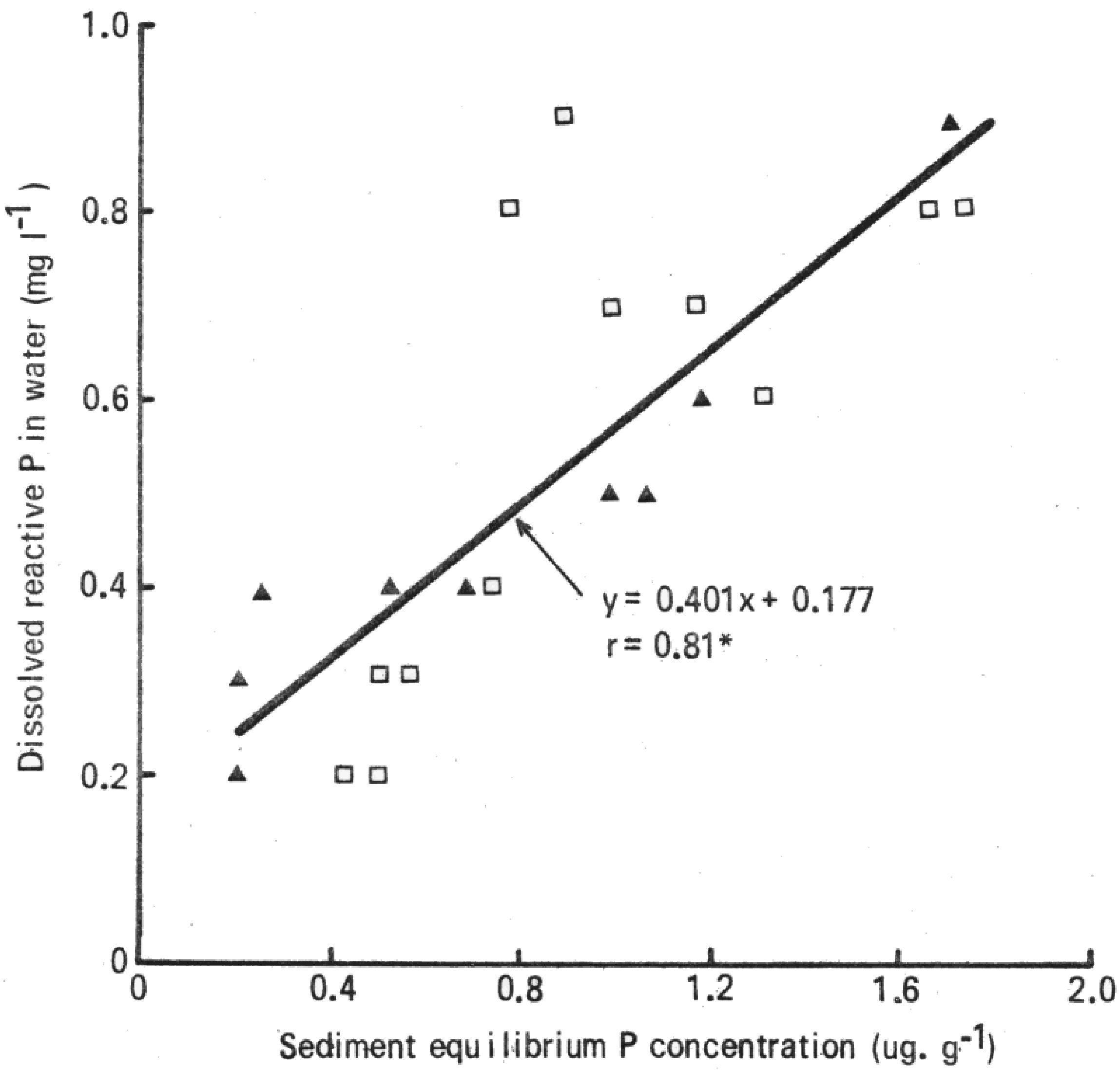

Figure 14: Relationship between Dissolved Reactive P content in runoff water and Sediment equilibrium P concentration at the Runoff Plots in Guelph (from Bhatnagar, 1977).

▲ No tillage

❑ Manured and Ploughed

* Significant at 5% level

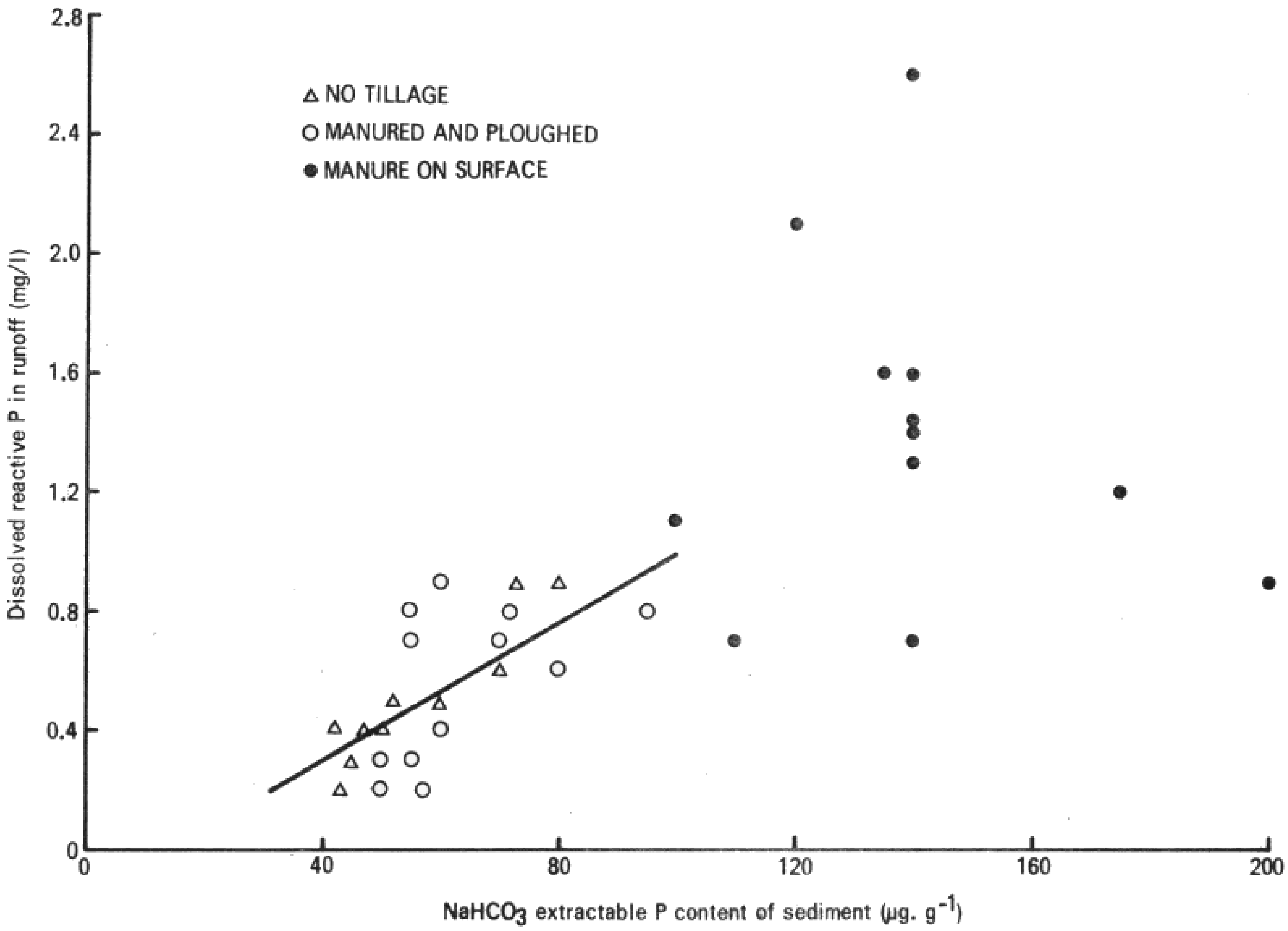

Figure 15: Relationship between extractable P of the sediment and dissolved P in the runoff at the experimental plots in Guelph (from Bhatnagar, 1977).

Similarly, there was no relationship between dissolved reactive P in the runoff from the watersheds (Ag #4 and Ag #5) and the extractable P in the surface soil (Figure 16). The effect of surface manure on dissolved reactive P is again apparent in Figure 16.

At the present time the dissolved reactive P content cannot be predicted although losses of P in this form are likely to be considerably greater from fields in which manure has been applied to the surface but not ploughed under. 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 0.01 - 0.21 and a mean of 0.08 mg/L for runoff from fields with no surface manure.

Total Dissolved P. Difficulties were encountered in obtaining reproducible results for total dissolved P in the runoff samples. The results are not reported for this reason. In those samples for which reliable results were obtained, the dissolved reactive P accounted for a very high proportion of the total dissolved P.

Dissolved NH_4^+ and NO_3 Dissolved NH_4^+ and NO_3 concentrations in the runoff samples from watersheds Ag #4 and Ag #5 were also measured and are reported in the Appendix - Table A6. There appears to be some relationship between high levels of dissolved NH_4-N and manure applied on the surface.

4.3 Phosphorus Delivery Ratio

The relationship for P loss will predict the amounts of P in the runoff water during transportation from fields. However, not all of this P will reach the stream. Sediment load predictions rely on the inclusion of a delivery ratio to account for losses during transport. If we assume that the coarser particles will travel the least distance, then a delivery ratio for phosphorus will be greater than the corresponding delivery ratio for sediment, the largest differences corresponding to the lowest sediment delivery ratios.

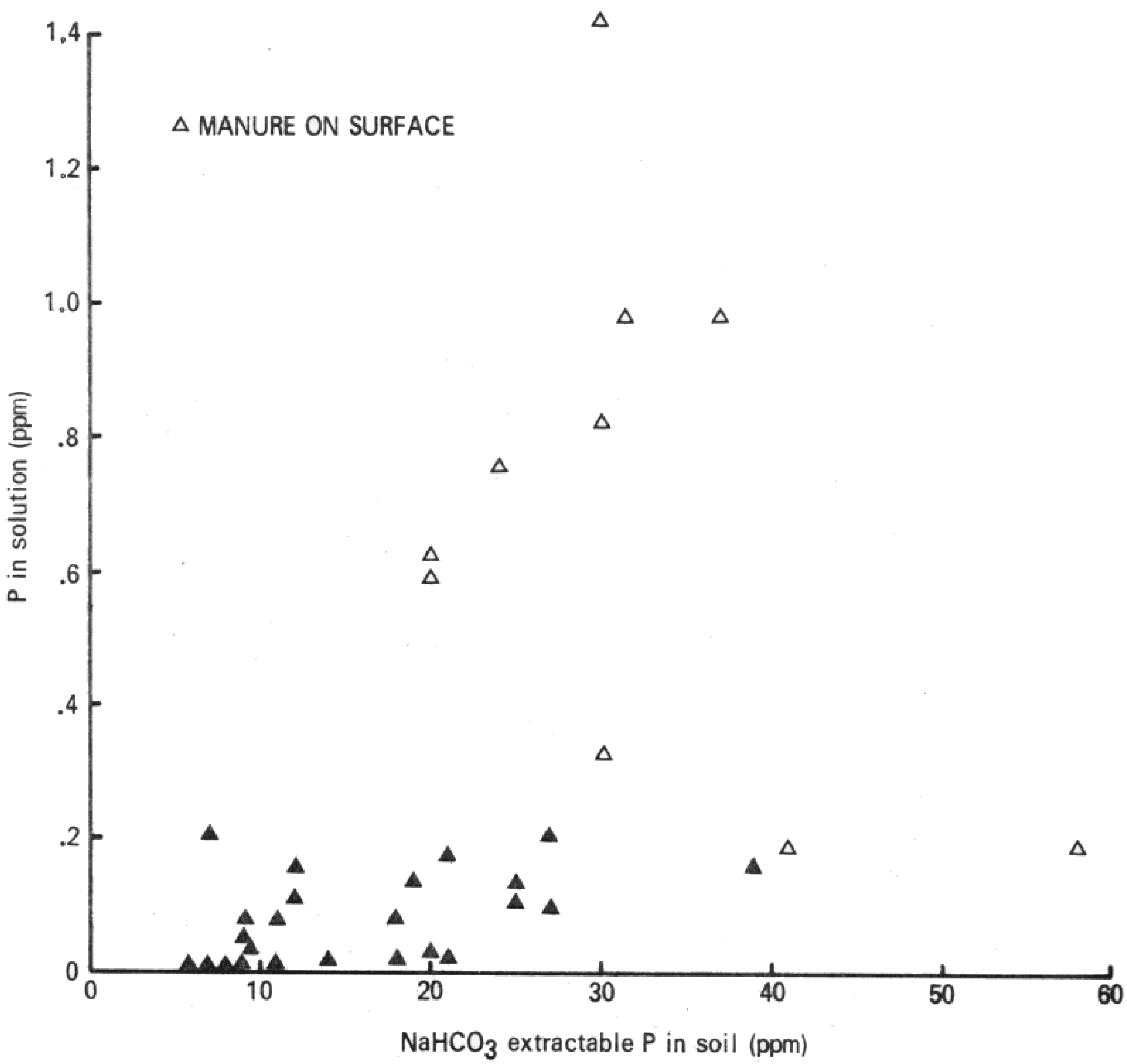

Figure 16: Relationship between $NaHCO_3$ extractable P of the soil and dissolved P in the runoff from field sites in Watersheds Ag 4 and Ag 5.

Attempts were made to clarify this situation, samples being taken from both fields and streams in three watersheds (1, 5 and 13), during the spring melt in 1977. Detailed results are reported in the Appendix (Table A7, A8, A9).

Samples collected from field runoff sites were also included in the regression analysis for the prediction of the phosphorus enrichment ratio. (page 30)

In watershed Ag #13 the concentration of sediment in field runoff was greater than in runoff entering the stream (table 3, Sites 13-1 and 13-2). Much of this difference was due to ponding of the water prior to entry to stream. The proportion of coarse material in the runoff sediment was reduced considerably (Table 3). However, although ponding reduced the amount of sediment entering the stream, the sediment delivery ratio from the field to the stream being 0.67, the reduction in sediment-associated P reaching the stream was much lower, the P delivery ratio being 0.87.

The sediment concentration, the dissolved reactive P levels and the total P lost did not appear to change appreciably during transportation in the stream (Table 3, Sites 13-3, 13-4 and 13-5).

The delivery ratios in the stream (between sites 13-4 and 13-5) were very similar, 0.83 and 0.79 for sediment and phosphorus respectively. This suggests that only minor changes occur during transportation in the stream. It also suggests that equilibrium between solution and sediment P is established when the runoff reaches the stream. Changes would occur only if sediment and/or P from another source entered the system. These conclusions must be considered as preliminary.

