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International Reference Group on Great Lakes Pollution from Land Use Activities

University of Windsor. Industrial Research Institute

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INTERNATIONAL REFERENCE GROUP ON GREAT LAKES POLLUTION FROM LAND USE ACTIVITIES

INTERNATIONAL
JOINT
COMMISSION

AGRICULTURAL WATERSHED STUDIES IN THE CANADIAN GREAT LAKES DRAINAGE BASIN

PRECIPITATION - QUANTITY AND QUALITY

IRI 9-30

FINAL REPORT

AGRICULTURAL WATERSHED STUDIES
GREAT LAKES DRAINAGE BASIN
CANADA

TASK GROUP C (CANADIAN SECTION) ACTIVITY I

PROJECT 6

PRECIPITATION QUANTITY AND QUALITY

Project Leader: M. Sanderson

September 1977

THE INDUSTRIAL RESEARCH INSTITUTE
OF THE UNIVERSITY OF WINDSOR

WINDSOR, ONTARIO, CANADA N9B 3P4

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and the precipitation chemistry analysts:

Clement Leung
Robert Osborne
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CONTENTS

CONTENTS (cont.)

TABLES

FIGURES

FIGURES (cont.)

APPENDICES

APPENDICES (cont.)

APPENDICES (cont.)

APPENDICES (cont'd)

1.0 PRECIPITATION QUANTITY

1.1 Objective

The objective of this part of the research was to provide accurate hourly values of precipitation during the course of the PLUARG study on the ten watersheds AG 1, 3, 4, 5, 6, 7, 10, 11, 13, 14.

1.2 The Precipitation Gauge

For the PLUARG project, as for many hydrological and engineering studies it is of vital importance to measure the precipitation reaching the ground from the atmosphere as accurately as possible. Under present technological conditions such measurement involves the use of some catching device or gauge, which catches and measures a sample of the precipitation. The questions which have always plagued the researcher are (1) Does the precipitation caught in the gauge represent accurately the amount of water reaching the ground? and (2) How many "samples" per unit area are needed for an accurate areal estimation of precipitation?

There are many types of precipitation gauges, official and unofficial, for rain and snowfall. Orifice diameters vary from 10 cm. (Canada) to over 34 cm. (Sweden) and the height at which the gauge is exposed from 30 cm. to more than 2 m. above the ground. Since the "catch" of a gauge varies with orifice size and height above ground, data from different types of gauges are not strictly comparable. It should also be noted that the Canadian standard gauge does not measure snowfall, and that the standard method of measuring snowfall in Canada is by measuring the depth of new-fallen snow with a ruler and converting to water equivalent by dividing by ten. Since the water content of the snow is not measured, this method leads to error in estimating precipitation from snow.

For the PLUARG project, the Belfort weighing type gauge was chosen (Fig. 1). It has the advantage of recording both rain and snow with a sensitivity of .5 mm. It requires no electricity, is simple to operate and relatively inexpensive.

1.3 Accuracy of Gauge Catch

There have been many studies done of the accuracy of the catch of various gauges compared to the amount of water reaching the ground. The general agreement is that the higher the orifice of the gauge above the ground, the less precipitation it catches. The gauge itself obstructs the air movement and the vertical component of the air trajectory immediately above the gauge may be large with respect to the settling speed of the rain drops or snow particles, and thus some of the precipitation is prevented from entering the orifice. In addition, turbulent eddies induced by the wind in the gauge mouth may reduce the catch and the increased horizontal wind speed at the height of the higher gauge may result in the transport of small droplets across the opening, which would, in the case of a gauge closer to the ground, fall into the gauge.

In a five year comparison of the Belfort gauge with the Canadian standard gauge in Windsor, the author found the Belfort to record 96% of the rainfall received in the standard gauge. A comparison was not done between the Belfort snowfall catch and standard Canadian snow measurement techniques because of the large errors inherent in the ruler measurement of snow. A survey of the literature on the accuracy of precipitation gauge catch indicates that in the Soviet Union, where extensive research has been done, the annual average precipitation is corrected (increased) over that measured by 10-20% in some areas, to 40-50% in Arctic Siberia (Larsen and Peck 1974). Canada's Atmospheric Environment Service does not yet "correct" measured precipitation values and

BELFORT
RECORDING RAIN GAUGE

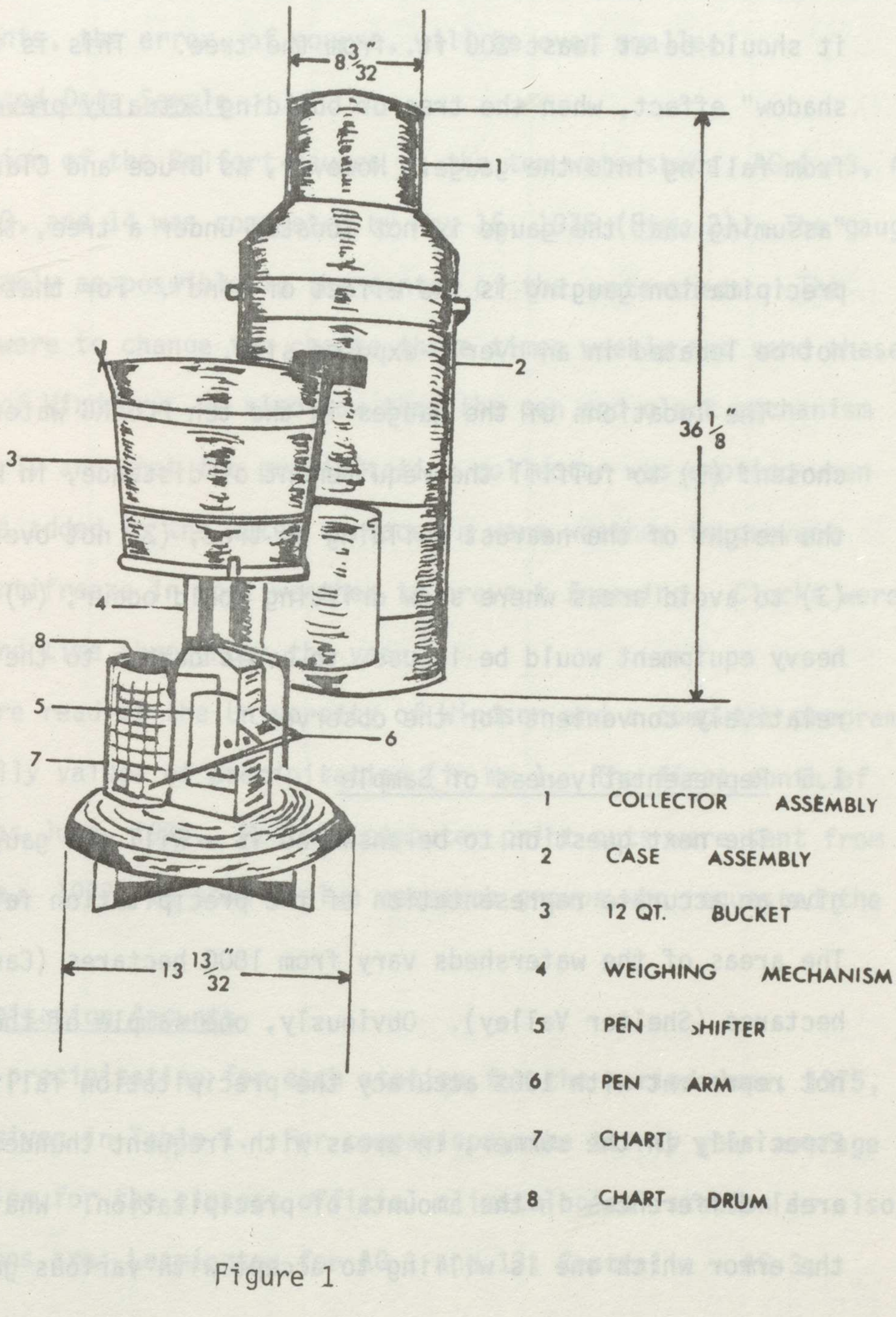


Figure 1

the present report also gives only measured precipitation data.

1.4 Exposure and Sources of Error

In the Atmospheric Environment Service handbook "Precipitation" it is stated that the gauge "must be remote from each object by a distance at least equal to the height of the object. For example, the gauge must be located at least 50 ft. away from a tree which is 50 ft. high. If possible and convenient, it should be at least 200 ft. from the tree." This is to prevent a "rain-shadow" effect, when the tree or building actually prevents the rain drops from falling into the gauge. However, as Bruce and Clark point out (1966), "assuming that the gauge is not located under a tree, the real problem in precipitation gauging is the effect of wind". For that reason, the gauge should not be located in an overly-exposed site.

The locations of the gauges in the ten PLUARG watersheds were carefully chosen: (1) to fulfill the requirement of distance, in most cases four times the height of the nearest building or tree; (2) not overly exposed to the wind; (3) to avoid areas where snow drifting would occur; (4) away from areas where heavy equipment would be in use, to avoid damage to the gauge; and (5) to be relatively convenient for the observer.

1.5 Representativeness of Sample

The next question to be answered is - will one gauge in each watershed give an accurate representation of the precipitation falling on the watershed? The areas of the watersheds vary from 1800 hectares (Canagagique) to 6600 hectares (Shelter Valley). Obviously, one sample of the precipitation will not represent with 100% accuracy the precipitation falling on the watershed. Especially in the summer, in areas with frequent thunderstorms, there will be areal differences in the amounts of precipitation. What is more meaningful is the error which one is willing to accept with various gauge densities. Several valuable studies have been done on this aspect. An intensive study in Japan (Larsen and Peck 1974) concluded that a rain gauge density of 1 gauge per 360 ha. gave a 3% error in storm rainfall measurement; 1 gauge per 4100 ha. a 5% error; 1 gauge per 4900 ha. a 6% error; and 1 gauge per 6000 ha. an 8% error. Thus, even in the largest watershed (Shelter Valley) the average error for storm rainfall would be about 8%. If one is concerned only with monthly precipitation amounts, the error, of course, will be even smaller.

1.6 Installation and Data Sample

The installation of the Belfort gauges at the ten watersheds, AG 1, 3, 4, 5, 6, 7, 10, 11, 13, and 14 was completed by May 15, 1975 (Fig. 2). The gauges were located as nearly as possible in the centre of the watersheds. The observer's duties were to change the charts three times weekly and send these to the University of Windsor. He also saw that the pen and clock mechanism were working properly and that the precipitation collector was emptied when necessary. Oil was added to the water surface in warm weather to prevent evaporation, and antifreeze in cool weather to prevent freezing. Clocks were operated on standard time throughout the year.

The charts were read at the University of Windsor and a computer program gave hourly and daily values of precipitation (in mm.). The first month of complete records was June, 1975. Monthly computer print outs were sent from June, 1975, to June, 1977, to some twelve research groups who requested the information.

1.7 Monthly Precipitation Amounts

Total monthly precipitation for each station for the period June, 1975, to June, 1977, is given in Table 1. For comparison, the thirty year average monthly precipitation for the closest official climatological station is also shown. (The stations are: Leamington for AG 1 and 13; Centralia - AG 3;

Shand Dam - AG 4; Woodstock - AG 5; Clifford - AG 6; Smithfield - AG 7; Caledonia - AG 10; Brampton - AG 11; and Southampton - AG 14.)

For the first year of the PLUARG record, June, 1975, to May, 1976, precipitation was above average for most stations: AG 1, 4, 5, 6, 7, 10, 13 and 14. AG 3 had slightly below average precipitation and AG 11 had average precipitation amounts. For the second year of record, June, 1976, to May, 1977, precipitation was everywhere below average for the gauged watersheds in Southern Ontario. Most stations recorded approximately 80% of the average precipitation (Table 1).

The precipitation charts for each station were also analyzed to provide information on the number of days with precipitation, heavy precipitation days and maximum precipitation in three hours, two hours and one hour. These data are of interest to researchers concerned with specific runoff events and are shown in Table 2 for each of the ten stations.

TABLE 1

Monthly Precipitation Amounts for PLUARG Stations (mm.)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
AG 1													
1975						141	30	211	67	31	52	77	
1976	48	64	117	68	57	94	88	14	87	57	18	17	963
1977	21	41	70	138	41	82							686
30 yr average	57	51	65	79	79	86	79	70	60	59	63	65	813
AG 3													
1975						100	65	163	68	12	60	71	
1976	56	52	92	85	69	82	142	61	79	50	53	39	893
1977	39	33	53	68	20	93							719
30 yr average	94	74	74	79	84	87	80	80	73	76	88	107	996
AG 4													
1975						113	89	179	73	44	65	80	
1976	90	67	143	83	71	111	84	35	107	65	29	40	1097
1977	55	73	69	52	23	-							743
30 yr average	69	61	72	69	84	72	82	76	75	79	82	77	898
AG 5													
1975						108	66	170	52	22	56	76	
1976	55	43	124	69	72	52	210	155	87	76	48	27	913
1977	27	45	50	54	13	65							844
30 yr average	64	54	64	70	74	84	80	77	66	74	69	70	846
AG 6													
1975						83	64	213	85	50	64	84	
1976	63	56	107	69	73	85	90	50	98	57	38	37	1011
1977	55	41	60	33	30	63							674
30 yr average	64	57	55	64	71	74	72	70	74	71	86	81	839

TABLE 1 (cont.)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
AG 7													
1975						88	57	52	97	40	79	87	940
1976	78	64	130	79	89	101	52	46	68	68	35	30	666
1977	36	38	90	78	24	-							
30 yr average	73	73	72	80	83	64	72	80	74	81	87	85	924
AG 10													
1975						96	74	180	71	51	60	65	1009
1976	49	53	134	82	94	95	69	31	74	55	12	31	651
1977	43	39	89	72	41	80							
30 yr average	60	57	67	69	71	56	75	80	68	62	61	55	781
AG 11													
1975						64	39	86	44	39	47	56	730
1976	41	68	99	64	83	73	108	36	71	62	7	25	576
1977	20	32	72	52	19	-							
30 yr average	56	54	62	76	76	60	75	80	63	70	67	58	797
AG 13													
1975						106	41	232	66	30	44	74	963
1976	58	80	121	60	52	95	87	16	93	56	32	20	712
1977	20	46	76	135	36	106							
30 yr average	57	51	65	79	79	86	79	70	60	59	63	65	813
AG 14													
1975						85	47	193	78	31	81	71	957
1976	122	53	108	30	58	144	70	26	108	75	85	45	896
1977	143	30	40	46	34	60							
30 yr average	99	66	61	67	69	62	64	73	83	77	85	103	909

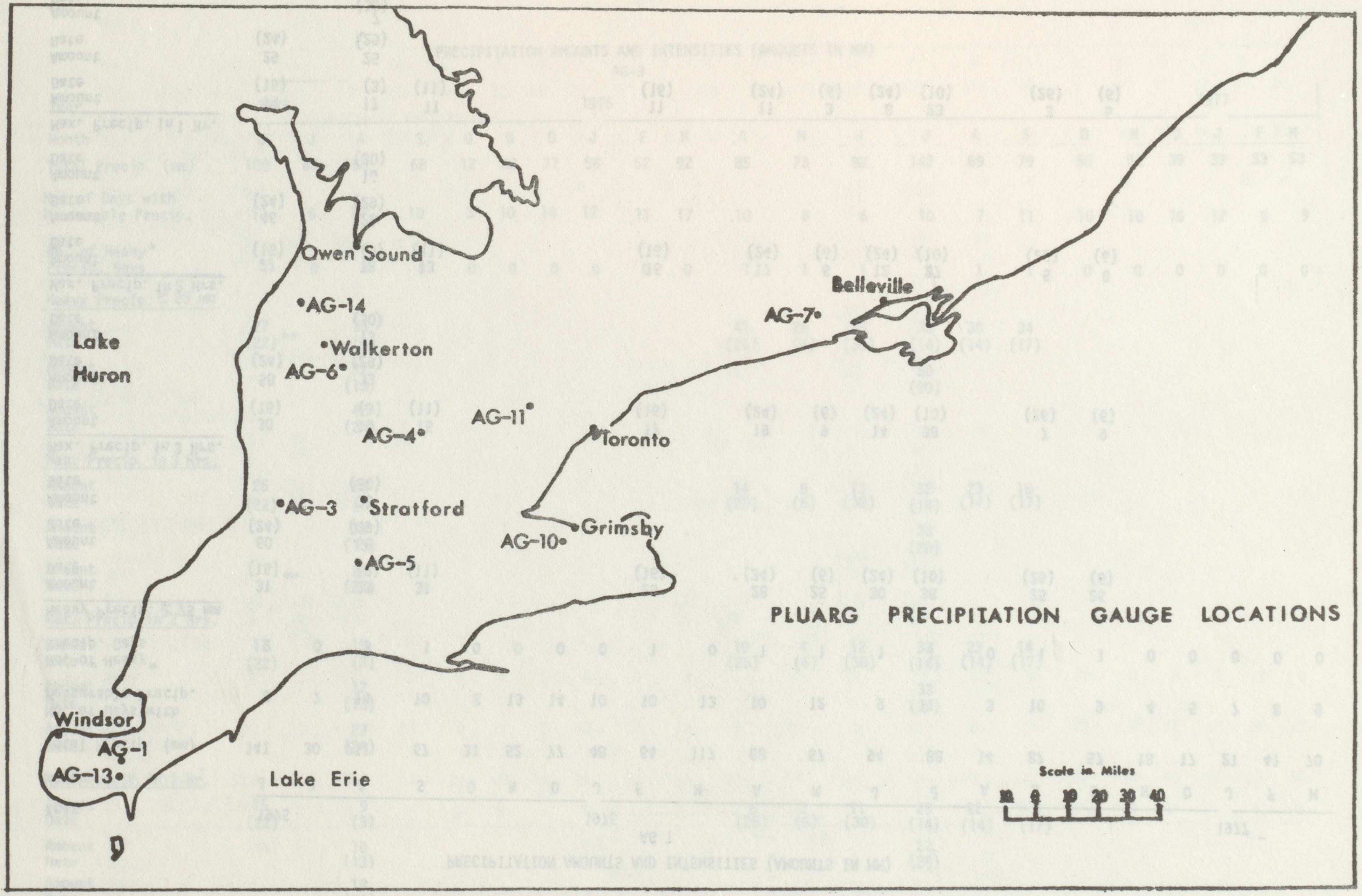

Owen Sound
AG-14
Lake
Huron
Walkerton
AG-6
AG-11
AG-4
Toronto
Belleville
AG-7
AG-3
Stratford
Grimsby
AG-10
AG-5
PLUARG PRECIPITATION GAUGE LOCATIONS
Windsor
AG-1
AG-13
Lake Erie
Scale in Miles
10
0
10
20
30
40