In watershed Ag #1 the sites sampled were less suitable. The field sample (table 3, Site 1-1) was collected as the runoff was flowing into a drainage ditch after having been ponded on the field. Again, the low content of coarser material should be noted.

Definite conclusions could not be drawn from the data obtained from watershed Ag #5.

Table 3: Runoff and Stream Samples collected during spring 1977.

	Amount of sediment collected (mg L^{-1})				Amount of P lost on sediment per litre of runoff (µg P)			
Site	>50µ	5-50µ	<5µ	Total	>50µ	5-50µ	<5µ	Total
Ag 13-1 Runoff within field	243	447	470	1160	58.8	604.8	987.9	1651.5
13-2 Field runoff entering stream	10	380	394	784	2.6	570.8	853.8	1427.2
13-3 Stream sample above point of runoff entry	68	539	322	929	22.4	668.4	929.0	1619.8
13-4 Stream sample 50 m below point of runoff entry	59	472	282	813	25.6	788.2	898.2	1712.0
13-5 Stream sample 400 m below point of runoff entry	61	341	272	674	17.8	538.4	791.2	1347.4
Ag 1-1 Runoff entering stream	296	473	932	1701	143.3	331.1	834.1	1308.5
Ag 1-2 Stream sample at mouth of watershed	7	146	592	745	2.6	126.4	580.4	709.2

4.4 Routine monitoring of Phosphorus in Streams

During 1976, sediment and dissolved reactive P levels in the streams of watersheds Ag #4 and Ag #5 were monitored (Appendix - Table A10). The sampling sites are shown in Figures 2 and 3. Dissolved reactive P appeared to account for a sizeable proportion of the total P transported. Site W2, however, had a much lower proportion of soluble P. The high soluble P levels on the east branch of the Canagagigue Creek (site E1) were thought to be due to a Trout farm located upstream of the sampling site.

Unusually high levels of phosphorus were found in one tributary of Hillman Creek Ag #13 (Gaynor, PLUARG Technical Report, Project 10). The source was believed to be either a mushroom farm where large amounts of manure were found along the edge of the stream or malfunctioning septic tanks from a rural residential area further upstream. To clarify the situation stream samples were collected from both upstream and downstream of the mushroom farm. The farm appeared to have no obvious influence on stream quality during the times at which sampling occurred (Appendix - Table A11). The levels of dissolved reactive phosphorus in the water at both sites were extremely high and were thought to be caused by malfunctioning septic systems. Dissolved reactive P losses ranged from 0.095 to 0.780 mg L^{-1} with a mean value of 0.324 mg L^{-1} and with one exception, constituted a greater loss of total P than P carried by sediment. Total P lost (sediment P + dissolved reactive P) ranged from 0.128 to 1.001 mg L^{-1} with a mean loss of 0.480 mg L^{-1}.

5.0 APPLICATION OF RELATIONSHIP TO OTHER WATERSHEDS

5.1 Estimations of the Sediment-Associated Phosphorus Load Leaving Agricultural Watersheds.

The total sediment-associated phosphorus from the agriculture watersheds was considered to be from three sources, namely: runoff from cropland, streambank erosion, and runoff from unimproved land.

The amount contributed by runoff from cropland was estimated using the model described in the preceeding section.

A. Total sediment-associated P load from cropland (Kg) = Total Sediment Load from cropland (T) x Total P content of the soil ($mg\ g^{-1}$) x Phosphorus Enrichment Ratio

B. Total sediment Load from cropland = Potential Soil Loss by sheet and rill erosion x Delivery Ratio

C. Total P content of the soil = 'Mean' value for Ontario soils x $0.733\ mg\ g^{-1}$

D. Phosphorus Enrichment Ratio = $\oint$(Sediment Concentration, % Sand, % Clay)

E. Sediment concentration = $\frac{\text{Total Sediment Load (B)}}{\text{Overland flow}}$

Both the delivery ratio and the amount of overland flow were estimated using measured values of sediment load and streamflow:

Delivery Ratio = $\frac{\text{(Total Sediment load - Streambank Sediment load)}}{\text{Potential Sheet and Rill Erosion}}$

(Dickinson, PLUARG Technical Report, Project 17)

(van Vliet and Wall, PLUARG Technical Report, Project 16)

Overland flow = $\oint$ (Streamflow, soil characteristics)

(Whiteley, PLUARG Technical Report, Project 15)

These values are thus based entirely on a one year data base which makes extrapolation beyond 1976 very hazardous. The reliance on measured values also means that the predicted values are not independent so the measured values can not be used as a valid test of the model.

P losses from streambank erosion were estimated in a similar way to field erosion:

P loss from streambank erosion (Kg) = Sediment loss due to streambank erosion (T) x Total P content of the streambank ($mg\ g^{-1}$) x Phosphorus Enrichment Ratio

Only particles less than 50µ diameter, ie. the silt and clay fractions, were assumed to leave the watershed. The phosphorus enrichment ratio was therefore estimated at 1.1 (see Figure 10). The actual figure would be expected to be slightly higher than this for a sandy watershed such as Ag #13 due to the higher phosphorus concentration associated with the finer soil fractions of such a watershed. Since a relatively small proportion of P was lost from streambanks in the sandy watersheds, this difference in phosphorus enrichment was ignored for predictive purposes.

Streambank materials from six of the watersheds were analyzed for total P (Knap, PLUARG Task C, Activity 6, Streambank Erosion Study). For these watersheds, straight arithmetic mean values were used to represent the total P content of streambank material. Where no values for actual P contents were available the arithmetic mean of all samples analyzed was used.

Sediment loss due to streambank erosion was calculated on a monthly basis by assuming that erosion was directly proportional to average monthly streamflow. Although this assumption has not been tested no other method for predicting monthly erosion rates was available.

Sediment associated P losses can be predicted using this model for both streambank and field erosion. Cropland will contribute a greater amount of this sediment associated P than unimproved land. For extrapolation to other areas, the unit area loading from unimproved land was assumed to be 0.08 Kg P ha^{-1}. The remainder of the phosphorus accounted for by erosion from fields was assumed to have originated from cropland (cropland includes land in hay and pasture) and unit area loadings were calculated on the area of cropland within each watershed. This assumes the input of sediment associated P from non-agriculture sources within each watershed to be negligible, the validity of which cannot be assessed at this time.

Predicted phosphorus loadings from use of the model are reported in tables 4 and 5. Predictions by month are recorded in the Appendix - Tables A12 - A21.

Table 4: Unit area load of Sediment Associated Phosphorus from Agricultural Watersheds

Watershed	Estimated Unit Area Load From:		
	Streambank Erosion	Cropland	Unimproved Land
	---------------------------- kg ha $^{-1}$ ------------------------------		
AG -1	0.11	1.09	0.08
AG -2	0.007	0.46	0.08
AG -3	0.02	0.30	0.08
AG -4	0.11	0.37	0.08
AG -5	0.005	0.49	0.08
AG -6	0.003	0.10	0.08
AG -7	0.005	0.05	0.08
AG - 10	0.01	0.65	0.08
AG - 11	0.06	0[1]	0.08
AG - 13	0.02	0.92	0.08
AG - 14	0.05	0.14	0.08
MEAN	0.036	0.415	0.08

[1] Streambank sediment losses exceeded measured total sediment losses. No prediction of P loss from cropland was possible.

Table 5: Estimated Annual Total Sediment associated Phosphorus Load from Agricultural Watersheds.

Watershed	Estimated Load From:			
	Streambank Erosion	Cropland	Unimproved Land	Total Estimated Load
	------------------------ Tonnes/yr. ----------------------------			
AG -1	0.57	5.04	0.02	5.63
AG -2	0.05	2.22	0.23	2.50
AG -3	0.13	1.65	0.04	1.82
AG -4	0.20	0.63	0.01	0.84
AG -5	0.01	1.19	0.04	1.24
AG -6	0.02	0.39	0.14	0.55
AG -7	0.03	0.16	0.21	0.40
AG - 10	0.04	1.56	0.05	1.65
AG - 11	0.15	0[1]	0.01	0.16
AG - 13	0.03	1.40	0.03	1.46
AG - 14	0.22	0.54	0.03	0.79

[1] Streambank sediment losses exceeded measured total sediment losses. No prediction of P loss from cropland was possible.

The annual loadings of sediment associated P from cropland varied from 0 to 1.09 Kg ha^{-1} and averaged 0.42 Kg ha^{-1}. The greatest losses of P were estimated to have come fromthe most intensively farmed areas in watersheds Ag #1 and 13. However, the estimated loss from cropland in Ag #13 probably represented an overestimate of P loss due to very high estimates of the P enrichment ratio caused by the high sand content of the soil. The original regression equation developed for prediction of the P enrichment ratio was based on samples containing between 15 and 35% sand. Similarly, overestimates of P losses from cropland would be expected in Ag #2 (80% sand) and Ag #7 (61% sand). However the total loss of P in Ag #7 was very low and thus the expected overprediction of the P enrichment ratio would have had little effect on the final estimations for this watershed.

Phosphorus unit area loadings for streambank erosion were greatest from watersheds 1 and 4, with intermediate loadings from watersheds 11 and 14. These four watersheds had the highest proportion of exposed streambank (21-43%) and were therefore more susceptible to erosion.

The major part of sediment associated P loss from fields occurred in February, March and April (Figure 17), the only exception being watershed Ag #5. This was due to extremely severe storms during July and August which caused losses of over 60% of the total P loss for 1976. Excluding this watershed, 88% of the total annual sediment associated P loss occurred during these three months.

6.0 RELATIONSHIP TO PLUARG OBJECTIVES

The objective of this project was to develop a capacity for prediction of the amount of phosphorus carried to streams by surface runoff from agricultural cropland in Ontario. This objective is directly related to the PLUARG objectives.

The project has succeeded in developing relationships for estimation of total phosphorus concentration in surface soils in Ontario and for prediction of the phosphorus enrichment ratio. However, it has not been as successful in predicting the sediment load, the third parameter required for estimating the contribution of phosphorus.

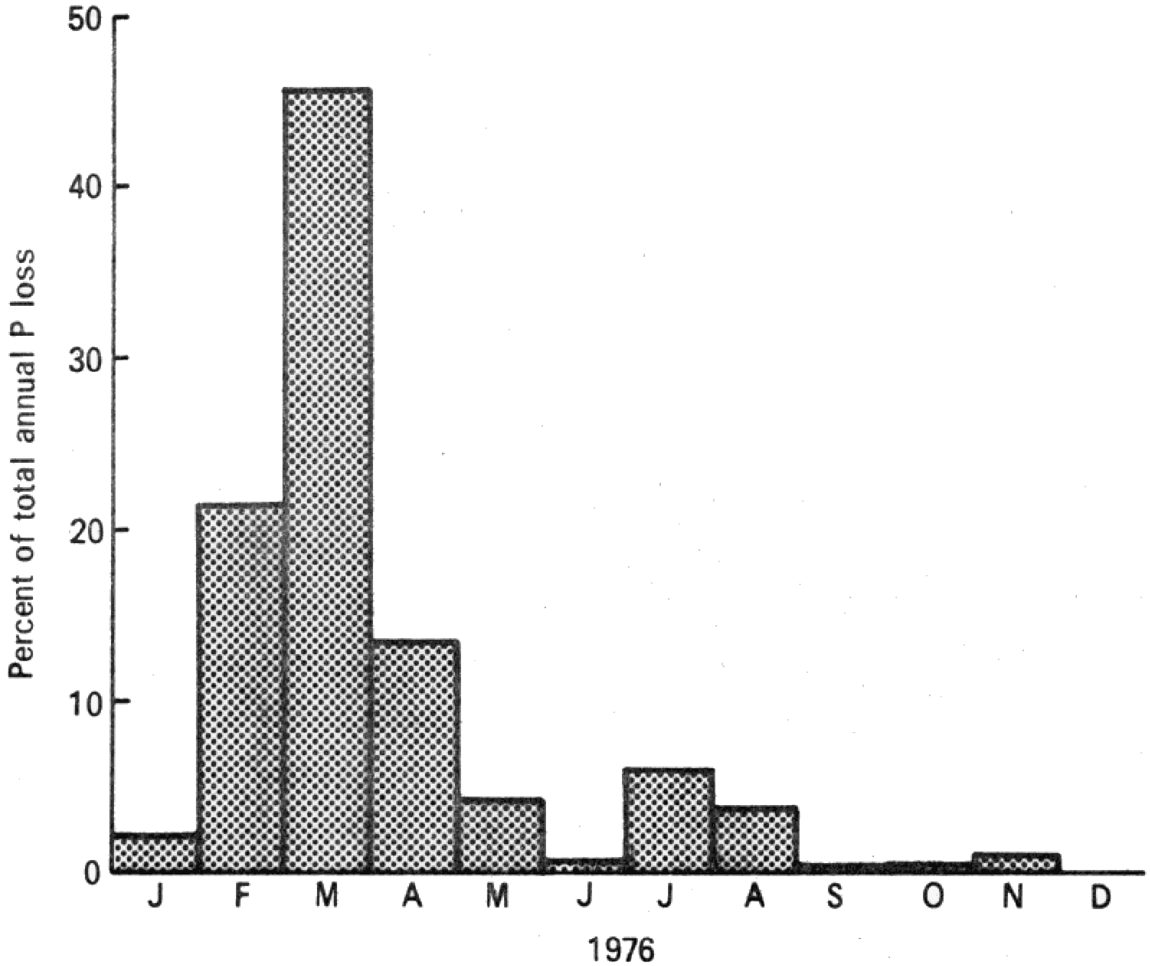

Figure 17: 1976 monthly mean phosphorus losses as a percentage of the annual total loading.

The difficulty in predicting the sediment load is due to difficulty in estimating the sediment delivery ratio.

This study has also indicated that the dissolved phosphorus in runoff from cropland is highly variable. The presence of manure on the surface at the time of the runoff event markedly increases the dissolved phosphorus. A significant relationship exists between dissolved P in runoff and the equilibrium phosphorus concentration and $NaHCO_3$-extractable phosphorus of the sediment from runoff plots indicating that increased extractable phosphorus in the surface soil would tend to increase the dissolved phosphorus in the runoff. However, other factors tend to obscure this relationship in runoff from farm fields. Thus it has not been possible to develop a relationship for estimation of the dissolved phosphorus concentration in runoff from cropland.

Some preliminary information has been obtained suggesting that the phosphorus delivery ratio is considerably higher than the sediment delivery ratio, especially in the transport from the field to the stream.

The study has improved our understanding of the processes involved in phosphorus loss from cropland and its transport to streams. Although the development of the predictive capacity has not been fully realized, the understanding obtained will greatly assist in interpretation and extension of the monitoring data from the Agricultural Watersheds Study.

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A P P E N D I X

Appendix - Table 1: Soil Analysis - data used in regression to estimate the total P content of the surface soil.

Site Location	Total P	0.5M $NaHCO_3$ Ext. P	pH	Organic matter	Clay[1] content	Texture[1]	Drainage[1]	Additional Information	
								Total N	1M NH_4OAC Extractable K
	---- (ug/g) ------			%	%			(µg/g)	(µg/g)
AG 4	Canagagigue Creek								
C2S1	807	24	7.6	4.7	20	SiL	1.5	2475	360
C3S1	878	30	7.8	6.0	19	SiL	1.4	2250	176
C3S2	676	25	7.6	4.2	19	SiL	2.3	2650	232
C3S3	873	21	7.3	5.1	18	SIL	2.3	2575	144
C3S4	686	12	7.3	5.0	25	SIL	1.7	2150	140
C3S5	648	14	7.4	4.4	25	SiL	1.7		148
C4S1	745	18	7.6	5.8	19	SiL	1.7	3112	148
C4S2	807	11	7.6	5.5	21	SIL	3.0		184
C4S3	755	17	7.6	5.3	28	SiL	1.9		152
C4S4	722	15	7.6	4.4	27	SIL	2.3		148
C4S5	859	23	7.7	5.0	27	SiL	2.3		184
C5S1	632	7	7.3	4.9	28	SIL	1.9	2475	108
C5S2	613	6	7.2	5.0	25	SiL	1.7	2538	120
C5S3	624	9	7.5	5.3	25	SiL	1.7	2050	156
C5S4	853	21	7.2	6.1	29	SiL	2.5	3325	324
C5S5	780	19	7.1	5.9	25	SiL	1.7		148
C5S6	783	29	7.4	5.2	31	SiL	1.7	2725	300
C5S7	731	15	7.0	5.1	25	SiL	1.9		112
C5S8	737	13	6.5	6.7	25	SiL	1.8		120
C5S9	591	14	7.3	4.4	28	SiL	2.5		116
C5S10	809	14	6.6	7.7	27	SiL	2.4		144
C5S11	653	12	7.0	4.8	25	SiL	1.7		104

[1] Clay content, texture and drainage were estimated from soil survey data.

Drainage was rated as follows:

Well drained	1.0
Imperfectly drained	2.0
Poorly drained	3.0

Site Location	Total P	0.5M $NaHCO_3$ Ext. P	pH	Organic matter	Clay[1] content	Texture[1]	Drainage[1]	Additional Information: Total N	Additional Information: 1M NH_4OAC Extractable K
	---- (ug/g) ------			%	%			(µg/g)	(µg/g)
C5S12	758	13	7.1	4.6	25	SiL	1.7		144
C5S13	690	19	7.4	4.3	25	SiL	1.9	2300	156
C5S14	709	17	7.0	5.5	27	SiL	2.3		148
C5S15	706	9	6.9	5.9	25	SiL	1.7		136
C5S16	659	11	7.4	5.7	14	SiL	1.9	2900	116
C5S17	681	11	7.0	5.1	25	SiL	1.9		92
C6S1	736	12	7.0	6.3	27	SIL	2.3		116
C6S2	651	7	7.5	6.1	25	SiL	1.8		100
C6S3	814	10	6.5	5.2	25	SiL	1.8		104
C6S4	844	16	6.7	6.7	27	SiL	2.3		136
C6S5	633	13	7.0	4.8	27	SiL	2.3		124
C6S6	727	19	7.3	5.5	27	SiL	2.3		220
C6S7	854	11	7.3	5.9	27	SiL	2.3		124
C6S8	921	11	7.2	5.7	27	SiL	2.3		112
C6S9	654	11	7.3	5.4	27	SiL	2.3		140
C6S10	715	19	7.6	5.3	27	SiL	2.3		116
C6S11	846	16	7.6	6.2	27	SiL	2.3		108
C6S12	618	8	7.4	5.0	29	SiCL	2.7		76
C6S13	986	30	7.3	6.4	25	SiL	1.7		132
C6S14	583	7	7.5	4.5	27	SiL	2.3		96
C6S15	731	10	7.5	6.0	25	SiL	1.8		152
C6S16	704	7	7.5	5.7	27	SiL	2.3		104
C6S17	819	8	7.4	6.1	27	SiL	2.3		124
C6S18	695	11	7.8	3.8	25	SiL	1.9		100
C6S19	733	10	7.0	6.1	25	SiL	1.8		128
C6S20	616	9	7.9	4.6	27	SiL	2.3		104
C7S1	684	16	7.8	4.7	25	SiL	1.7		116
C7S2	1147	12	6.7	9.7	29	SiCL	2.7		144
C7S3	644	6	7.9	5.5	27	SiL	2.3		96
C7S4	565	10	6.5	5.6	27	SiL	2.3		92
C7S5	679	9	6.7	5.7	29	SiCL	2.7		92

Site Location	Total P	0.5M $NaHCO_3$ Ext. P	pH	Organic matter	Clay[1] content	Texture[1]	Drainage[1]	Additional Information	
								Total N	1M NH_4OAC Extractable K
	---- (ug/g) ------			%	%			(µg/g)	(µg/g)
C7S6	636	10	6.8	5.3	25	SiL	1.7		76
C7S7	935	14	7.5	6.9	27	SiL	2.3		176
C7S8	577	8	7.8	4.7	27	SiL	2.3		116
C7S9	985	15	7.4	5.5	27	SiL	2.3		144
C7S10	966	15	7.5	5.6	27	SiL	2.3		144
C7S11	953	16	7.4	4.7	27	SiL	2.3		108
C7S12	986	13	6.9	6.1	29	SiCL	2.7		112
C7S13	1088	20	6.6	6.6	27	SiL	2.3		128
C7S14	876	20	7.0	6.5	27	SiL	2.3		184
C7S15	938	19	7.6	6.1	27	SiL	2.3		116
C7S16	725	12	7.1	5.3	27	SiL	2.3		76
C8S1	611	8	7.5	4.0	18	SiL	2.4	2675	96
C8S2	589	12	7.5	4.3	23	SiL	1.9	2238	104
C8S3	837	20	7.7	6.9	23	SiCL	2.3	3288	156
C8S4	794	18	7.1	3.9	25	SiL	1.9	2400	160
C8S5	724	17	7.3	4.1	25	SiL	1.9		152
C8S6	647	15	7.8	5.2	22	SiL	1.9		120
C8S7	672	11	7.2	5.3	22	SiL	1.9		108
C8S8	837	16	7.0	5.8	27	SiL	1.9		164
C8S9	639	8	7.5	4.1	18	SiL	2.4		84
C8S10	633	17	7.1	4.2	25	SiL	1.7		104
C8S11	727	14	6.7	5.4	27	SiL	2.3		92
C8S12	595	14	7.4	4.5	23	SiL	1.9		116
C3S13	825	18	7.0	7.1	23	SiCL	2.3		140
C8S14	781	12	7.0	4.5	26	SiL	2.0		144
C8S15	796	12	7.2	5.5	27	SiL	2.3		96
C8S16	962	18	7.1	5.3	27	SiL	2.3		144
C8S17	851	11	7.0	6.0	27	SiL	2.3		116
C8S18	653	9	7.4	5.4	25	SiL	1.7		76
C8S19	766	15	7.0	5.2	25	SiL	1.9		84
C8S20	88o	14	7.0	7.1	25	SiL	1.9		140
C8S21	772	11	6.8	5.4	29	SiCL	2.7		84
C8S22	794	12	7.1	6.8	25	SiL	1.9		108

Site	Location	Total P	0.5M $NaHCO_3$ Ext. P	pH	Organic matter	Clay[1] content	Texture[1]	Drainage[1]	Additional Information	
									Total N	1M NH_4OAC Extractable K
		---- (ug/g) ------			%	%			(µg/g)	(µg/g)
	C9S1	678	11	7.4	4.7	29	SiCL	2.7		112
	C9S2	735	9	6.9	5.7	25	SiL	1.7		96
	C10S1	725	12	7.3	6.0	27	SiCL	2.3		116
	C11S1	984	12	7.7	4.5	20	SicL	2.7	2300	100
	C11S2	852	12	7.3		20	SiCL	2.7		100
	C11S3	540	9	7.3	3.8	14	SiL	2.2	1888	92
	C11S4	535	10	7.2	4.1	14	SiL	2.2		92
	C11S5	641	13	7.3	4.6	25	SiL	1.7		120
	C11S6	743	16	7.1	5.6	27	SiL	2.3		144
	C11S7	750	18	7.2	5.6	29	SiCL	2.7		124
	C11S8	613	14	7.0	4.1	29	SiCL	2.7		96
	C12S1	670	19	7.4		25	SiL	1.9		152
	C12S2	583	6	7.4	4.5	28	SiL	1.9		100
	C12S3	690	12	7.6	5.8	14	SiL	1.9		120
	C12S6	765	30	7.5	5.4	31	SiL	1.7		284
Ag 5	Holiday Creek									
	H1S1	674	21	7.5	4.6	20	SiL	2.5		92
	H1S2	639	10	7.2	5.3	21	SiL	2.7		136
	H1S3	658	12	7.0	5.1	21	SiL	2.7		100
	H2S1	678	24	6.8	5.2	19	SiL	2.4		125
	H2S3	617	7	7.5	6.1	21	SiL	2.7		68
	H2S4	620	8	7.7	7.1	19	SiL	2.3		84
	H2S5	802	12	6.9	5.6	21	SiL	2.7		108
	H2S6	963	17	6.2	6.1	17	SiL	2.0		104
	H2S7	859	19	6.4	5.3	21	SiL	2.7		100
	H2S8	986	55	6.7	7.0	19	SiL	2.3		220
	H2S9	679	7	7.1	5.4	19	SiL	2.3		80

Site	Location	Total P	0.5M $NaHCO_3$ Ext. P	pH	Organic matter	Clay[1] content	Texture[1]	Drainage[1]	Additional Information: Total N	Additional Information: 1M NH_4OAC Extractable K
		---- (ug/g) ------			%	%			(µg/g)	(µg/g)
	H3S1	865	39	7.4	4.9	17	SiL	1.3	2625	140
	H3S2	640	41	6.9	3.7	19	SiL	2.3	2025	132
	H3S3	720	12	7.9	5.2	19	SiL	2.3		84
	H3S4	965	58	7.1	5.2	19	SiL	2.3	3000	140
	H3S5	572	14	6.7	4.8	19	SiL	2.3		128
	H3S6	694	41	6.5	5.2	17	SiL	1.4		216
	H3S7	937	11	6.6	6.7	17	SiL	1.3		116
	H3S8	710	6	6.7	5.9	17	SiL	2.0		72
	H3S9	882	9	6.6	6.5	17	SiL	2.0		52
	H3S10	732	9	7.3	5.2	17	SiL	1.7		64
	H3S11	763	7	7.1	7.1	21	SiL	2.6		76
	H3S12	769	14	6.9	6.5	19	SiL	2.3		132
	H3S13	635	41	7.2	4.1	19	SiL	2.3		104
	H3S14	975	57	7.3	5.6	19	SiL	2.3		108
	H3S15	892	43	7.1	4.9	17	SiL	1.3		144
	H3S16	612	13	7.3	5.2	17	SiL	1.3		124
	H3S17	664	26	6.7	5.2	17	SiL	1.3		108
	H3S18	693	15	6.5	5.4					84
	H4S1	744	9	7.4	5.2	17	SiL	1.7	2800	92
	H4S2	510	16	6.6	3.5	17	SiL	1.3		100
	H4S4	729	20	6.8	4.9	17	SiL	1.3	2400	92
	H4S5	750	9	7.4	5.5	17	SiL	1.7		84
	H4S6	655	8	7.5	5.3	17	SiL	1.3		68
	H4S9	731	20	6.8	4.8	17	SiL	1.3		84
	H5S1	994	39	7.3	6.8	19	SiL	2.6	3475	132
	H5S2	884	26	6.5	4.7					116
	H5S3	762	11	7.2	5.6	23	SiL	3.0	2750	80
	H5S4	950	8	6.5	6.5	17	SiL	1.3		92
	H5S5	634	39	7.2	6.3	19	SiL	2.6		124
	H5S6	773	13	7.1	5.6	23	SiL	3.0		80
	H5S7	795	14	6.3	5.3	21	SiL	2.1		80
	H5S8	764	14	7.1	5.2	17	SiL	1.3		84

Site	Location	Total P	0.5M $NaHCO_3$ Ext. P	pH	Organic matter	Clay[1] content	Texture[1]	Drainage[1]	Additional Information	
									Total N	1M NH_4OAC Extractable K
		---- (ug/g) ------			%	%			(µg/g)	(µg/g)
	H6S1	1160	18	7.6	16.4	19	SiL	2.4		112
	H6S2	835	27	7.6	4.9	19	SiL	2.4	2600	116
	H6S3	567	25	7.7	7.8	19	SiL	2.4		156
	H6S4	815	27	7.4	5.1	19	SiL	2.4		128
	H6S5	703	17	7.3	4.0	17	SiL	1.3		72
	H6S6	581	15	7.1	4.4	21	SiL	2.7		84
	H6S7	804	41	6.0	3.8	17	SiL	1.3		140
	H7S1	530	13	6.7	3.6	17	SiL	1.0		100
	H7S2	723	13	7.7	2.9	17	SiL	1.3		68
	H7S3	454	5	6.9	4.1	17	SiL	1.7		56
	H7S4	816	29	7.4	5.7	21	SiL	2.1		136
	H7S5	626	10	7.3	4.1	21	SiL	2.6		64
	H8S1	651	17	6.3	4.3	19	SiL	2.3		104
	H8S2	1032	17	6.9	8.4	19	SiL	2.3		96
	H8S3	835	17	7.2	5.5	19	SiL	2.4		96
	H8S4	868	17	6.9	6.6	23	SiL	3.0		104
	H8S5	714	11	6.9	5.2	17	SiL	1.7		68
	H8S6	571	15	7.1	4.8	17	SiL	1.7		92
	H8S7	730	11	6.8	6.1	17	SiL	1.7		88
	H8S8	730	26	5.4	3.8	17	SiL	1.7		140
	H8S9	764	15	6.7	6.3					80
	H8S10	589	19	6.8	4.0	19	SiL	2.3		112
	H8S11	1032	17	6.9	4.7	17	SiL	1.3		120
	H8S12	833	33	6.6	4.4	17	SiL	1.3		140
	H8S13	612	20	7.8	4.3	19	SiL	2.3		116
	H8S14	534	17	7.2	6.9	19	SiL	2.3		120
	H8S15	657	14	6.9	5.1	17	SiL	1.3		104
	H9S1	534	27	6.6	2.9	17	SiL	1.6	1525	116
	H9S2	949	30	6.9	6.0	23	SiL	3.0	2700	152
	H9S3	1067	37	6.4	5.6	19	SiL	2.3	2750	124