Figure 2

TABLE 2

PRECIPITATION AMOUNTS AND INTENSITIES (AMOUNTS IN MM)

AG 1

Year	1975							1976												1977		
Month	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Total Precip. (mm)	141	30	211	67	31	52	77	48	64	117	68	57	94	88	14	87	57	18	17	21	41	70
No. of Days with Measurable Precip.	8	7	14	10	8	13	14	10	10	13	10	12	9	11	3	10	9	4	5	7	8	9
No. of Heavy* Precip. Days	2	0	3	1	0	0	0	0	1	0	1	1	1	1	0	1	1	0	0	0	0	0
Heavy Precip. ≥ 25 mm																						
Amount Date	31 (15) **		33 (3)	31 (11)					25 (16)		28 (24)	25 (6)	30 (24)	38 (10)		25 (26)	26 (6)					
Amount Date	60 (24)		68 (29)																			
Amount Date			35 (30)																			
Max. Precip. in 3 Hrs.																						
Amount Date	30 (15)		19 (3)	15 (11)					17 (16)		19 (24)	9 (6)	14 (24)	38 (10)		7 (26)	9 (6)					
Amount Date	58 (24)		33 (29)																			
Amount Date			13 (30)																			
Max. Precip. in 2 Hrs.																						
Amount Date	27 (15)		18 (3)	13 (11)					16 (16)		17 (24)	6 (6)	12 (24)	27 (10)		5 (26)	8 (6)					
Amount Date	46 (24)		28 (29)																			
Amount Date			10 (30)																			
Max. Precip. in 1 Hr.																						
Amount Date	19 (15)		17 (3)	11 (11)					11 (16)		11 (24)	3 (6)	8 (24)	23 (10)		3 (26)	5 (6)					
Amount Date	29 (24)		25 (29)																			
Amount Date			7 (30)																			

* Days with precipitation ≥ 25 mm

** Bracketed figures are dates -- [(15) = 15th day)]

** Bracketed figures are dates -- [(15) = 15th day)]

TABLE 2 (cont.)

PRECIPITATION AMOUNTS AND INTENSITIES (AMOUNTS IN MM)
AG-3

Year	1975							1976												1977		
Month	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Total Precip. (mm)	100	65	153	68	12	60	71	56	52	92	85	73	82	142	69	79	50	53	39	39	33	53
No. of Days with Measurable Precip.	12	6	10	10	3	10	14	12	11	17	10	8	6	10	7	11	10	10	16	12	9	9
No. of Heavy* Precip. Days	1	0	3	0	0	0	0	0	0	0	1	1	1	2	1	1	0	0	0	0	0	0
Heavy Precip. ≥ 25 mm																						
Amount	27		35								41	28	36	38	30	34						
Date	(22) **		(3)								(25)	(6)	(30)	(14)	(14)	(17)						
Amount			27											50								
Date			(13)											(20)								
Amount			42																			
Date			(24)																			
Max. Precip. in 3 Hrs.																						
Amount	25		20								14	6	13	32	23	18						
Date	(22)		(3)								(25)	(6)	(30)	(14)	(14)	(17)						
Amount			13											38								
Date			(13)											(20)								
Amount			24																			
Date			(24)																			
Max. Precip. in 2 Hrs.																						
Amount	17		15								10	4	12	32	23	14						
Date	(22)		(3)								(25)	(6)	(30)	(14)	(14)	(17)						
Amount			12											33								
Date			(13)											(20)								
Amount			23																			
Date			(24)																			
Max. Precip. in 1 Hr.																						
Amount	15		9								6	2	11	29	22	9						
Date	(22)		(3)								(25)	(6)	(30)	(14)	(14)	(17)						
Amount			10											22								
Date			(13)											(20)								
Amount			13																			
Date			(24)																			

* Days with precipitation ≥ 25 mm

** Bracketed figures are dates [(22) = 22nd day]

TABLE 2 (cont.)

PRECIPITATION AMOUNTS AND INTENSITIES (AMOUNTS IN MM)

AG-4

Year	1975							1976												1977		
Month	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Total Precip. (mm)	113	89	179	73	44	65	22	90	67	143	81	73	111	84	35	107	65	29	40	55	73	69
No. of Days with Measurable Precip.	12	7	9	13	8	14	5	23	15	18	9	10	7	10	9	13	12	8	15	18	14	12
No. of Heavy* Precip. Days	2	1	1	0	0	0	0	0	0	1	1	0	2	2	0	0	0	0	0	0	0	0
Heavy Precip. ≥ 25 mm																						
Amount	28	35	93							37	26		31	27								
Date	(15)**	(19)	(24)							(1)	(15)		(13)	(20)								
Amount	35												52	27								
Date	(19)												(30)	(29)								
Max. Precip. in 3 Hrs																						
Amount	28	30	64							-***	17		26	20								
Date	(15)	(19)	(24)								(15)		(13)	(20)								
Amount	31												30	15								
Date	(19)												(30)	(29)								
Max. Precip. in 2 Hrs																						
Amount	22	20	51							-	16		23	19								
Date	(15)	(19)	(24)								(15)		(13)	(20)								
Amount	27												18	11								
Date	(19)												(30)	(29)								
Max. Precip. in 1 Hr																						
Amount	12	20	32							-	9		18	12								
Date	(15)	(19)	(24)								(15)		(13)	(20)								
Amount	19												14	8								
Date	(19)												(30)	(29)								

* Days with precipitation ≥ 25 mm

** Bracketed figures are dates -- [(15) = 15th day]

*** Data from Elora Station (- no intensities available)

TABLE 2 (cont.)

PRECIPITATION AMOUNTS AND INTENSITIES (AMOUNTS IN MM)

AG-5

Year	1975							1976												1977		
Month	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Total Precip. (mm)	108	66	170	52	22	56	76	55	43	124	69	72	52	210	155	87	76	48	27	27	45	50
No. of Days with Measurable Precip.	8	5	12	8	7	12	14	16	9	14	11	9	5	11	8	9	12	10	10	14	7	10
No. of Heavy* Precip. Days	1	0	1	0	0	0	0	0	0	1	1	1	0	4	2	0	0	0	0	0	0	0
Heavy Precip. ≥ 25 mm																						
Amount	26		47							26	37	41		49	48							
Date	(3)**		(24)							(2)	(25)	(6)		(7)	(13)							
Amount														29	73							
Date														(14)	(14)							
Amount														61								
Date														(20)								
Amount														35								
Date														(29)								
Max. Precip. in 3 Hrs																						
Amount	25		35							10	9	8		49	40							
Date	(3)		(24)							(2)	(25)	(6)		(7)	(13)							
Amount														27	70							
Date														(14)	(14)							
Amount														55								
Date														(20)								
Amount														19								
Date														(29)								
Max. Precip. in 2 Hrs																						
Amount	22		32							8	7	6		47	36							
Date	(3)		(24)							(2)	(25)	(6)		(7)	(13)							
Amount														24	70							
Date														(14)	(14)							
Amount														50								
Date														(20)								
Amount														12								
Date														(29)								
Max. Precip. in 1 Hr																						
Amount	18		22							5	4	3		38	24							
Date	(3)		(24)							(2)	(25)	(6)		(7)	(13)							
Amount														20	37							
Date														(14)	(14)							
Amount														44								
Date														(20)								
Amount														11								
Date														(29)								

* Days with precipitation ≥ 25 mm

** Bracketed figures are dates -- [(3) = 3rd day]

TABLE 2 (cont.)

PRECIPITATION AMOUNTS AND INTENSITIES (AMOUNTS IN MM)

AG-6

Year	1975							1976												1977		
Month	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Total Precip. (mm)	72	64	213	85	50	64	84	63	56	107	60	82	85	90	50	98	51	38	37	55	41	60
No. of Days with Measurable Precip.	9	7	10	12	6	11	15	14	12	16	8	11	9	10	8	12	9	13	15	20	11	10
No. of Heavy* Precip. Days	1	0	2	1	1	0	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0
Heavy Precip. ≥ 25 mm																						
Amount	25 **		79	25	34				29	30			33	37								
Date	(19)		(24)	(11)	(13)				(21)	(2)			(30)	(29)								
Amount			44																			
Date			(29)																			
Max. Precip. in 3 Hrs																						
Amount	19		48	17	32				12	11			13	17								
Date	(19)		(24)	(11)	(13)				(21)	(2)			(30)	(29)								
Amount			33																			
Date			(29)																			
Max. Precip. in 2 Hrs																						
Amount	18		29	16	32				9	9			13	15								
Date	(19)		(24)	(17)	(13)				(21)	(2)			(30)	(29)								
Amount			29																			
Date			(29)																			
Max. Precip. in 1 Hr																						
Amount	12		20	13	21				5	5			11	10								
Date	(19)		(24)	(17)	(13)				(21)	(2)			(30)	(29)								
Amount			25																			
Date			(29)																			

* Days with precipitation ≥ 25 mm

** Bracketed figures are dates -- [(19) = 19th day]

TABLE 2 (cont.)