Site	Location	Total P	0.5M $NaHCO_3$ Ext. P	pH	Organic matter	Clay[1] content	Texture[1]	Drainage[1]	Additional Information: Total N	Additional Information: 1M NH_4OAC Extractable K
		------- (µg/g) -------			%	%			(µg/g)	(µg/g)
	H9S4	891	9	7.4	5.2	21	SiL	2.7		68
	H9S5	1142	17	6.3	7.5	19	SiL	2.3		92
	H9S6	1016	14	6.8	6.1	19	SiL	2.3		88
	H9S7	801	18	7.2	5.8	19	SiL	2.3		108
	H9S8	1072	32	6.4	6.2	23	SiL	1.6		164
	H9S9	1109	30	5.9	5.5	19	SiL	2.3		100
	H9S10	554	30	6.0	3.3	17	SiL	1.6		132
	H9S11	664	29	5.3	2.4	17	SiL	1.6		96
	H9S12	653	14	6.4	5.2	19	SiL	2.3		108
	H10S1	731	22	6.6						
	H10S2	588	14	7.0	5.5	19	SiL	2.3		128
	H10S4	700	17	6.1	4.3	17	SiL	1.3		100
	H10S5	721	13	7.1	6.0	17	SiL	1.3		80
	H11S2	775	28	7.1	6.0	21	SiL	2.6		268
	H11S3	999	25	6.4	9.8	21	SiL	2.7		104
	H11S4	580	17	6.7	4.2	17	SiL	1.3		84
	Wellington Co.									
	Other1	792	15	7.5	5.4	15	L	1.0	2650	108
	Other 2	929	22	7.8	4.9	15	L	2.0	2400	124
	Other 3	1019	25	7.5	4.8	15	L	2.0	2300	88
	Other 4	766	17	7.9	5.2	15	L	1.0	2025	112
	Other 5	959	27	7.7	5.4	15	L	2.0	2575	108
	Other 6	1008	25	7.0	4.6	15	L	2.0	2400	92
	Other 7	685	45	7.9	4.9	15	L	2.0	2500	268
	Other 8	762	31	7.6	5.0	15	L	2.0	2425	208
	Other 9	663	30	7.7	4.0	15	L	2.0	2550	76
	Other10	707	30	7.6	4.2	15	L	2.0	1975	76
	Other11	586	15	7.7	3.5	15	L	1.0	1775	84
	Other12	550	12	7.8	3.5	15	L	1.0	1800	76

Site	Location	Total P	0.5M $NaHCO_3$ Ext. P	pH	Organic matter	Clay[1] content	Texture[1]	Drainage	Ref.No. [2]
		--------- (µg/g) ---------			%	%			
	Elgin Co.								
	Dorchester Township	610	12	7.1	3.6	34	CL	1.5	72A
	Dorchester Township	575	12	6.8	3.9	18	L	1.0	73B
	Dorchester Township	427	6	7.1	3.2	14	SiL	1.0	74R
	Perth Co.								
	Hibbert Township	580	11	6.7	3.8	23	CL	1.5	72B
	Lincoln Co.								
	Gainsborough Township	434	11	5.0	4.2	34	CL	2.0	72C
	Wentworth Co.								
	Binbrook Township	604	10	6.0	4.5	14	SiL	1.0	72D
	Halton Co.								
	----	444	12	6.8	3.7	34	CL	2.0	72E
	N.Oakville	499	11	5.8	3.8	27	CL	1.5	75D
	Peel Co.								
	Caledon Township	899	20	6.8	5.0	11	L	1.0	72F
	Chinguacousy Township	648	12	6.8	5.2	18	L	2.0	74S
	Chinguacousy Township	701	13	7.1	5.2	20	SiCL	1.0	74T

Site	Location	Total P	0.5M $NaHCO_3$ Ext. P	pH	Organic matter	Clay[1] content	Texture[1]	Drainage	Ref.No. [2]
		--------- (µg/g)	----------		%	%			
	Simcoe Co.								
	Vespra Township	1028	22	7.5	6.3	34	CL	1.5	72H
	Vespra Township	695	25	5.9	3.1	2	SL	1.0	72J
	Vespra Township	848	14	7.9	6.3	34	CL	3.0	664
	Vespra Township	867	10	7.9	6.5	34	CL	3.0	664
	Vespra Township	625	14	8.0	5.2	34	CL	3.0	665
	Vespra Township	606	12	7.8	10.4	34	CL	3.0	665
	Gwillimbury Township	782	12	7.7	4.8	20	SiCL	1.0	75G
	Ontario Co.								
	Brock Township	887	16	7.6	5.1	19	L	1.0	72K
	Brock Township	840	12	7.6	5.3	19	L	1.0	74X
	Thorah Township	957	14	7.6	5.2	18	L	2.0	73K
	Durham Co.								
	Manvers Township	972	35	7.2	3.8	3	SL	1.0	72L
	Manvers Township	826	9	7.7	6.0	11	SL	1.0	75J
	Manvers Township	731	12	7.9	4.9	19	L	1.0	667
	Manvers Township	735	10	8.0	4.5	19	L	1.0	667
	Darlington Township	650	14	7.7	4.1	19	SL	1.0	666

Site	Location	Total P	0.5M $NaHCO_3$ Ext. P	pH	Organic matter	Clay[1] content	Texture[1]	Drainage	Ref.No. [2]
		--------- (µg/g) -------			%	%			
	Darlington Township	540	9	7.7	3.5	19	SL	1.0	666
	Victoria Co.								
	Verulam Township	746	15	7.6	5.0	20	L	1.0	72M
	Emily Township	860	13	7.8	3.5	18	SiL	1.0	75K
	Emily Township	867	15	7.6	5.4	18	L	1.0	73L
	Mariposa Township	680	11	7.8	5.5	18	L	1.0	74Y
	Peterborough Co.								
	Otanabee Township	668	16	7.5	3.9	12	SL	1.0	72N
	Asphodel Township	846	34	7.6	3.8	22	LS	1.8	73P
	Prince Edward Co.								
	Hallowell Township	843	21	7.3	4.4	22	SiL	1.8	72P
	Hastings Co.								
	Rawdon Township	710	12	6.8	5.1	28	SiCL	2.0	72R
	Tyendinaga Township	873	27	7.8	4.7	28	CL	1.0	669
	Tyendinaga Township	944	11	7.9	5.5	28	CL	1.0	669
	Tyendinaga Township	576	13	7.1	3.7	34	C	1.0	74A

Site	Location	Total P	0.5M $NaHCO_3$ Ext. P	pH	Organic matter	Clay[1] content	Texture[1]	Drainage	Ref.No. [2]
		--------- (µg/g) -------			%	%			
	Huron Co.								
	Howick Township	768	14	6.0	3.8	11	L	1.0	73C
	Haldimand Co.								
	Moulton Township	422	14	5.8	4.6	22	SiL	1.8	73D
	Seneca Township	539	15	5.6	4.8	34	CL	1.0	75B
	Caistor Township	1033	9	5.3	4.9	20	CL	1.0	75C
	Niagara Co.								
	Thorold Township	497	13	6.9	4.4	34	CL	1.5	73E
	Dufferin Co.								
	Melancthon Township	514	7	7.2	5.0	11	L	1.0	73F
	Melancthon Township	553	9	7.1	6.0	14	SiL	1.0	75E
	Melancthon Township	571	12	7.4	9.3	14	SiL	1.0	651
	Melancthon Township	525	5	7.4	5.8	14	SiL	1.0	651
	Amaranth Township	733	19	7.3	3.7	14	SiL	1.0	663
	Amaranth Township	626	9	7.4	4.6	14	SiL	1.0	663
	Mulmur Township	725	26	7.2	1.8	12	SL	1.0	75F

Site	Location	Total P	0.5M $NaHCO_3$ Ext. P	pH	Organic matter	Clay[1] content	Texture[1]	Drainage	Ref.No. [2]
		--------- (µg/g) -------			%	%			
	Grey Co.								
	Sydenham Township	1013	11	7.6	7.0	15	SiL	1.0	73G
	St .Vincent Township	671	11	6.6	5.1	18	L	1.0	73H
	Brock Township	557	14	7.2	4.7	34	CL	1.0	74V
	Euphrasia Township	578	10	7.3	5.1	18	L	1.0	74W
	Northumberland Co.								
	Hamilton Township	750	15	6.7	5.2	18	L	1.0	73M
	Hamilton Township	779	27	7.6	3.3	14	SiL	1.0	75L
	Haldimand Township	787	16	6.3	3.8	6	LS	1.0	73N
	Brighton Township	690	15	6.6	4.3	14	SiL	1.0	75M
	York Co.								
	Markham Township	721	9	7.7	3.5	34	SiCL	1.0	75H
	Brant Co.								
	Brantford Township	588	14	7.1	3.4	15	L	1.0	661
	Brantford Township	718	29	7.0	3.7	15	L	1.0	661
	Burford Township	539	20	6.6	2.1	12	SL	1.0	662
	Burford Township	552	30	6.8	2.0	12	SL	1.0	662

[2] Samples form part of a study by Dr. T. Bates, University of Guelph. The reference numbers refer to experimental sites used in this study.

Appendix - Table 2: Management Practices on Fields from which Soil Samples Collected.

Site	Location	Crop 1975	Grown 1974	1973	Fertilizer P applied 1973-75 Kg P/ha	No. of yrs. manure applied 1973-75	Manure on surface during winter
Ag 4	Cannagagigue Creek						
	C2S1	M.Grain	Corn	Pasture	2.2	3	*
	C3S1	Corn	Corn	Corn	12.7	3	*
	C3S2	Corn	Hay	Hay	5.3	3	
	C3S3	Grain	Grain	Grain	8.1	0	
	C3S4	Corn	Corn	Hay	5.1	3	
	C3S5	Pasture	Hay	Grain	0	2	
	C4S1	Grain	Grain	Grain	7.7	1	
	C4S2	Pasture	Pasture	Grain	3.3	2	*
	C4S3	Grain	Pasture	Pasture	1.5	3	
	C4S4	Corn	Corn	Pasture	4.2	2	*
	C4S5	Hay	Hay	Corn		1	
	C5S1	Grain	Hay	Hay	1.8	1	
	C5S2	Grain	Grass	Grass	2.4	3	
	C5S3	Grain	Grass	Grass	2.4	3	
	C5S4	Grain	Grain	Corn	6.0	0	
	C5S5	Hay	Hay	Grain		1	*
	C5S6	Corn	Pasture	Hay	2.6	1	*
	C5S7	Grain	Hay	Hay		1	
	C5S8	Grain	Grain	Hay	4.4	1	
	C5S9	Grass	Grain	Grain	4.8	2	*
	C5S10	Grass	Grass	Grass	3.8	2	
	C5S11	Grain	Grain	Grain	11.6	0	
	C5S12	Sod	Grain	Corn		1	
	C5S13	Corn	Corn	Corn	14.1	1	
	C5S14	Corn	Grass	Grass	7.7	3	
	C5S15	Grass	Grass	Grass		3	
	C5S17	Grain	Grain	Corn	7.3	1	

Site	Location	Crop 1975	Grown 1974	1973	Fertilizer P applied 1973-75 Kg P/ha	No. of yrs. manure applied 1973-75	Manure on surface during winter
	C6S1	Grain	Grain	Pasture	2.4	1	
	C6S2	Hay	Hay	Hay	0	1	
	C6S3	Hay	Hay	-	0	0	
	C6S4	Grain	Grain	Corn	15.0	0	
	C6S5	Alfalfa	Alfalfa	Alfalfa		1	
	C6S6	Grain	Corn	Corn	11.4	3	
	C6S7	Pasture	Pasture	Pasture	0	0	
	C6S8	Pasture	Pasture	Pasture	0	0	
	C6S9	Grain	Corn	Grass	4.0	1	
	C6S10	Grain	Grain	Corn	11.6	0	
	C6S11	Grain	Grain	Hay	7.7	0	
	C6S12	Grass	Grass	Grain		1	*
	C6S13	Corn	Grain	Pasture		1	
	C6S14	Hay	Hay	Hay	5.1	0	
	C6S15	Hay	Hay	Hay	5.1	0	
	C6S16	Hay	Hay	Hay	5.1	0	
	C6S17	Hay	Hay	Hay	5.1	0	
	C6S18	Hay	Grain	Grain	9.0	0	
	C7S1	Grain	Grain	Pasture	9.0	1	
	C7S2	Corn	Corn	Grain		3	
	C7S3	Grass	Grass	Grass	0	0	
	C7S4	Grain	Grain	Grain	3.8	0	
	C7S5	Grain	Grass	Grass	3.8	0	
	C7S6	Hay	Hay	Grain	3.8	0	
	C7S7	Corn	Corn	-	10.3	0	
	C7S8	Corn	Grass	Grass	7.7	0	
	C7S9	Pasture	Grain	Corn	4.6	0	
	C7S10	Hay	Grain	Corn	4.6	0	
	C7S11	Hay	Grain	Corn	4.6	0	
	C7S12	Grain	Hay	Hay	3.8	2	
	C7S13	Grain	Hay	Hay	3.8	2	
	C7S14	Corn	Corn	Grain	12.8	1	
	C7S15	Grain	Grain	Grain	11.6	1	
	C7S16	Grain	Grain	Grain	6.0	1	

Site	Location	Crop 1975	Grown 1974	1973	Fertilizer P applied 1973-75 Kg P/ha	No. of yrs. manure applied 1973-75	Manure on surface during winter
	C8S1	Grain	Hay	Hay	3.7	2	
	C8S2	Grain	Grain	Corn	8.8	3	
	C8S3	Corn	Pasture	Pasture	7	1	
	C8S4	Corn	Corn	Hay	5.1	3	
	C8S5	Corn	Corn	Hay	5.1	3	
	C8S8	Corn	Corn	Hay	6.4	2	
	C8S9	Grain	Hay	Hay	3.7	2	
	C8S10	Corn	Corn	Grass	8.8	2	
	C8S11	Barley	Grain	Clover	8.2	1	
	C8S12	Grain	Grain	Corn	8.8	3	
	C8S13	Corn	Pasture	Pasture	7.0	1	
	C8S14	Corn	Grass	Grass	2.9	3	
	C8S15	Grain	Grain	Corn	10.1	0	
	C8S16	Barley	Corn	Corn	10.6	2	*
	C8S17	Corn	Grass	Grass	3.3	1	
	C8S18	Hay	Hay	Hay	0	1	
	C8S19	Hay	Hay	Grain	8.4	2	
	C8S20	Hay	Hay	Grain	8.4	2	
	C8S21	Grain	Grain	Hay	10.3	1	
	C8S22	Hay	Hay	Grain	8.4	2	
	C9S1	Grain	Corn	Grass	5.7	2	
	C9S2	Grain	Grass	Grass	2.4	3	
	C10S1	Corn	Pasture	Hay	2.6	2	
	C11S1	Grain	Grain	Grain	5.9	0	
	C11S2	Grain	Grain	Grain	5.9	0	
	C11S3	Grain	Grain	Grain		1	
	C11S4	Grain	Grain	Grain		1	
	C11S5	Grass	Grain	Grain	2.4	2	
	C11S6	Corn	Pasture	Pasture	6.4	2	
	C11S7	Hay	Grain	Grain	3.3	1	
	C11S8	Grain	Corn	Corn	9.7	2	*