PRECIPITATION AMOUNTS AND INTENSITIES (AMOUNTS IN MM)

AG-7

Year	1975							1976												1977		
Month	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Total Precip. (mm)	88	57	52	97	40	79	87	78	64	130	78	90	101	52	46	68	68	35	30	36	38	90
No. of Days with Measurable Precip.	12	6	8	9	8	10	12	16	13	17	8	15	13	12	9	11	9	10	9	14	8	10
No. of Heavy* Precip. Days	0	1	0	1	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1
Heavy Precip. ≥ 25 mm																						
Amount		31 **		39		26							31				31					32
Date		(20)		(18)		(10)							(30)				(9)					(13)
Max. Precip. in 3 Hrs																						
Amount		31		16		13							24				14					21
Date		(20)		(18)		(10)							(30)				(9)					(13)
Max. Precip. in 2 Hrs																						
Amount		31		12		10							24				11					17
Date		(20)		(18)		(10)							(30)				(9)					(13)
Max. Precip. in 1 Hr																						
Amount		25		7		7							17				6					11
Date		(20)		(18)		(10)							(30)				(9)					(13)

* Days with precipitation ≥ 25 mm

** Bracketed figures are dates -- [(20) = 20th day]

TABLE 2 (cont.)

PRECIPITATION AMOUNTS AND INTENSITIES (AMOUNTS IN MM)

AG-10

Year	1975							1976												1977		
Month	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Total Precip. (mm)	96	74	180	71	51	60	65	49	53	134	82	94	95	69	31	74	55	12	31	43	39	89
No. of Days with Measurable Precip.	10	6	14	12	7	11	11	13	11	15	7	9	8	12	5	11	9	4	10	12	13	10
No. of Heavy * Precip. Days	0	0	3	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
Heavy Precip. ≥ 25 mm																						
Amount			46 **	25							39	34	30									
Date			(10)	(18)							(25)	(6)	(24)									
Amount			33																			
Date			(24)																			
Amount			58																			
Date			(29)																			
Max. Precip.in 3 Hrs																						
Amount			46	11							10	11	24									
Date			(10)	(18)							(25)	(6)	(24)									
Amount			21																			
Date			(24)																			
Amount			33																			
Date			(29)																			
Max. Precip.in 2 Hrs																						
Amount			46	7							7	9	23									
Date			(10)	(18)							(25)	(6)	(24)									
Amount			19																			
Date			(24)																			
Amount			31																			
Date			(29)																			
Max, Precip.in 1 Hr																						
Amount			27	4							4	6	15									
Date			(10)	(18)							(25)	(6)	(24)									
Amount			13																			
Date			(24)																			
Amount			22																			
Date			(29)																			

* Days with precipitation ≥ 25 mm
** Bracketed figures are dates -- [(10) = 10th day)]

TABLE 2 (cont.)

PRECIPITATION AMOUNTS AND INTENSITIES (AMOUNTS IN MM)

AG-11

Year	1975							1976												1977		
Month	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Total Precip. (mm)	64	39	86	44	39	47	56	41	68	99	64	83	73	108	36	71	62	7	25	20	32	72
No. of Days with Measurable Precip.	6	4	9	7	6	11	11	13	9	11	8	8	8	12	8	12	12	4	12	7	8	12
No. of Heavy* Precip. Days	1	0	1	0	0	0	0	0	1	1	1	1	0	1	0	1	0	0	0	0	0	0
Heavy Precip. ≥ 25 mm																						
Amount	31		32						36	33	34	26		30		34						
Date	(19)**		(24)						(21)	(2)	(25)	(6)		(29)		(18)						
Max. Precip in 3 Hrs																						
Amount	22		21						14	14	7	5		12		20						
Date	(19)		(24)						(21)	(2)	(25)	(6)		(29)		(18)						
Max. Precip in 2 Hrs																						
Amount	19		19						11	9	5	4		10		15						
Date	(19)		(24)						(21)	(2)	(25)	(6)		(29)		(18)						
Max. Precip. in 1 Hr																						
Amount	16		15						6	6	3	2		5		10						
Date	(19)		(24)						(21)	(2)	(25)	(6)		(29)		(18)						

* Days with precipitation ≥ 25 mm

** Bracketed figures are dates -- [(19) = 19th day]

TABLE 2 (cont.)

PRECIPITATION AMOUNTS AND INTENSITIES (AMOUNTS IN MM)

AG-13

Year	1975							1976												1977		
Month	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Total Precip. (mm)	106	41	232	66	30	44	74	58	80	2	60	52	95	87	16	93	56	32	20	20	46	76
No. of Days with Measurable Precip.	8	5	13	9	8	13	14	10	10	2	10	11	8	13	3	8	9	5	7	8	8	9
No. of Heavy* Precip. Days	2	0	2	1	0	0	0	0	1	0	1	0	1	1	0	1	0	0	0	0	0	0
Heavy Precip. ≥ 25 mm																						
Amount	30		105	25					29		27		39	38		26						
Date	(15) **		(29)	(11)					(16)		(24)		(24)	(10)		(26)						
Amount	25		45																			
Date	(24)		(30)																			
Max. Precip. in 3 Hrs																						
Amount	28		93	16					21		20		19	38		9						
Date	(15)		(29)	(11)					(16)		(24)		(24)	(10)		(26)						
Amount	24		13																			
Date	(24)		(30)																			
Max. Precip. in 2 Hrs																						
Amount	25		79	14					20		19		16	38		7						
Date	(15)		(29)	(11)					(16)		(24)		(24)	(10)		(26)						
Amount	22		12																			
Date	(24)		(30)																			
Max. Precip. in 1 Hr																						
Amount	17		47	8					19		15		8	19		4						
Date	(15)		(29)	(11)					(16)		(24)		(24)	(10)		(26)						
Amount	12		7																			
Date	(24)		(30)																			

* Days with precipitation ≥ 25 mm
** Bracketed figures are dates -- [(15) = 15th day)]

TABLE 2 (cont.)

PRECIPITATION AMOUNTS AND INTENSITIES (AMOUNTS IN MM)
AG-14

Year	1975							1976												1977		
Month	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Total Precip. (mm)	85	47	193	78	31	81	71	122	53	108	30	58	144	70	26	108	75	85	45	143	30	40
No. of Days with Measurable Precip.	17	7	9	16	8	14	16	25	12	12	7	8	9	7	4	11	12	18	12	21	99	9
No. of Heavy* Precip. Days	0	0	2	0	0	0	0	0	0	0	0	0	2	1	0	0	1	0	0	1	0	0
Heavy Precip. ≥ 25 mm																						
Amount			32 **										30	34			30			25		
Date			(11)										(28)	(29)			(6)			(17)		
Amount			77										53									
Date			(24)										(30)									
Max, Precip. in 3 Hrs																						
Amount			32										17	15			10			5		
Date			(11)										(28)	(29)			(6)			(17)		
Amount			56										24									
Date			(24)										(30)									
Max. Precip. in 2 Hrs																						
Amount			32										12	12			8			4		
Date			(11)										(28)	(29)			(6)			(17)		
Amount			41										21									
Date			(24)										(30)									
Max. Precip. in 1 Hr																						
Amount			17										10	8			5			2		
Date			(11)										(28)	(29)			(6)			(17)		
Amount			25										15									
Date			(24)										(30)									

* Days with precipitation ≥ 25 mm

** Bracketed figures are dates - [(11) = 11th day)]

2.0 PRECIPITATION QUALITY

Precipitation chemistry studies are of importance in the PLUARG study for information on direct loadings to the lakes and also on chemical inputs to the agricultural soils in the PLUARG watersheds. The importance of the atmosphere as a source of nutrients or other material loading on the earth's surface has not received significant attention until recently. However, the World Meteorological Organization is now interested in the problem and a network of precipitation chemistry stations has been installed by the Atmospheric Environment Service in Canada (Whelpdale 1977).