Site	Location	Crop 1975	Grown 1974	1973	Fertilizer P applied 1973-75 Kg P/ha	No. of yrs. manure applied 1973-75	Manure on surface during winter
AG 5	Holiday Creek						
	H1S1	Corn	Corn	Corn	13.0	0	
	H1S2	Pasture	Pasture	Pasture	4.0	0	
	H1S3	Corn	Corn	Corn	11.7	1	
	H2S1	Corn	Corn	Corn	18.5	2	
	H2S3	Pasture	Pasture	Pasture	0	2	
	H2S4	Pasture	Pasture	Pasture	0	2	
	H2S5	Corn	Corn	Corn	11.4	1	*
	H2S6	Cabbage	Corn	Corn	18.1	1	
	H2S7	Cabbage	Beans	Oats	12.8	0	
	H2S8	Pasture	Pasture	Pasture	20.3	0	
	H2S9	Hay	Grain	Hay	10.3	0	
	H3S1	Corn	Corn	Corn	12.1	3	
	H3S2	Corn	Corn	Corn	14.5	1	*
	H3S3	Corn	Corn	Corn	58.0	1	
	H3S4	Corn	Corn	Corn	14.5	1	*
	H3S5	Hay	Hay	Hay	7.3	2	
	H3S6	Corn	Corn	Corn	15.0	2	
	H3S7	Corn	Corn	Corn	15.0	0	
	H3S8	Alfalfa	Alfalfa	Alfalfa	0	1	
	H3S9	Grain	Hay	Hay		1	
	H3S10	Hay	Hay	Hay	15.4	3	
	H3S11	Corn	Hay	Hay	6.4	2	
	H3S12	Pasture	Pasture	Pasture	0	3	
	H3S13	Corn	Corn	Corn	14.5	1	*
	H3S14	Corn	Corn	Corn	14.5	1	*
	H3S15	Corn	Corn	Corn	12.1	3	
	H3S16	Corn	Corn	Corn	12.1	0	
	H3S17	Oats	Corn	Corn	11.9	0	
	H3S18	W. Beans	W. Beans	Corn		0	

Site	Location	Crop 1975	Grown 1974	1973	Fertilizer P applied 1973-75 Kg P/ha	No. of yrs. manure applied 1973-75	Manure on surface during winter
	H4S1	Corn	W. Beans	W. Beans		0	
	H4S2	Corn	Corn	Barley		2	*
	H4S4	Corn	Corn	Pasture	18.0	2	*
	H4S5	Corn	W. Beans	W. Beans		0	
	H4S6	Hay	Hay	Hay	0	2	
	H4S9	Corn	Corn	Pasture	18.0	2	*
	H5S1	Corn	Corn	Corn	14.5	3	*
	H5S2	Alfalfa	Corn	Corn		0	
	H5S3	Pasture	Pasture	Pasture	0	1	
	H5S4	Pasture	Pasture	Pasture	0	1	
	H5S5	Corn	Corn	Corn	14.5	3	*
	H5S6	Pasture	Pasture	Pasture	0	1	
	H5S7	Corn	Barley	Barley	9.3	1	
	H5S8	Barley	Barley	Corn		2	
	H6S1	Pasture	Pasture	Pasture	0	1	
	H6S2	Wheat/Oats	Corn	Soybean	11.6	3	
	H6S3	Corn	Corn	Corn	12.1	0	
	H6S4	Wheat/Oats	Corn	Soybean	11.6	3	
	H6S5	Corn	Corn	Corn	11.6	0	
	H6S6	Corn	Corn	Corn	11.6	1	
	H6S7	Oats	Oats	Oats	13.0	2	*
	H7S1	Oats/Barley	Pasture	Pasture	3.3	2	
	H7S2	Corn	Hay	Hay	5.3	2	*
	H7S3	Hay	Hay	Oats/Barley	3.8	0	
	H7S4	Corn	Corn	Corn	12.1	0	
	H7S5	Oats	Barley	Corn	7.9	0	
	H8S1	Corn	Corn	Corn	18.7	1	
	H8S2	Corn	Hay	Hay	7.3	2	
	H8S3	Corn	Corn	Corn	16.7	0	
	H8S4	Corn	Corn	Corn	16.7	0	

Site Location	Crop 1975	Grown 1974	1973	Fertilizer P applied 1973-75 Kg P/ha	No. of yrs. manure applied 1973-75	Manure on surface during winter
H8S5	Grass	Grass	Grass	0	0	
H8S6	Alfalfa	Alfalfa	Alfalfa	3.3	2	*
H8S7	Hay	Hay	Hay	0	3	*
H8S8	Corn	Grain	Corn	14.1	3	*
H8S9	Corn	Grain	Corn		1	
H8S10	Corn	Corn	Corn	18.7	1	
H8S11	Corn	Corn	Corn	18.7	3	
H8S12	Corn	Corn	Corn	18.7	3	
H8S13	Corn	Corn	Corn	9.5	1	*
H8S14	Corn	Pasture	Pasture	2.0	1	*
H8S15	Soybean	Corn	Corn	11.9	0	
H9S1	Beans	Potatoes	Beans	17.8	0	
H9S2	Hay	Hay	Corn	3.3	3	*
H9S3	Corn	Corn	Corn	9.7	3	*
H9S4	Grain	Hay	Hay	7.9	2	*
H9S5	Hay	Hay	Hay	8.8	3	*
H9S6	Pasture	Pasture	Pasture	6.0	1	
H9S7	Pasture	Oats/Hay	Oats	11.7	2	
H9S8	Hay	Hay	Corn	3.3	3	*
H9S9	Corn	Corn	Corn	9.7	3	*
H9S10	Beans	Potatoes	Beans	17.8	0	
H9S11	Corn	Bush	Bush	3.7	0	
H9S12	Cabbage	Sprouts	Beans	11.4	0	
H10S2	Corn	Corn	Corn	7.7	2	
H10S3	Corn	Corn	Corn	7.7	2	
H10S4	Grass	Grass	Grass	5.1	1	
H10S5	Grass	Grass	Grain	7.1	0	
H11S2	Pasture	Pasture	Pasture	8.1	1	
H11S3	Corn	Corn	Corn	11.0	2	
H11S4	Hay	Grain	Corn	11.0	0	

Site	Location	Crop 1975	Grown 1974	1973	Fertilizer P applied 1973-75 Kg P/ha	No. of yrs. manure applied 1973-75	Manure on surface during winter
	Wellington Co.						
	Other1	Corn				0	
	Other 2	Corn	Corn	Corn	7.7	2	*
	0ther 3	Corn	Corn	Corn		0	
	Other 4	Corn				0	
	Other 5	Corn	Corn	Corn	7.7	2	*
	Other 6	Corn	Corn	Corn		0	
	Other 7	Corn	Hay	Hay	6.4	3	*
	Other 8	Corn	Hay	Hay	6.4	3	*
	0ther 9	Corn	Corn	Corn	11.6	3	
	Other 10	Corn	Corn	Corn	11.6	3	
	Other11	Corn	Corn	Grain	14.7	1	
	Other12	Corn	Corn	Grain	14.7	1	

Appendix - Table 3: Mechanical Analysis of Field Soils (percentage equal to or less than indicated size)

	CANAGAGIGUE TOPSOIL 0 -15 cm.									
	Calgon Dispersed					Water Dispersed				
	50µ	20µ	10µ	5µ	2µ	50µ	20µ	10µ	5µ	2µ
C2S1	77	59	45	32	20	69	46	30	15	4
C3S1	72	53	40	29	19					
C3S2	75	56	42	31	19					
C3S3	74	58	46	32	18					
C3S4	83	65	51	38	25					
C4S1	83	61	47	33	19					
C5S1	84	65	49	39	29	76	41	22	12	4
C12S2	80	52	39	28	17					
C5S2	82	65	53	40	26					
C5S3	85	73	62	47	28					
C5S4	81	67	56	44	29					
C5S6	82	68	58	47	31	81	59	42	27	10
C12S6	77	71	59	47	33					
C5S13	77	59	49	38	25	72	49	33	21	9
C5S16	80	52	37	26	14					
C12S3	80	51	36	24	14					
C8S1	65	44	34	26	18					
C8S9	65	43	33	24	15					
C8S2	78	55	43	34	23					
C8S12	79	58	46	36	23					
C8S3	72	55	44	33	21					
C8S13	75	57	46	36	23					
C8S4	79	64	53	42	29					
C8S5	76	58	48	38	26					
C8S6	83	62	47	35	23					
C8S6	77	55	44	34	23					
C8S7	79	57	45	33	19					
C11S1	75	54	42	32	20					
C11S2	78	58	46	35	25					
C11S3	74	47	36	25	14					
C11S4	74	50	40	30	17					
AVERAGE	77	58	44	34	22	75	49	32	19	7

Appendix - Table 3 (cont'd)

	Calgon Dispersed				
	50µ	20µ	10µ	5µ	2µ
Canagagigue Ag4					
Subsoil					
C2S1	77	61	49	38	23
C3S1	68	47	35	26	19
C3S2	75	55	43	33	19
C3S3	75	55	44	32	20
C3S4	84	67	55	43	27
C4S1	83	63	48	34	21
C5S1	78	54	39	27	17
C5S2	83	68	58	47	33
C5S3	85	73	62	48	29
C5S4	80	67	57	46	31
C5S6	89	79	70	56	38
C5S13	78	64	54	42	29
C5S16	80	57	42	28	17
C8S1	68	47	36	28	13
C8S2	82	60	46	36	25
C8S3	78	59	46	36	23
C8S6	83	62	50	40	28
C8S7	79	58	47	38	27
C11S1	81	60	47	36	25
C11S3	77	52	39	28	17

Appendix Table 3: (cont'd)

	HOLIDAY TOPSOIL 0-15 cm.									
	Calgon Dispersed					Water Dispersed				
	50µ	20µ	10µ	5µ	2µ	50µ	20µ	10µ	5µ	2µ
H1S1	73	42	28	19	13					
H2S1	80	47	29	18	12					
H2S3	66	43	29	20	14					
H3S1	81	49	32	21	14	68	37	19	7	3
H3S2	65	43	33	24	15					
H3S4	80	51	33	22	13					
H3S13	65	45	32	23	14					
H3S14	78	49	34	22	13					
H3S15	77	49	33	22	13					
H4S1	81	50	33	23	14					
H4S4	76	50	34	25	14					
H4S5	79	45	28	17	8					
H4S9	77	53	36	24	15					
H5S1	74	46	32	21	11					
H5S5	67	43	29	20	12					
H6S2	77	48	33	23	13					
H6S4	76	47	31	19	10					
H9S1	70	42	28	19	12	67	33	19	9	2
H9S2	75	51	37	27	17	64	35	19	8	3
H9S3	79	47	34	24	16	77	37	19	9	3
H9S8	69	46	33	23	14					
H9S9	78	47	32	23	16					
H9S10	67	37	23	14	7					
AVERAGE	74	47	32	21	13	69	36	19	8	3

Appendix - Table 3 (cont'd)

			Calgon Dispersed					Water Dispersed				
			50µ	20µ	10µ	5µ	2µ	50µ	20µ	10µ	5µ	2µ
Wellington Co.												
Topsoil	0-15 cm											
Other	1		70	49	35	23	13					
0	2		53	36	25	18	14					
0	3		62	40	28	18	14	62	34	20	9	3
o	4		63	45	33	22	12					
0	5		59	42	32	24	16					
0	6		62	41	30	21	13					
0	7		56	37	25	17	13					
0	8		59-	39	27	19	11					
0	9		54	34	22	14	11					
0	10		55	36	24	16	9					
0	11		67	42	30	21	14					
0	12		63	45	31	21	12					

1977 Soil Samples

AG13 HILLMAN CK.							
Topsoil	0-15cm	W13R	49	34	26	19	14
		W13T	45	29	22	16	13
AG1 BIG CK.							
Topsoil	0-15cm	W1R	74	66	58	47	35
		W1T	77	70	63	53	39
AG5 HOLIDAY CK.							
Topsoil	0-15	W5Ri	78	52	34	23	15
		W5Ti	75	48	34	23	14
		W5Rii	72	47	34	22	14
		W5Tii	71	46	33	23	15

Appendix - Table 4: Characteristics of Sediment in Field Runoff Samples.

Runoff Sample		Soil Sample	Sed. Conc. (mg L^{-1})	Particle Size Distribution (%)									Clay Enrich Ratio	Org. Matter %	Org. Matter Enrich Ratio
				Non Dispersed Sample			Dispersed Sample			Dispersed Soil Sample					
Site No.	Date			>50µ	50-5µ	<5µ	>50µ	50-5µ	<5µ	>50µ	50-5µ	<5µ			
C2F1	19.04.75	C2S1	44	37.0	42.7	20.3									
C3F1	15.04.75	C3S1	485	70.0	27.5	2.5	18.6	55.6	25.7	28	43	29	0.89	7.05	1.18
	19.04.75		3101	70.4	25.6	4.1								5.41	0.90
C3F2	15.04.75	C3S2	231	1.6	69.6	28.8									
	19.04.75		485	39.4	48.8	11.8								4.59	1.09
C3F3	19.04.75	C3S4	450	5.9	39.4	54.7								6.30	1.27
C3F4	19.04.75	C3S3	272	20.9	55.1	24.0	9.7	45.1	45.2	26	42	32	1.41	5.61	1.10
C4F1	19.04.75	C4S1												5.96	1.02
C5F1	19.03.75	C5S1 C12S2	16798	64.6	30.8	4.6									
	22.03.75		555	13.1	34.1	52.7	2.4	27.1	70.4	18	49	33	2.13	10.81	2.32
	15.04.75		12221	54.2	41.3	4.6									
	19.04.75		3606	60.9	31.9	7.2									
C5F2	15.04.75	C5S2	222	13.1	59.5	27.5	4.1	34.9	61.0	18	42	40	1.53		
C5F3	15.04.75	C5S3	1490	23.0	62.2	14.8	4.4	38.5	57.1	14	39	47	1.21	5.72	1.08
C5F4	15.04.75	C5S4	897	5.4	61.5	33.1	1.2	41.1	57.7	19	37	44	1.31	7.49	1.24
C5F5 A[1]	16.04.75	C5S13 C12S1	4783												
B	16.04.75		4918												
C5F6	19.04.75	C5S6 C12S6	65	23.5	17.6	58.9									
C5F7	06.05.75	C5S16 C12S3	524	48.9	39.2	11.9								5.53	0.96

Runoff Sample		Soil Sample		Sed. Conc. ($mg\ L^{-1}$)	Particle Size Distribution (%)										Clay Enrich Ratio	Org. Matter %
					Non Dispersed Sample			Dispersed Sample			Dispersed Soil Sample					
Site No.	Date				>50µ	50-5µ	<5µ	>50µ	50-5µ	<5µ	>50µ	50-5µ		<5µ		
C8F1	15.04.75	C8S1	C8S9	2397	27.6	60.5	11.9	5.4	56.9	37.8	35	40	25	1.51		
C8F2	15.04.75	C8S2	C8S12	2517	34.3	47.4	18.3									
C8F3	16.04.75	C8S3	C8S13	814	39.0	34.5	26.5								6.91	0.99
C8F4	19.04.75	C8S4	C8S5	1559	53.4	37.5	9.1	11.2	56.3	32.6	23	37	40	0.82		
C11F1 A[1]	16.04.75	C11S1	C11S2	1178				8.1	60.9	31.0	23	43	34	0.91		
B	16.04.75			1197												
C11F4	16.04.75	C11S3	C11S4	1383	41.3	49.0	9.8									
H3F1	19.03.75	H3S1	H3S15	786	0.4	85.3	14.3									
	24.03.75			131	33.2	44.0	22.8	0.7	21.7	77.6	21	58	21	3.70	12.55	2.57
H3F2	24.03.75	H3S2	H3S13	648	81.6	17.3	1.1	38.9	47.2	13.9	34	42	24	0.58	7.22	1.85
H3F4	16.04.75	H3S4	H3S14	72	53.2	42.8	4.0	12.1	64.0	23.9	21	57	22	1.09		
H4F1	19.03.75	H4S1	H4S5	4883	45.6	50.6	3.8								6.44	1.20
	16.04.75			10771	42.8	52.0	5.2								8.27	1.55
H4F4	22.03.75	H4S4	H4S9	584	35.0	59.4	5.6								7.26	1.49
	24.03.75			230	25.2	70.0	4.7	5.8	52.9	41.3	24	51	25	1.65	7.46	1.53
H5F1	24.03.75	H5S1	H5S5	135	49.9	47.5	2.6	2.5	69.8	27.7	27	53	20	1.39	11.05	1.68
H5F2	24.03.75	H5S3	H5S6	40	2.8	84.2	13.0									
H6F2	22.03.75	H6S2	H6S4	168	6.3	85.0	8.7									

Runoff Sample		Soil Sample		Sed. Conc. (mg L^{-1})	Particle Size Distribution (%)									Clay Enrich Ratio	Org. Matter %	Org. Matter Enrich Ratio
					Non Dispersed Sample			Dispersed Sample			Dispersed Soil Sample					
Site No.	Date				>50µ	50-5µ	<5µ	>50µ	50-5µ	<5µ	>50µ	50-5µ	<5µ			
H9F1 a[2]	05.06.75	H9S1	H9S10	1092		31.1[3]	68.9	2.4	10.7	86.9	32	52	16	5.43		
b	05.06.75			918	7.6	12.0	80.4	3.6	9.7	86.7	32	52	16	5.42	9.54	3.08
H9F2	24.03.75	H9S2	H9S8	24	55.7	9.7	34.6									
H9F3	24.03.75	H9S3	H9S9	40	49.0	24.5	26.5									
E1	13.10.75	02	05	1296	5.3	46.2	48.5								13.97	2.72
E2	13.10.75	03	06	2548	18.9	50.5	30.5								10.74	2.28
E3	13.10.75	--	--	2037	6.9	51.2	41.9									
E4	01.11.75	01	04	1528	17.5	58.1	24.4								11.40	2.16
E5	01.11.75	011	012	851	8.3	51.9	39.7								8.48	2.42
E6	01.11.75	09	010	1165	4.4	80.6	14.9								9.00	2.22

[1] duplicate samples

[2] samples collected on same day. Sample a was collected at 13.15 h and sample b at 14.30 h

[3] includes all fractions >5µ

Appendix - Table 5: Phosphorus concentration in field runoff samples.

Runoff Sample		Soil Sample		Sed. assoc. P conc. µg g^{-1}	P conc. µg g^{-1} Non-dispersed runoff sample			P conc of soil µg g^{-1}	P Enrichment Ratio	Diss. Reactive P in Runoff mgL^{-1}	Manure on surface
Site No.	Date				>50µ	5-50µ	<5µ				
C2F1	19.04.75	C2S1		1589				807	1.97	0.760	*
C3F1	15.04.75	C3S1		1448	1088	1593	10080	878	1.65	0.820	*
	19.04.75			927	849	1007	1777	878	1.06	0.330	*
C3F2	15.04.75	C3S2		1040	1170	948	1245	676	i.54	0.115	
	19.04.75			820	752	733	1400	676	1.21	0.125	
C3F3	19.04.75	C3S4		884	983	740	977	686	1.29	0.110	
C3F4	19.04.75	C3S3		1098	841	969	1618	873	1.26	0.175	
C4F1	19.04.75	C4S1		862	805	738	1300	745	1.16	0.080	
C5F1	19.03.75	C5S1	C12S2	663	630	698	902	607	1.09	0.205	
	22.03.75			881	578	799	1009		1.45	0.008	
	15.04.75			666	626	700	841		1.10	0.005	
	19.04.75			645	645	605	825		1.06	0.005	
C5F2	15.04.75	C5S2		746	603	668	981	613	1.22	0.015	
C5F3	15.04.75	C5S3		645	640	606	818	624	1.03	0.075	
C5F4	15.04.75	C5S4		870	878	837	930	853	1.02	0.020	
C5F5 A[1]	16.04.75	C5S13	C12S1	764	775	702	903	680	1.12	0.185	
B	16.04.75			764	763	693	917		1.12	0.085	
C5F6	19.04.75	C5S6	C12S6	1976	1051	1919	2364	774	2.55	0.980	*
C5F7	06.05.75	C5S16	C12S3	875	818	767	1465	675	1.30	0.005	
C8F1	15.04.75	C8S1	C8S9	629	633	597	782	625	1.01	0.005	
C8F2	15.04.75	C8S2	C8S12	783	652	771	1059	592	1.32	0.015	
C8F3	16.04.75	C8S3	C8S13	918	1045	760	935	831	1.10	0.030	
C8F4	19.04.75	C8S4	C8S5	774	784	682	1096	759	1.02	0.020	
C11F1 A[1]	16.04.75	C11S1	C11S2	664	601	645	1088	913	0.73	0.155	
B	16.04.75			668	606	661	1173		0.73	0.160	
C11F4	16.04.75	C11S3	C11S4	690	636	658	1074	537	1.28	0.015	

Runoff Sample		Soil Sample		Sed. assoc. P conc. µg g^{-1}	P conc. µg g^{-1} Non-dispersed runoff sample			P conc of soil µg g^{-1}	P Enrichment Ratio	Diss. Reactive P in Runoff mg L^{-1}	Manure on surface
Site No.	Date				>50µ	5-50µ	<5µ				
H3F1	19.03.75	H3S1	H3S15	1444	1970	1373	1853	879	1.64	0.160	
	24.03.75			1954	1866	1815	2351		2.22	0.160	
H3F2	24.03.75	H3S2	H3S13	751	712	815	2670	638	1.18	0.190	*
H3F4	16.04.75	H3S4	H3S14	1270	1193	1074	4333	970	1.31	0.190	*
H4F1	19.03.75	H4S1	H4S5	679	587	702	1477	747	0.91	0.045	
	16.04.75			1383	901	1780	1388		1.85	0.025	
H4F4	22.03.75	H4F4	H4S9	1077	900	1069	2253	730	1.48	0.625	*
	24.03.75			1254	983	1265	2544		1.72	0.590	*
H5F1	24.03.75	H5S1	H5S5	1538	1590	1336	4265				
H5F2	24.03.75	H5S3	H5S6	1860	2670	1658	2965	767	2.43	0.080	
H6F2	22.03.75	H6S2	H6S4	1407	1208	1303	2568	825	1.71	0.210	
H9F1 a[2]	05.06.75	H9S1	H9S10	1160		14843	1683	544	2.13	0.100	
b	05.06.75			2039	628	1225	2293		3.75	0.090	
H9F2	24.03.75	H9S2	H9S8	5969	4670	5480	8190	1010	5.91	1.420	*
H9F3	24.03.75	H9S3	H9S9	3470	1430	3930	6824	1088	3.19	0.980	*
E1	13.10.75	02	05	2415	1809	2372	2522	944	2.56		
E2	13.10.75	03	06	1790	1184	1806	2138	1014	1.77		
E3	13.10.75	----	---	1523	968	1470	1680	779	1.96		
E4	01.11.75	01	04	1611	1280	1566	1955	588	2.84		
E5	01.11.75	011	012	1414	1037	1339	1590	685	2.06		
E6	01.11.75	09	010	1820	1407	1691	2640	723	2.52		

[1] duplicate samples

[2] samples collected on same day. Sample a was collected at 13.15 h and sample b at 14.30 h

[3] includes all fractions >5µ

Appendix - Table 6: Dissolved NH_4-N and NO_3-N in surface runoff samples.

Site No.	Date	Dissolved NH_4-N (ppm)	Dissolved NO_3-N (ppm)	Manure on surface
C2F1	19/04/75	3.15	0.64	*
C3F1	15/04/75	11.34	0.96	*
	19/04/75	2.39	10.30	*
C3F2	15/04/75	0.14	4.37	
	19/04/75	0.12	4.06	
C3F3	19/04/75	0.21	3.43	
C3F4	19/04/75	0.22	34.3	
C4F1	19/04/75	0.09	7.18	
C5F1	19/03/75	0.36	6.55	
	22/03/75	0.26	3.43	
	15/04/75	0.09	11.75	
	19/04/75	0.08	9.88	
C5F2	15/04/75	0.11	7.07	
C5F3	15/04/75	0.11	8.32	
C5F4	15/04/75	0.16	4.37	
C5F5	16/04/75	0.22		
C5F6	19/04/75	1.54	0.23	*
C5F7	06/05/75	0.10	25.7	
C8F1	15/04/75	0.07	6.03	
C8F2	15/04/75	0.09	6.14	
C8F3	16/04/75	0.20	1.04	
C8F4	19/04/75	0.07	8.63	
C11F1	16/04/75	0.23	1.14	
C11F4	16/04/75	0.06	7.59	
H3F1	19/03/75	0.62	5.20	
	24/03/75	0.85	1.35	
H3F2	24/03/75	0.50	10.4	*
H3F4	16/04/75	0.26	16.74	*

Site No.	Date	Dissolved NH_4-N (ppm)	Dissolved NO_3-N (ppm)	Manure on surface
H4F1	19/03/75	0.35	1.46	
	16/04/75	0.10	22.15	
H4F4	22/03/75	1.40	0.59	*
	24/03/75	1.50	0.77	*
H5F1	24/03/75	0.40	8.11	
H5F2	24/03/75	0.36	3.96	
H6F2	22/03/75	0.37	4.16	
H9F1b	05/06/75	0.19	0.94	
H9F2	24/03/75	3.15	0.39	*
H9F3	24/03/75	2.75	0.42	*

Appendix - Table 7: Runoff and Stream Samples collected during spring 1977.
- Sediment Characteristics

Site			Sed. Conc mg L^{-1}	Particle size distribution (%) Non dispersed sample			Dispersed sample			Dispersed soil sample			Clay Enrichment Ratio
				>50µ	5-50µ	<5µ	>50µ	5-50µ	<5µ	>50µ	5-50µ	<5µ	
AG13	1	Runoff within field	1160	20.9	38.5	40.5	17.9	26.6	55.5	51	31	18	3.08
	2	Field runoff entering stream	784	1.3	48.5	50.3	0.9	27.0	72.1				4.01
	3	Stream sample above point of runoff entry	929	7.3	58.0	34.7	3.8	42.4	53.8				
	4	Stream sample 50 m below point of runoff entry	813	7.3	58.1	34.7	4.2	39	56.9				
	5	Stream sample 400 m below point of runoff entry	674	9.1	50.6	40.4	7	31.8	61.3				
	6	Stream sample of joining stream	336	3.9	43.5	52.7	2.8	17.6	79.6				
	7	Stream sample at mouth of watershed	801	22.1	42.6	35.3	20.0	22.4	57.6				
AG1	1	Runoff entering stream	1701	17.4	27.8	54.8	11.7	17.7	70.7	25	24	51	1.39
	2	Stream sample at mouth of watershed	745	0.9	19.6	79.5	0.6	8.0	91.3				
AG5	1	Runoff within field	17362		83.6[1]	16.4	11.4	51.1	37.5	24	53	23	1.63
	2	Stream sample above point of runoff entry	491	14.7	66.1	19.2	8.1	33.7	58.2				

Site		Sed. Conc.	Particle size distribution (%)									Clay Enrichment Ratio
			Non dispersed sample			Dispersed sample			Dispersed soil sample			
		mg L^{-1}	>50µ	5-50µ	<5µ	>50µ	5-50µ	<5µ	>50µ	5-50µ	<5µ	
3	Stream sample 400 m below point of entry	5624		82.8[1]	17.2	6.2	42.1	51.7				
4	Runoff entering stream from barnyard	10431		85.8[1]	14.2	22.7	45.6	31.6	27	50	23	1.37
5	Stream sample 1 km below point of runoff entry	371	7.0	75.1	17.8	1.1	45.4	53.4				

[1] includes both coarse and medium sized fractions

Appendix - Table 8: Runoff and Stream Samples collected during spring 1977.
- Phosphorus concentrations

Site		Sed. Assoc. P conc. µg g^{-1}	P conc. Non-dispersed runoff sample >50µ	5-50$^{\mu}$	<5µ	P conc. of soil µg g^{-1}	Diss. Reactive P in Runoff mg L^{-1}	P Enrichment Ratio
AG13	1 Runoff within field	1424	242	1353	2102	654 541	0.170	2.41
	2 Field runoff entering stream	1820	257	1502	2167		0.164	3.07
	3 Stream sample above point of runoff entry	1744	329	1240	2885		0.201	
	4 Stream sample 50 m below point of runoff entry	2106	434	1670	3185		0.236	
	5 Stream sample 400 m below point of runoff entry	1999	291	1579	2909		0.244	
	6 Stream sample of joining stream	3319	317	2805	3963		0.212	
	7 Stream sample at mouth of watershed	1601	292	1766	2221		0.250	
AG1	1 Runoff entering stream	769	484	700	895	597	0.008	1.29
	2 Stream sample at mouth of watershed	952	367	866	980		0.020	
AG5	1 Runoff within field	1124		999[1]	1762	708	0.034	1.59
	2 Stream sample above point of runoff entry	8907	1095	9000	14566		0.175	
	3 Stream sample 400 m below point of entry	1584		15281	1852		0.194	
	4 Runoff entering stream from barnyard	1781		15311	3295	1056	0.225	1.69
	5 Stream sample 1 Km below point of runoff entry	1717	1411	1596	2356		0.444	

[1] includes both coarse and medium fractions

Appendix:- Table 9: Runoff and Stream Samples collected during spring 1977.
- Total dissolved P concentrations, organic matter content and $NaHCO_3$ extractable P content.