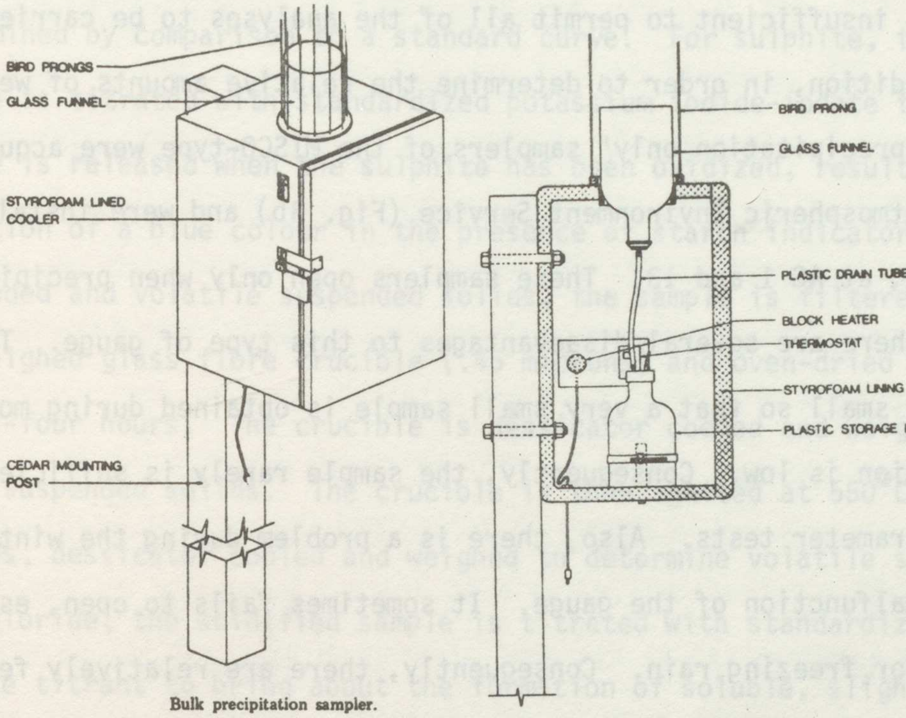
2.1 Sources of Pollutants in Precipitation

The chemical elements found in precipitation enter the atmosphere by both natural and man-made processes. Probable sources of sulphate and sulphite are the combustion of fossil fuels and industrial processes. Phosphates in the atmosphere can come from fertilizers and soil dust. Industrial processes as well as soil dust are the probable sources of potassium, magnesium and chloride. Sodium and calcium may also come from soil dust. Road salting is a potential source of sodium and chloride in winter. P.C.B.s are pollutants, relatively recently identified in the environment, which are also related to industrial processes. Nitrogen comes from the soil, fertilizer and animal wastes.

2.2 The Samplers

Bulk precipitation samplers of a type originally obtained from the Canada Centre for Inland Waters (Shiomi and Kuntz 1973) were built by the University of Windsor (Fig. 3a). These were installed on the six intensive watersheds (AG 1, 3, 4, 5, 10 and 13) during the first two weeks of May, 1975.

The collecting orifice is 30 cm. in diameter with a non-metallic screen filter at its base and the glass collecting bottle is four litres in volume. The samples are collected at the end of each month. The amount of the sample,



Bulk precipitation sampler.

Bulk precipitation sampler interior.

Figure 3a

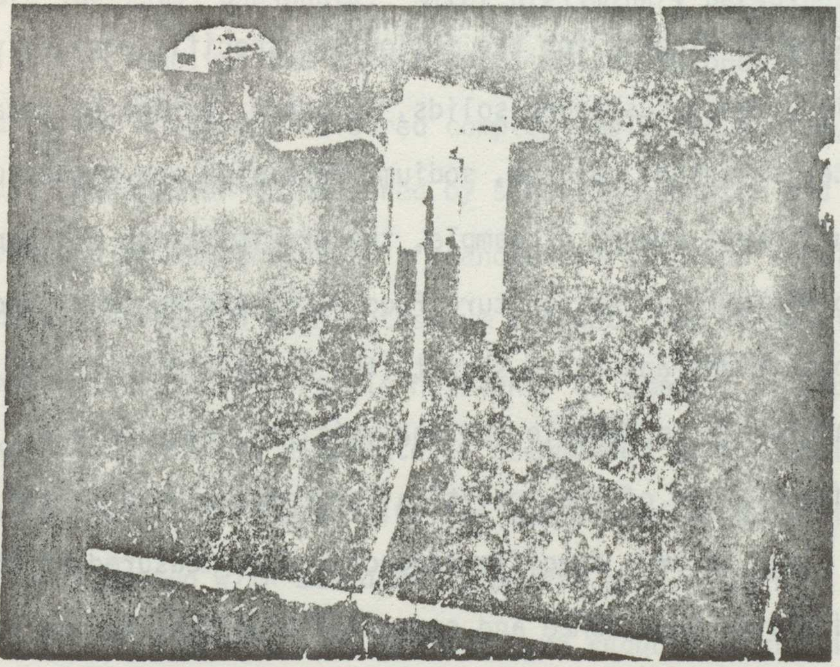


Figure 3b

Misco Model 93 Precipitation Monitor

of course, varies with the amount of precipitation, and in some cases, the sample was insufficient to permit all of the analyses to be carried out.

In addition, in order to determine the relative amounts of wet and dry fallout, "precipitation only" samplers of the MISCO-type were acquired on loan from the Atmospheric Environment Service (Fig. 3b) and were installed in June, 1976, at AG 1 and 13. These samplers open only when precipitation occurs. However, there are several disadvantages to this type of gauge. The gauge orifice is small so that a very small sample is obtained during months when precipitation is low. Consequently, the sample rarely is sufficient to permit all the parameter tests. Also, there is a problem during the winter months with the malfunction of the gauge. It sometimes fails to open, especially with snow or freezing rain. Consequently, there are relatively few sample values for each parameter.

2.3 Analytical Procedures

The samples were collected monthly from the six sites and were analyzed at the University of Windsor for the following: specific conductivity, volatile suspended solids, total suspended solids, sulphate, sulphite, total nitrogen, total phosphate, chloride, calcium, sodium, potassium and magnesium. When there was a sufficient amount of sample, the precipitation was sent to Guelph, to the Ontario Ministry of Agriculture Food Pesticide Residue Laboratory for analysis for pesticides and P.C.B.s,or to the Ontario Ministry of the Environment laboratory in Rexdale for analysis for heavy metals.

A brief description of the analytical procedures used at the University of Windsor is given below. Specific conductance is measured at 25°C using a Copenhagen radiometer type CDM2e and corrected according to the cell constant. For sulphate, the turbidimetric method used is based on the precipitation of the sulphate ion in a hydrochloric acide medium with barium chloride to form barium sulphate crystals of uniform size. Absorbance of the barium sulphate suspension is measured by spectrophotometer and the sulphate concentration is determined by comparison to a standard curve. For sulphite, the acidified sample is titrated with standardized potassium iodide-iodate titrant. Free iodine is released when the sulphite has been oxidized, resulting in the formation of a blue colour in the presence of starch indicator. For total suspended and volatile suspended solids, the sample is filtered through a pre-weighed glass fibre crucible (.45 microns) and oven-dried at 103°C for twenty-four hours. The crucible is dessicator cooled and weighed to determine total suspended solids. The crucible is then ignited at 550°C for thirty minutes, dessicator cooled and weighed to determine volatile suspended solids. For chloride, the acidified sample is titrated with standardized mercuric nitrate titrant to bring about the formation of soluble, slightly dissociated mercuric chloride.

As far as the nutrient parameters are concerned, the following is the procedure for total phosphate. After preliminary persulphate digestion, the principle involves the formation of molydophosphoric acid which is reduced to the intensely coloured complex, molybdenum blue, by stannous chloride. Absorption is measured by spectrophotometer and the concentration is determined by comparison to a standard curve. For total kjeldahl nitrogen, the sample is digested with potassium sulphate and sulphuric acid to convert the ammonia nitrogen of organic nutrients to ammonia bisulphate. The mercury ammonium complex in the digestate is decomposed by sodium thiosulphate and the ammonia is distilled from an alkaline medium and absorbed in boric acid. The ammonia is titrated with standard sulphuric acid titrant. For nitrate and nitrite, after filtering, the nitrates are reduced to nitrites with zinc. Colour development is achieved by the addition of naphthylamine hydrochloride and sodium acetate. The absorbance is determined by spectrophotometer and the nitrite concentration is determined by comparison to a standard curve.

For potassium, sodium, calcium and magnesium, the sample is aspirated into the air hydrogen tri-flame burner of the Jarrel Ash Atomic Absorption Spectrophotometer 82-500 using the appropriate hollow cathode lamp. The concentration is determined by comparison of the absorption reading to a standard curve prepared from certified atomic absorption standards.

2.4 Concentrations

The results of the analyses are given in Appendix I for the following (Tables I to XIII):

I Conductivity
II Suspended Solids
III Sulphate
IV Sulphite
V Nitrogen
VI Phosphate
VII Chloride
VIII Calcium
IX Sodium
X Potassium
XI Magnesium
XII Heavy Metals
XIII P.C.B.s

(Note: The dates of the collection periods 1-23, as listed in these tables, are shown in Table 3, p. 26.)

3.0 SURFACE LOADINGS

The concentrations of each parameter, shown in Appendix I, are of less importance to the researcher than the surface loadings, the amount of each element that reaches the earth's surface. To determine surface loadings, the amount of precipitation which occurred during each collection period at each station was determined. Table 3 shows the twenty-three collection periods with corresponding precipitation amounts for the six precipitation chemistry stations.