Site		Total Diss. Pin Runoff mg L^{-1}	$NaHCO_3$ Extractable P µg g^{-1} (Non dispersed sediment)			% organic matter (nondispersed sediment)		
			>50µ	50-5µ	>5µ	>50µ	50-5µ	>5µ
13-1	Runoff within field		16	89		1.87	3.71	
2	Field runoff entering stream			91			7.01	
3	Stream sample above point of runoff entry		3	86		0.82	4.36	
4	Stream sample 50 m below point of runoff entry		3	109		2.03	4.78	
5	Stream sample 400 m below point of runoff entry		7	150		0.00	5.33	
6	Stream sample of joining stream			165			10.49	
7	Stream sample at mouth of watershed			127		1.22	6.68	
1-1	Runoff entering stream	0.014	12	18		4.73	3.82	
2	Stream sample at mouth of watershed	0.087		41			3.71	
5 -1	Runoff within field				30			5.98
2	Stream sample above point of runoff entry	1.840	19	97			8.03	
3	Stream sample 400 m below point of entry	0.150			140			7.43
4	Runoff entering stream from barnyard	0.200			290			7.63
5	Stream sample 1 Km below point of runoff entry	0.280	58	150				

Appendix - Table 10: Sediment and Phosphorus levels in the streams of watersheds Ag 4 and 5.

Date		Total Sediment ($\mu g\ L^{-1}$)					P concentration on sediment ($\mu g\ g^{-1}$)				
	Site[1]	W1	W2	Wa	E1	E2	W1	W2	Wa	E1	E2
06.05.76		3.95	10.29	16.56	7.04	4.70	3000	2012	1242	4269	3488
10.05.76			3.31		2.49	1.59		2678		5114	5357
17.05.76		8.09	3.56	4.83	4.24	6.55	6183	5000	4808	4460	7113
31.05.76			5.26	7.93	19.25			3125	4648	2802	
07.06.76		3.73	3.60	2.34	2.85	3.77		5172	4500		5625
14.06.76		8.82	90.49		33.60	30.95	8780	1538		2284	1932
21.06.76		1.86	4.30		4.82	3.70	7500	4737		4667	3529
28.06.76			2.41		4.57	3.74		8478		5122	7714
05.07.76		1.64	8.44		4.41	9.74	8000	2174		4167	1807
12.07.76		4.77	2.57		3.23	5.17	2500	5000			3061
19.07.76					2.62	6.72				5455	4364
26.07.76			4.40		3.64	5.88		4091		4688	7091
29.07.76		7.41	14.42		120.51	16.24	8451	5111		1459	7929
09.08.76			5.80		2.93	7.02		2941		6111	5000
23.08.76					2.25						

[1] For site location refer to figure 2.

Table 10 cont'd

Date		Total P lost on sediment (mg L^{-1})					Diss. Reactive P lost (mg L^{-1})				
	Site	W1	W2	Wa	E1	E2	W1	W2	Wa	E1	E2
06.05.76		.012	.021	.021	.030	.016	.002	.000	.010	.002	.025
10.05.76			.009		.013	.009		.001		.012	
17.05.76		.050	.018	.023	.019	.047	.027	.000	.010	.030	.002
31.05.76			.016	.037	.054		.007	.001	.020	.067	.000
07.06.76			.019	.011		.021	.012	.001	.007	.200	.007
14.06.76		.077	.139		.077	.060		.032		.052	.028
21.06.76		.014	.020		.022	.013	.006	.004		.076	.006
28.06.76			.020		.023	.029		.002		.064	.008
05.07.76		.013	.018		.018	.018	.034	.006		.032	.002
12.07.76		.012	.013			.016	.015	.005		.062	.012
19.07.76					.014	.029				.070	.017
26.07.76			.018		.017	.042		.002		.074	.020
29.07.76		.063	.074		.176	.129					
09.08.76			.017		.018	.035					
23.08.76											

Table 10 cont'd

Date	Site [2]	Total sediment (mg L^{-1})		P concentration on sediment (µg g^{-1})		Total P lost on sediment (mg L^{-1})		Diss. Reactive P lost (mg L^{-1})	
		H1	H2	H1	H2	H1	H2	H1	H2
11.05.76		2.26	4.06	3750	2206	.0085	.0090	.000	.003
18.05.76		1.40	1.82	6250	5769	.0088	.0105	.005	.005
25.05.76		2.06	2.27	3947	3750	.0081	.0085	.002	.002
08.06.76		3.30	4.02	3214	3429	.0106	.0138	.005	.010
15.06.76		3.09	4.25	2143	3158	.0066	.0134	.006	.020
22.06.76		3.92	7.10	2647	2632	.0104	.0187	.005	.016
29.06.76			4.49		3000		.0135		
06.07.76		2.50	4.17	2609	2432	.0065	.0101	.005	.015
13.07.76		2.42	10.14	3158	1515	.0076	.0154	.080	.014
20.07.76		1.86	2.16	5000	3000	.0093	.0065	.005	.016
27.07.76			5.28		2093		.0111		.014
03.08.76		1.98	3.03	4737	3333	.0094	.0101		.027
10.08.76		3.28	2.15	2903	3333	.0095	.0072		
24.08.76		4.00	1.65						

[2] For site location refer to figure 3.

Appendix - Table 11: Sediment and phosphorus concentrations from sites upstream and downstream of a mushroom farm in Ag 13.

Date	Time	Site	Sediment Concentration (mg L^{-1})	P Concentration on sediment (µg g^{-1})	Sediment P load (µg L^{-1})	Dissolved Reactive P (µg L^{-1})
24.02.77	1100	F[1]	63.4	4236	269	732
		G	79.6	5434	433	558
	1700	F	42.4	4511	191	740
		G	24.4	3048	74	780
28.02.77	1400	F	24.1	4706	113	546
		G	24.4	4577	112	708
04.03.77	1220	Fa	198.0	3140	622	150
		Fb	227.3	2438	554	210
		Ga	266.6	2229	594	
		Gb	295.3	1841	544	
05.03.77	1500	Fa	22.6	5172	117	171
		Fb	22.4	5263	118	235
		Ga	14.3	10067	144	232
		Gb	14.1	5137	72	
09.03.77	1240	F	9.5	5740	55	225
	1600	F	9.7	5682	55	240
10.03.77	1350	Fa	4.1	6105	25	230
		Fb	4.8	7500	36	222
		Ga	29.1	4449	130	150
		Gb	27.3	4002	109	163
11.03.77	1450	Ga	9.9	6683	66	125
		Gb	9.7	5740	56	204
14.03.77	1540	F	4.4	7500	33	95
		Ga	3.4	9375	32	218
		Gb	3.7	25000	93	185

[1] F:Upstream site
G: Downstream site

Appendix - Table 12: Prediction of sediment associated P losses from various sources within watershed Ag 1 during 1976.

Watershed -1	Big Creek	% Clay 35 % Sand 35	Area: 5080 ha	Cultivated Land Un-improved Land Non-Agricultural Land	4619 ha 201 ha 260 ha

	Sed. Load	Stream-bank Load	Stream-flow as % of total	Potential Sheet Erosion	Sed. Load from Sheet Erosion	Del. Ratio	Overland Flow	Sed. Conc.	P Enrich Ratio	Estimated P lost (sed. assoc.) Field	Streambank	Total	Actual P lost (sed. assoc.)
	T	T		T	T		1 ha^{-1} $x10^{-3}$	mg L^{-1}		Kg	Kg	Kg	Kg
J	26.4	26.4	7.7		0		105	-			13.4	13.4	45.7
F	4194.6	667.9	55.6		3526.7		106	694	1.72	4446.3	333.0	4784.3	4597.4
M	523.2	236.9	19.9		286.3		3×10^5	188	2.27	476.4	119.9	596.3	1173.5
A	66.5	59.2	4.9		7.3		7.5×10^4	19	4.05	21.7	30.0	51.7	116.8
M	41.7	41.7	3.8		0		2×10^4	-			21.1	21.1	315.0
J	25.4	25.5	2.1		0		1.5×10^4	-			12.9	12.9	116.8
J	138.7	69.5	5.8		69.2		6×10^4	227	2.18	110.6	35.2	165.8	635.0
A	0	0	0		0		0	-			0	0	0
S	0.5	0	0		0.5		0	-			0.	0	0
O	0.5	0.5	0.1		0		0	-			0.3	0.3	0
N	0	0	0		0		0	-			0	0	0
D	0.5	0.5	0.1		0		0	-			0.3	0.3	0
YR	5018.0	1131.0		43,160	3890.0	6%				5055.0	571.1	5626.1	7000.2

Loss of P	Kg ha^{-1}
Cultivated Land	1.09
Unimproved Land	0.08

Appendix - Table 13: Prediction of sediment associated P losses from various sources within watershed Ag 2 during 1976.

Watershed - 2	Venison Creek	% Clay 7 % Sand 80	Area: 7913 ha	Cultivated Land Unimproved Land Non-Agricultural Land	4872 ha 2872 ha 169 ha

	Sed. Load	Stream-bank Load	Stream-flow as % of total	Potential Sheet Erosion	Sed. Load from Sheet Erosion	Del. Ratio	Overland Flow	Sed. Conc.	P Enrich Ratio	Estimated P lost (sed. assoc.) Field	Streambank	Total	Actual P lost (sed. assoc.)
	T	T		T	T		1 $ha^{-1}x10^{-3}$	mg L^{-1}		Kg	Kg	Kg	Kg
J	73.6	6.2	7.9		67.4		2 $x10^{4}$	426	3.87	191.2	4.1	195.3	55.4
F	239.0	14.6	18.4		224.4		8 $x10^{4}$	354	3.94	648.1	9.7	657.8	237.4
M	363.2	15.7	19.8		347.5		8 $x10^{4}$	549	3.75	955.2	10.4	965.6	459.0
A	172.5	9.1	11.5		173.4		10^{4}	2191	3.35	425.8	6.0	431.8	213.7
M	95.0	8.0	10.1		87.0		10^{4}	1099	3.57	227.7	5.3	233.0	110.8
J	41.1	4.1	5.2		37.0		0	0			2.7	2.7	55.4
J	26.9	3.7	4.7		23.2		0	0			2.5	2.5	39.6
A	34.0	3.6	4.5		30.4		0	0			2.4	2.4	63.3
S	16.6	3.0	3.8		13.6		0	0			2.0	2.0	15.8
O	11.1	3.2	4.1		7.9		0	0			2.1	2.1	23.7
N	12.7	3.2	4.1		9.5		0	0			2.1	2.1	15.8
D	20.6	3.2	4.0		17.4		0	0			2.1	2.1	23.7
YR	1106.3	79.1			1038.7					2448.0	52.5	2499.4	1353.1

Loss of P	Kg ha^{-1}
Cultivated Land	0.46
Unimproved Land	0.08

Appendix - Table 14: Prediction of sediment associated P losses from various sources within watershed Ag 3 during 1976.

Watershed - 3	Little Ausable River	% Clay 30	Area: 6200 ha	Cultivated Land	5558 ha
		% Sand 10		Unimproved Land	468 ha
				Non-Agricultural Land	174 ha

	Sed. Load	Stream-bank Load	Stream-flow as % of total	Potential Sheet Erosion	Sed. Load from Sheet Erosion	Del. Ratio	Overland Flow	Sed. Conc.	P Enrich Ratio	Estimated P lost (sed. assoc.)			Actual P lost (sed. assoc.)
										Field	Streambank	Total	
	T	T		T	T		$1\ ha^{-1}x10^{-3}$	$mg\ L^{-1}$		Kg	Kg	Kg	Kg
J	26.0	8.3	5.5		17.7		$5\ x10^{4}$	57	2.38	30.9	7.0	37.9	74.4
F	261.6	43.6	28.9		218.0		$5\ x10^{5}$	70	2.25	359.6	37.0	396.6	409.2
M	370.1	40.0	26.5		330.1		$5\ x10^{5}$	106	1.96	474.3	33.9	508.2	706.8
A	483.6	14.2	9.4		469.4		10^{5}	753	1.07	368.2	12.0	380.2	74.4
M	29.8	7.7	5.1		22.1		$3\ x10^{4}$	119	1.90	30.8	6.5	37.3	74.4
J	3.1	1.3	0.9		1.8		$5\ x10^{3}$	58	2.38	3.1	1.1	4.2	68.2
J	334.2	12.8	8.5		321.4		$1.8\ x10^{5}$	286	1.44	339.3	10.9	350.2	942.4
A	31.0	6.7	4.4		24.3		$3\ x10^{4}$	131	1.34	23.9	5.7	29.6	37.2
S	1.9	1.1	0.7		0.8		0	0			0.9	0.9	6.2
O	1.9	1.2	0.8		0.7		0	0			1.0	1.0	18.6
N	53.3	11.3	7.5		42.0		$4\ x10^{4}$	169	1.70	52.4	9.6	62.0	173.6
D	4.3	2.5	1.7		1.8		0	0			2.1	2.1	6.2
YR	1600.2	151.0		85,393	1450.1	1%				1682.5	128.0	1810.2	2597.8

Loss of P	$Kg\ ha^{-1}$
Cultivated Land	0.3
Unimproved Land	0.08

Appendix - Table 15: Prediction of sediment associated P losses from various sources within watershed Ag 4 during 1976.

Watershed - 4	Canagagigue	% Clay 22	Area: 1860 ha	Cultivated Land	1696 ha
		% Sand 23		Unimproved Land	128 ha
				Non-Agricultural Land	37 ha

	Sed. Load	Stream-bank Load	Stream-flow as % of total	Potential Sheet Erosion	Sed. Load from Sheet Erosion	Del. Ratio	Overland Flow	Sed. Conc.	P Enrich Ratio	Estimated P lost (sed. assoc.) Field	Estimated P lost (sed. assoc.) Stream-bank	Estimated P lost (sed. assoc.) Total	Actual P lost (sed. assoc.)
	T	T		T	T		$1\ ha^{-1}x10^{-3}$	$mg\ L^{-1}$		Kg	Kg	Kg	Kg
J	0	0			0		10^4				0	0	3.8
F	28.3	28.3			0		10^5				22.5	22.5	49.2
M	694.9	153.2			541.7		$1.3\ x10^6$	206	1.6	635.3	121.8	757.1	614.6
A	42.4	43.4			0		$1.5\ x10^5$				34.5	34.5	34.0
M	2.0	2.0			o		10^5				1.6	1.6	35.9
J	4.0	4.0			0		$6.0\ x10^4$				3.2	3.2	22.7
J	6.1	6.1			0		0				4.9	4.9	7.6
A	0	0			0		0				0	0	0
S	0	0			0		0				0	0	9.5
o	6.1	6.6			0		10^3				5.2	5.2	20.8
N	12.1	10.7			1.4		$6\ x10^4$	12	3.2	3.3	8.5	11.8	17.0
D	0	0			0		0				0	0	0
YR	791.9	254.3		4,972	543.1	11%				638.6	202.2	840.8	815.1

Loss of P	$Kg\ ha^{-1}$
Cultivated Land	0.37
Unimproved Land	0.08

Appendix - Table 16: Prediction of sediment associated P losses from various sources within watershed Ag 5 during 1976.

Watershed - 5	Holiday Creek	% Clay 13	Area: 3000 ha	Cultivated Land	2427 ha
		% Sand 26		Unimproved Land	461 ha
				Non-Agricultural Land	112 ha

	Sed. Load	Stream-bank Load	Stream-flow as % of total	Potential Sheet Erosion	Sed. Load from Sheet Erosion	Del. Ratio	Overland Flow	Sed. Conc.	P Enrich Ratio	Estimated P lost (sed. assoc.)			Actual P lost (sed. assoc.)
										Field	Streambank	Total	
	T	T		T	T		1 $ha^{-1}x10^{-3}$	mg L^{-1}		Kg	Kg	Kg	Kg
J	18.9	1.6			17.3		10^5	58	2.25	28.5	1.3	29.8	21.0
F	124.6	3.6			121.0		2.5 $x10^5$	161	1.80	160.5	2.9	163.4	207.0
M	115.3	4.2			111.1		9 $x10^5$	41	2.45	199.5	3.3	202.8	411.0
A	12.1	1.2			10.9		2.4 $x10^4$	151	1.83	14.6	1.0	15.6	6.0
M	35.7	1.1			34.6		3 $x10^4$	384	1.55	39.3	0.9	40.2	60.0
J	0.5	1.0			0		0	0	0	0	0.8	0.8	3.0
J	315.4	0.9			314.5		9 $x10^4$	1164	1.34	308.9	0.7	309.6	678.0
A	404.1	1.2			402.9		3 $x10^5$	448	1.52	445.9	1.0	446.9	759.0
S	1.1	0.2			0.9		10^3	300	1.60	1.1	0.2	1.3	6.0
0	2.7	0.5			2.2		6 $x10^3$	122	1.92	3.1	0.4	3.5	9.0
N	21.1	0.9			20.2		4 $x10^4$	168	1.78	26.4	0.7	27.1	15.0
D	1.9	0.6			1.3		10^4	43	2.43	2.3	0.5	2.8	3.0
YR	1053.4	17.0		73,206	1036.9	1%				1230.1	13.7	1243.8	2178.0

Loss of P	Kg ha^{-1}
Cultivated Land	.49
Unimproved Land	.08

Appendix - Table 17: Prediction of sediment associated P losses from various sources within watershed Ag 6 during 1976.

Watershed - 6	Unnamed tributary of Maitland River	%Clay 16 % Sand 24	Area: 5472 ha	Cultivated Land Unimproved Land Non-Agricultural Land	3717 ha 1541 ha 213 ha

	Sed. Load	Stream-bank Load	Stream-flow as % of total	Potential Sheet Erosion	Sed. Load from Sheet Erosion	Del. Ratio	Overland Flow	Sed. Conc.	P Enrich Ratio	Estimated P lost (sed. assoc.)			Actual P lost (sed. assoc.)
										Field	Stream-bank	Total	
	T	T		T	T		1 ha^{-1} x10^{-3}	mg L^{-1}		Kg	Kg	Kg	Kg
J	13.7	1.8	6.5		11.9		5 x10^{4}	43	2.45	21.4	1.2	22.6	27.4
F	21.3	3.7	13.5		17.6		10^{5}	32	2.65	34.2	2.5	36.7	49.2
M	158.1	8.8	32.2		149.3		8 x10^{5}	34	2.6o	284.5	5.8	290.3	235.3
A	92.5	3.7	13.5		88.8		1.5 x10^{5}	108	1.90	123.7	2.5	126.2	21.9
M	18.6	2.6	9.4		16.0		2.5 x10^{4}	117	1.85	21.7	1.7	23.4	43.8
J	4.9	1.0	3.7		3.9		2 x10^{4}	36	2.59	7.4	0.7	8.1	10.9
J	13.1	1.3	4.8		11.8		9 x10^{4}	24	2.87	24.8	0.9	25.7	5.5
A	8.2	0.7	2.6		7.5		0	0		0	0.5	0.5	21.9
S	6.0	0.9	3.2		5.1		10^{4}	93	1.98	7.4	0.6	8.0	5.5
0	5.5	1.0	3.6		4.5		2 x10^{4}	41	2.50	8.2	0.7	8.9	5.5
N	2.7	1.0	3.6		1.7		0	0		0	0.7	0.7	5.5
D	4.9	0.9	3.3		4.0		0	0		0	0.6	0.6	5.5
YR	349.7	27.4			322.1					533.3	18.2	551.5	443.2

Loss of P	Kg ha^{-1}
Cultivated Land	0.11
Unimproved Land	0.08

Appendix - Table 18: Prediction of sediment associated P losses from various sources within watershed Ag 7 during 1976.

Watershed - 7	Shelter Valley	% Clay 10	Area: 5645 ha	Cultivated Land	3009 ha
		Sand 61		Unimproved Land	1345 ha
				Non-Agricultural Land	1291 ha

	Sed. Load	Stream-bank Load	Stream-flow as % of total	Potential Sheet Erosion	Sed. Load from Sheet Erosion	Del. Ratio	Overland Flow	Sed. Conc.	P Enrich Ratio	Estimated P lost (sed. assoc.)			Actual P lost (sed. assoc.)
										Field	Streambank	Total	
	T	T		T	T		1 ha^{-1} $x10^{-3}$	mg L^{-1}		Kg	Kg	Kg	Kg
J	10.2	1.7	4.2		8.5		0				1.1	1.1	22.6
F	18.1	5.3	13.5		12.8		7.5×10^4	30	3.95	37.1	3.5	40.6	56.5
M	80.2	10.8	27.4		69.4		3×10^5	41	3.75	190.8	7.2	198.0	175.0
A	58.7	4.7	11.9		54.0		2×10^4	478	2.75	108.9	3.1	112.0	107.3
M	24.3	3.6	9.0		20.7		0				2.4	2.4	45.2
J	14.1	2.4	6.0		11.7		0				1.6	1.6	50.8
J	11.9	2.3	5.8		9.6		5×10^3	340	2.8	19.7	1.5	21.2	28.2
A	4.5	1.7	4.4		2.8		0				1.1	1.1	5.6
S	3.4	1.9	4.8		1.5		0				1.3	1.3	5.6
O	2.8	2.1	5.3		0.7		2×10^4	6	5.2	2.7	1.4	3.1	16.9
N	8.5	1.8	4.5		6.7		10^4	119	3.18	15.6	1.2	16.8	5.6
D	4.0	1.3	3.3		2.7		0				0.9	0.9	5.6
YR	240.5	39.5			201.0					374.8	26.2	400.1	524.9

Loss of P	Kg ha^{-1}
Cultivated Land	0.05
Unimproved Land	0.08

Appendix - Table 19: Prediction of sediment associated P losses from various sources within watershed Ag 10 during 1976.

Watershed -10	North Creek	% Clay 40	Area: 3025 ha	Cultivated Land	2385 ha
		% Sand 10		Unimproved Land	537 ha
				Non-Agricultural Land	103 ha

	Sed. Load	Stream-bank Load	Stream-flow as % of total	Potential Sheet Erosion	Sed. Load from Sheet Erosion	Del. Ratio	Overland Flow	Sed. Conc.	P Enrich Ratio	Estimated P lost (sed. assoc.)			Actual P lost (sed. assoc.)
										Field	Streambank	Total	
	T	T		T	T		1 ha^{-1} $x10^{-3}$	mg L^{-1}		Kg	Kg	Kg	Kg
J	17.8	4.1	8.1		13.7		1.5 $x10^5$	30	3.45	34.6	3.3	37.9	118.0
F	169.1	20.9	40.9		148.2		1.3 $x10^6$	38	3.25	353.0	16.7	369.7	1004.3
M	268.0	13.4	26.3		254.6		9 $x10^5$	95	2.55	475.9	10.7	486.6	771.4
A	340.9	6.6	13.1		334.3		2.8 $x10^5$	396	1.67	409.2	5.3	414.5	335.8
M	333.1	4.1	8.1		329.0		1.25 $x10^5$	872	1.33	320.7	3.3	324.0	496.1
J	1.8	0.3	0.5		1.5		0	0			0.2	0.2	9.1
J	11.2	0.5	1.0		10.7		2 $x10^4$	177	2.12	16.6	0.4	17.0	18.2
A	1.5	0.1	0.3		1.4		0	0			0.1	0.1	6.1
S	1.5	0.1	0.3		1.4		0	0			0.1	0.1	39.3
0	2.4	0.3	0.6		2.1		0	0			0.2	0.2	3.0
N	0.6	0.1	0.3		0.5		0	0			0.1	0.1	3.0
D	4.2	0.3	0.5		3.9		0	0			0.2	0.2	27.2
YR	1152.2	51.0		5,282	1101.2	14%				1610.0	40.6	1650.6	2831.4

Loss of P	Kg ha^{-1}
Cultivated Land	0.52
Unimproved Land	0.08

Appendix - Table 20: Prediction of sediment associated P losses from various sources within watershed Ag 13 during 1976.

Watershed -13	Hillman Creek	%Clay 11	Area: 1990 ha	Cultivated Land	1516 ha
		% Sand 75		Unimproved Land	138 ha
				Non-Agricultural Land	336 ha

	Sed. Load	Stream-bank Load	Stream-flow as % of total	Potential Sheet Erosion	Sed. Load from Sheet Erosion	Del. Ratio	Overland Flow	Sed. Conc.	P Enrich Ratio	Estimated P lost (sed. assoc.)			Actual P lost (sed. assoc.)
										Field	Streambank	Total	
		T		T	T		1 $ha^{-1} x10^{-3}$	mg L^{-1}		Kg	Kg	Kg	Kg
J	25.5	8.2	10.1		17.3		10^5	87	4.05	51.4	3.1	54.5	41.8
F	240.4	36.1	44.2		204.3		10^6	103	3.96	593.0	13.6	606.6	326.4
M	206.8	19.8	24.3		187.0		$3.5 x10^5$	268	3.5	479.7	7.5	487.2	181.1
A	100.3	6.2	7.6		94.1		$6 x10^4$	788	3.28	226.2	2.3	228.5	55.7
M	21.9	4.2	5.1		17.7		$2 x10^4$	445	3.47	45.0	1.6	46.6	29.9
J	13.7	1.9	2.3		11.8		$1.5 x10^4$	395	3.5	30.3	0.7	31.0	89.6
J	1.4	2.0	2.5		0		$1.5 x10^4$	0		0	0.8	0.8	17.9
A	0.6	0.2	0.3		0.4		0	0		0	0.1	0.1	6.0
S	1.8	0.4	0.5		1.4		0	0		0	0.2	0.2	2.0
O	1.6	0.9	1.1		0.7		104	35	4.5	2.3	0.3	2.6	0
N	0.4	0.8	1.0		0		$5 x10^3$	0		0	0.3	0.3	4.0
D	2.4	0.8	1.0		1.6		0	0		0	0.3	0.3	15.9
YR	617.1	81.6		22,720	536.3	2%				1427.9	30.8	1458.7	770.3

Loss of P	Kg ha^{-1}
Cultivated Land	0.93
Unimproved Land	0.08

Appendix - Table 21: Prediction of sediment associated P losses from various sources within watershed Ag 14 during 1976.

Watershed -14	Wilmot Creek (Mill Creek)	% Clay 28 % Sand 26	Area: 4504 ha	Cultivated Land Unimproved Land Non-Agricultural Land	3972 ha 422 ha 110 ha

	Sed. Load	Stream-bank Load	Stream-flow as % of total	Potential Sheet Erosion	Sed. Load from Sheet Erosion	Del. Ratio	Overland Flow	Sed. Conc.	P Enrich Ratio	Estimated P lost (sed. assoc.)			Actual P lost (sed. assoc.)
										Field	Streambank	Total	
	T	T		T	T		$1\ ha^{-1}x10^{-3}$	$mg\ L^{-1}$		Kg	Kg	Kg	Kg
J	11.7	11.7	4.2		0		$5\ x10^{4}$				7.8	7.8	27.0
F	31.1	31.1	12.8		0		10^{5}				20.7	20.7	103.6
M	493.2	233.1	61.1		260.1		$1.75\ x10^{6}$	33	2.95	562.4	154.8	717.2	752.2
A	2.3	2.3	1.2		0		10^{4}				1.5	1.5	4.5
M	3.6	3.6	1.2		0		10^{4}				2.4	2.4	9.0
J	14.0	5.3	1.4		8.7		$2\ x10^{4}$	97	2.18	13.9	3.5	17.4	31.5
J	8.1	8.1	3.1		0		$6\ x10^{4}$				5.4	5.4	27.0
A	0	0	0		0		0				0	0	0
S	0	0	0		0		0				0	0	0
0	0.9	0.9	0.5		0		0				0.6	0.6	0
N	38.7	38.7	12.1		0		$7.5\ x10^{4}$				25.7	25.7	63.1
D	3.2	3.2	2.4		0		$2.5\ x10^{4}$				2.1	2.1	4.5
YR	606.7	337.8			268.8					576.3	224.3	800.8	1022.4

Loss of P	$Kg\ ha^{-1}$
Cultivated Land	0.14
Unimproved Land	0.08