The surface loadings in kg/ha for each collection period are given in Appendix II for each of the parameters.

3.1 Surface Loadings and Precipitation Amounts

Since the number of days in each collection period differed, it is not possible to use the loading data in Appendix II (kilograms per hectare) to compare station loadings. However, the various loadings were compared with the amount of precipitation which occurred during the collection period to determine if precipitation does indeed "cleanse the air" of pollutants or if increasing amounts of precipitation resulted in increased surface loadings.

In a study of individual precipitation events and sulphate loadings in Windsor, Osborne (1976) used regression analysis and found that the amount of precipitation accounted for 80% of the variation in sulphate surface loadings. In the present study, surface loadings for each collection period were plotted against total precipitation during the collection period for each parameter and regression lines and correlation coefficients obtained. These are given for the chemical components in Table 4 in descending order of correlation coefficient.

An example of the scatter diagrams using the surface loadings of sulphite for various precipitation amounts is seen in Fig. 4. Sulphite loadings showed the highest correlation (0.81) with precipitation amounts. From the coefficient

TABLE 3

Precipitation Amounts for Collection Periods at 6 PLUARG Stations (mm)

	Collection Period	No of days	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
1975	1. May (1) - June 23	variable	100	120	131	162	121	81
	2. June 23 - July 29	36	90	65	89	66	74	66
	3. July 29 - Sept 3	36	221	163	184	172	185	247
	4. Sept 3 - Oct 8	35	63	69	70	53	68	58
	5. Oct 8 - Nov 16	39	40	55	84	56	75	38
	6. Nov 16 - Dec 15	29	84	62	45	66	70	78
1976	7. Dec 15 - Jan 16	32	51	48	79	58	54	52
	8. Jan 16 - Feb 16	31	37	46	69	34	34	42
	9. Feb 16 - Mar 7	20	120	79	119	103	113	145
	10. Mar 7 - Apr 17	41	63	71	101	64	74	57
	11. Apr 17 - May 15	28	88	105	89	116	139	81
	12. May 15 - June 12*	28	28	30	31	16	29	23
	13. July 13 - Aug 8	27	33	128	74	158	68	42
	14. Aug 8 - Sept 9	32	15	67	53	152	32	14
	15. Sept 9 - Oct 1	22	86	79	88	87	97	93
	16. Oct 1 - Nov 3	33	57	50	65	76	55	56
	17. Nov 3 - Dec 4	31	20	60	37	53	17	36
1977	18. Dec 4 - Jan 3	30	15	35	37	23	27	16
	19. Jan 3 - Feb 5(10)^2	33(38)^2	24	42	58	34	59	28
	20. Feb 5(10)^2 - Mar 6	29(24)	54	37	86	49	40	35
	21. Mar 6 - Apr 2	27	64	36	49	39	72	81
	22. Apr 2 - May 1	29	128	65	51	53	71	122
	23. May 1 - June 11(12)^3	42(43)^3	87	54	36	42	63	76

* June 12 - July 13, no chemical analysis; all samples destroyed by accident.

(1) Start of period variable: AG 1 - May 27; AG 3 - May 15; AG 4 - May 7; AG 5 - May 6; AG 10 - May 15; AG 13 - May 27.

(2) Feb 5 for AG 1, 13. Feb 10 for AG 3, 4, 5, 10.

(3) June 11 for AG 1, 10, 13. June 12 for AG 3, 4, 5.

TABLE 4

The Relationship Between Surface Loading and Precipitation Amounts

Chemical Component	Coefficient r	Coefficient of Determination r^2	Regression line x = precipitation (mm.) y = rate of loading (kg/ha)
Sulphite	0.81	0.66	y = 0.09 + 0.016 x
Copper	0.77	0.59	y = .00072 + 0.00012 x
Chloride	0.62	0.38	y = -0.66 + 0.022 x
Posphate	0.55	0.32	y = -0.05 + 0.005 x
Sulphate	0.52	0.27	y = 1.91 + 0.044 x
Zinc	0.47	0.22	y = 0.046 + 0.002 x
Nitrogen	0.41	0.17	y = 1.25 + 0.024 x
Calcium	0.40	0.16	y = 0.35 + 0.007 x
Potassium	0.38	0.14	y = 0.19 + 0.006 x
Magnesium	0.36	0.13	y = 0.23 + 0.004 x
Lead	0.33	0.11	y = 0.0048 + 0.00004 x
Sodium	0.05	0.002	y = 1.31 + 0.004 x

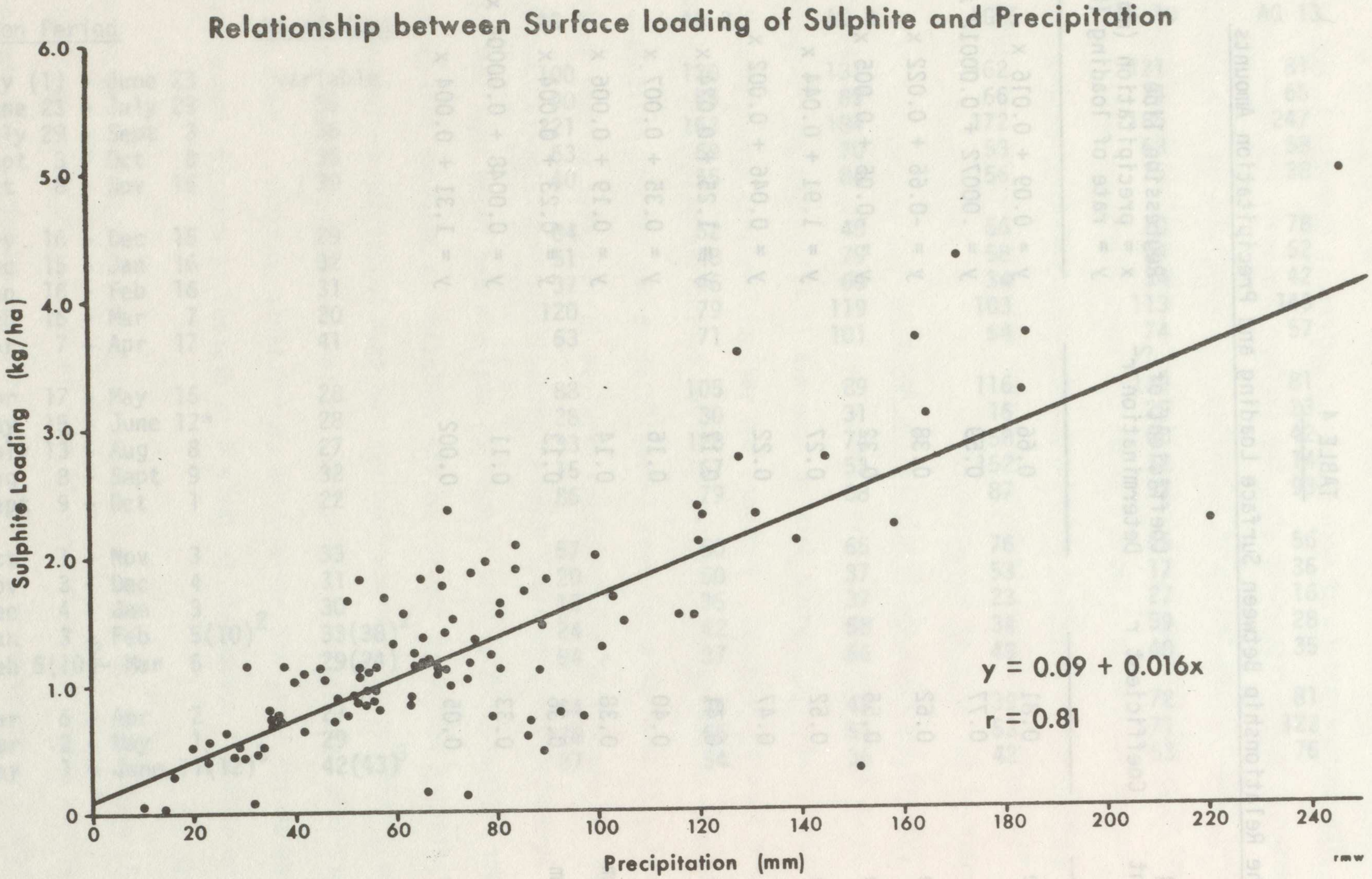

Relationship between Surface loading of Sulphite and Precipitation
Sulphite Loading (kg/ha)
6.0
5.0
4.0
3.0
2.0
1.0
0
0
20
40
60
80
100
120
140
160
180
200
220
240
Precipitation (mm)
y = 0.09 + 0.016x
r = 0.81
rmw

Figure 4

of determination, 66% of the total variance in the rate of loading of sulphite was due to a linear association between precipitation and rate of loading. For every 1 mm. increase in precipitation during the collection period, the rate of loading increased 0.016 kg/ha. For copper, the total amount of precipitation explained 59% of the surface loadings, for chloride 32%, phosphate 38%, sulphate 27%, etc. All chemical components except sodium showed significant relationships between loadings and precipitation amounts at the .05 level of significance. This is contrary to the idea of "scavenging" which implies that as precipitation amounts increase, the rate of loading decreases. Rather, with most components, as the amount of precipitation increased, so did the loading rates.

3.2 Surface Loadings in grams per hectare per day

In order to compare the chemical loadings over time and geographically, all data were transformed into surface loadings expressed as grams per hectare per day. Monthly and annual loadings can thus be easily obtained. These data are shown in Appendix III Tables I-XI. It will be noted in the nitrogen table (Table III) that only eleven collection periods were reported. A great deal of trouble was encountered with the nitrogen analyses and with analyst errors in the method used. Consequently many data were discarded. The data in Appendix III, the loadings in grams per hectare per day, were then subjected to various statistical tests as seen in Section 4.

4.0 STATISTICAL PROPERTIES OF SURFACE LOADING DATA (by P. D. LaValle)

4.1 Introduction

The purpose of this part of the investigation was to describe the basic statistical properties of the chemical data derived from the six intensive watersheds. An attempt was made to assess both the temporal and spatial variability of the precipitation chemistry samples taken over a two year period. Due to the relatively short period of sampling and the problem of occasional sample loss from the reporting watersheds, the temporal analysis was limited to the search for significant short term trends and possible periodicity. Spatial comparisons were made on a watershed basis.

4.2 Normality Tests

Since most detailed parametric statistical tests require that the sampling distributions of the data be distributed according to the Normal Probability Distribution, each set of chemical data was subjected to a test for normality. In this investigation, a modified Kolmogorov-Smirnov One sample test, especially designed to assess normality, was utilized following the procedure outlined by Lilliefors (1967). Where the null hypothesis that the sample distribution fits the normal curve is rejected, we tested the distribution for extreme values and also tested it against the null hypothesis that it may conform to a log - normal distribution. The results are summarized in Appendix IV Tables I -X. The data on P.C.B.s and heavy metals were not tested due to the small sample size.

Most of the data sets were normally distributed. The specific conductivity data were found to be log - normal (Table I). The sulphate and sulphite data were normal except AG 4 for sulphate and AG 13 for sulphite which were log normal (Tables II and III). A similar pattern was observed for the chloride data where all watersheds except AG 4 were normally distributed (Table VI) and AG 4 was normally distributed with the deletion of one extreme value.

The nitrogen samples were found to be normally distributed (Table IV). This may be due to the fact that the sample sizes were moderately small, but when the significance level was reduced to 0.20, all of the watershed samples still fit a normal distribution. This latter procedure is necessary to reduce the probability of a type II error, which is accepting the false null hypothesis that the data conform to a normal probability distribution keeping in mind that the significance level reflects the probability of making a type I error, which is rejecting a true null hypothesis.

With respect to the phosphate data (Table V) watersheds AG 3 and AG 4 were found to depart significantly from normality at the .05 level. When the data were subjected to a logarithmic transformation better fit to the normal curve was obtained implying that these data might best be described a log - normal.

As far as the metals were concerned, all of the sodium, potassium and magnesium sample sets (Tables VIII, IX and X) were normally distributed at the .05 level of significance. For calcium (Table VII) only one watershed sample, AG 10 departed significantly from normality at the .05 level. When the single high value was deleted from the sample, it was found to conform to normality.

The sample data were sufficiently close to normality to run analysis of variance comparisons between the sample watersheds on all the data save the phosphate and conductivity data, because the F-test is reasonably robust and not strongly affected by occasional departures from normality. However, it did seem wise to subject the phosphate and conductivity data to a log transformation before running any parametric tests on that data.

4.3 Time Series Studies

Since the data were obtained monthly over a two year period, some of the temporal variation that may exist between the watersheds may be associated with long term trends and possible cyclical or seasonal effects. Unfortunately complete records were not available for all of the chemical parameters for all of the watersheds, so the analysis was limited to the fitting of least squares trend lines to each watershed sample time series for each parameter, and to the use of the "runs" test (Siegal 1954) which was designed to detect possible cyclical effects on a short term basis. It would have been more informative to subject the data to autocorrelation and autoregression analysis, but the presence of gaps in certain data sets renders this operation quite difficult. However, the least squares trend analysis coupled with the runs test may bring to light any systematic temporal patterns in the watershed chemical sample data, and the results of this analysis are summarized in Appendix V Tables I to IX and shown graphically in Figures 5-32. These graphs show for each watershed for each parameter the loadings (g/ha/d) for each sampling period. Trend lines are shown on each graph. A dotted line indicates that the slope of the trend line is not significantly different from zero. Statistically significant trend lines are shown by solid lines.

All the trend lines for electroconductivity are positive. This could be expected since this parameter measures the ion concentration and during the two year sampling period, precipitation decreased and, as could be expected, conductivity increased. The conductivity data for AG 4 showed a statistically significant trend line. It can be observed that this station had the greatest decrease in precipitation from the first to the second year.

It can be noted on the graphs that almost all of the trend lines show a decreasing loading of the parameter over time. Since it is unlikely that pollution in the air has decreased over the two year sampling period, this phenomenon can be explained by decreasing precipitation. As Section 3 showed more precipitation resulted in more surface loading and Table 4 indicated the magnitude of the correlation coefficient linking loading and precipitation amount. It is noted that the parameters with trend lines horizontal or with slightly decreasing slope were those with the lowest correlation with precipitation amount (e.g. sodium).

Statistically significant trends were also detected for calcium in AG 3, potassium AG 1, and phosphate for AG 1, 4 and 10. The decreased loadings for phosphate more than the other parameters, could indicate a true decrease in the phosphates in the atmosphere.

Once the trend lines were fit to the data, a runs test was applied to the positive and negative deviations from the trend line in order to detect possible cyclical effects (Hammond and McCullagh 1974). In this investigation, the runs tests were all negative indicating that the pattern of deviations from the various trend lines all did not depart significantly from a random pattern suggesting that the short term temporal variations of the precipitation chemical data behaved in a random fashion. However, a longer term study may yield quite different results, because the sample period in this investigation is too short to have much confidence in these results.

4.4 Analysis of Variance Tests

In order to assess the areal variability of watershed precipitation chemistry, an analysis of variance and Bartlett's test were run on each chemical parameter except heavy metals where sufficient data were not available. In the case of the phosphate data and the specific conductivity data, the analysis of variance was run on the logarithms of the data due to the normality problem. Prior to each analysis of variance, Bartlett's test was run to assess the equal variance requirement of analysis of variance. Basically the Bartlett's test is used to test the null hypothesis that the sample variances are equal (Lindquist 1956). The results of the Bartlett's test are summarized in

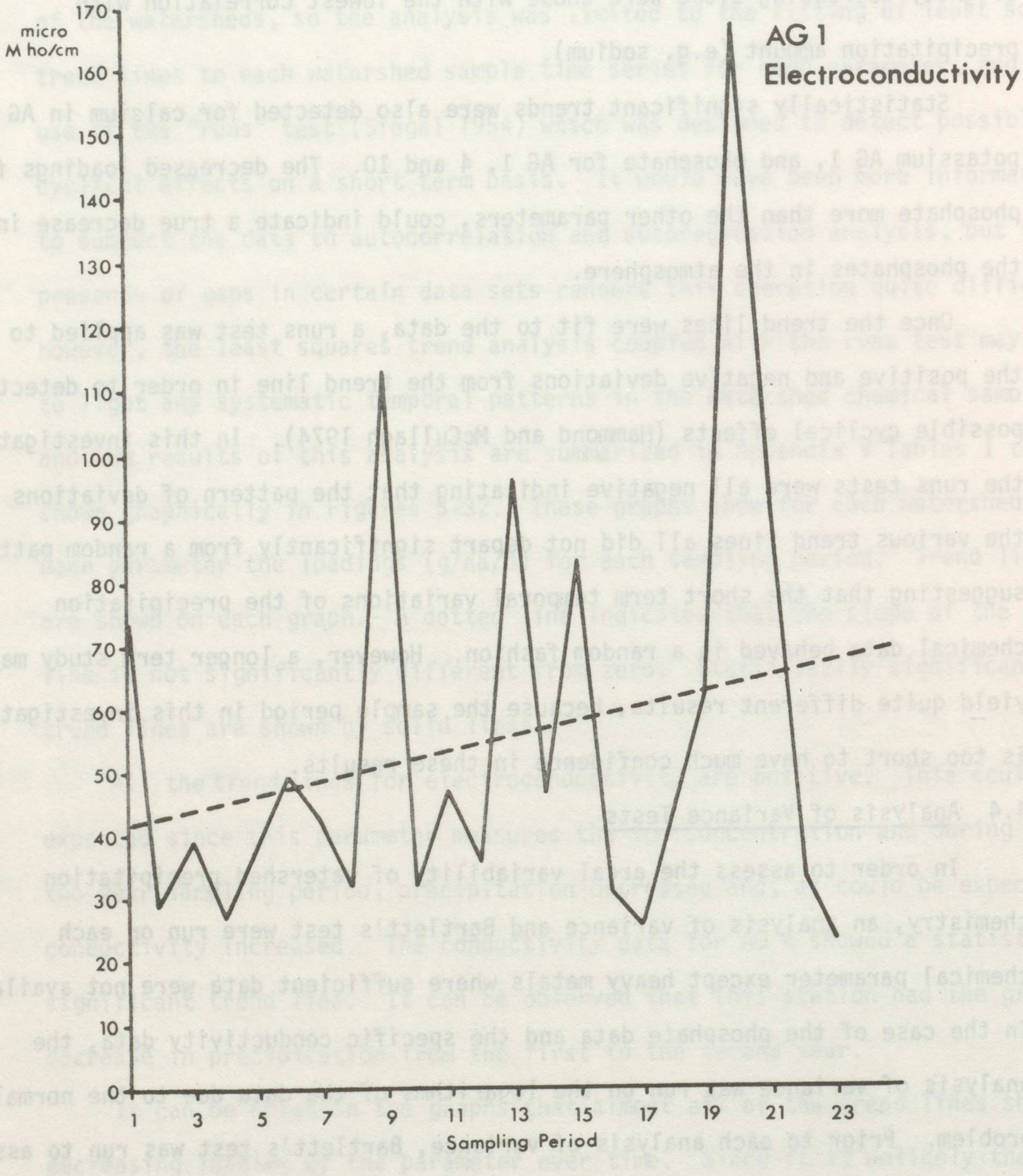

AG 1
Electroconductivity
micro
M ho/cm
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 5

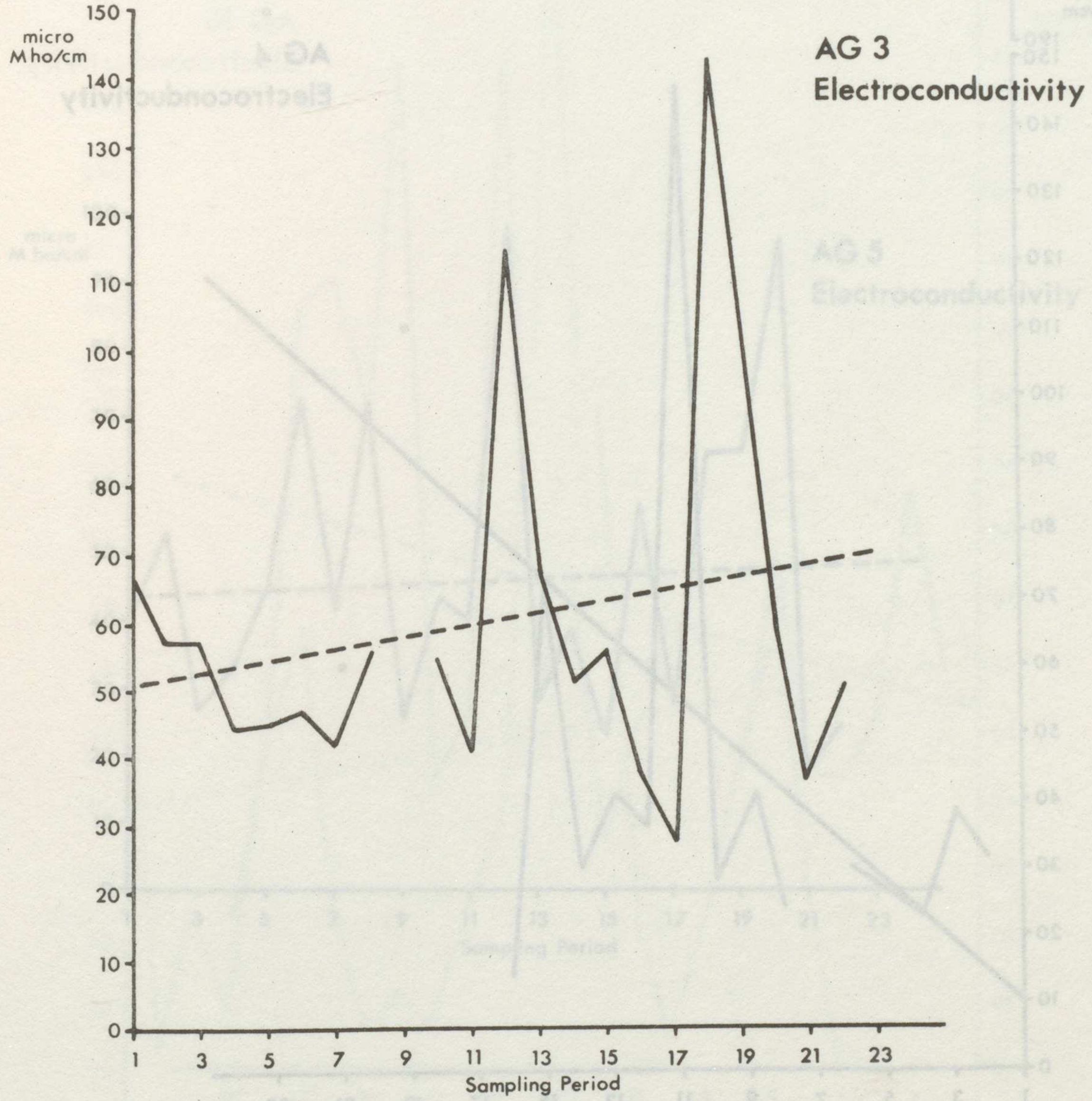

AG 3
Electroconductivity
micro
Mho/cm
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 6

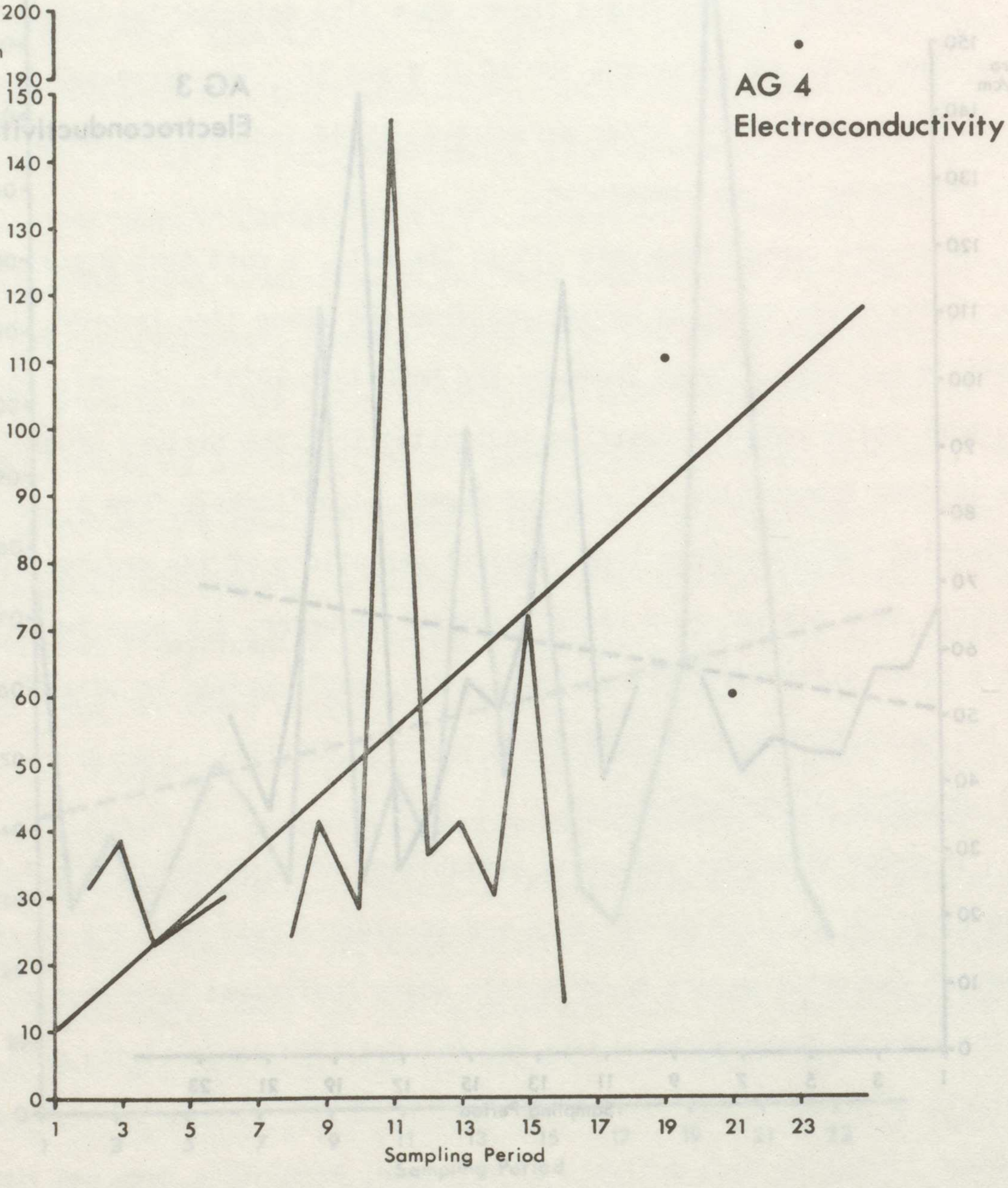

micro
M ho/cm
200
190
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 4
Electroconductivity

Figure 7

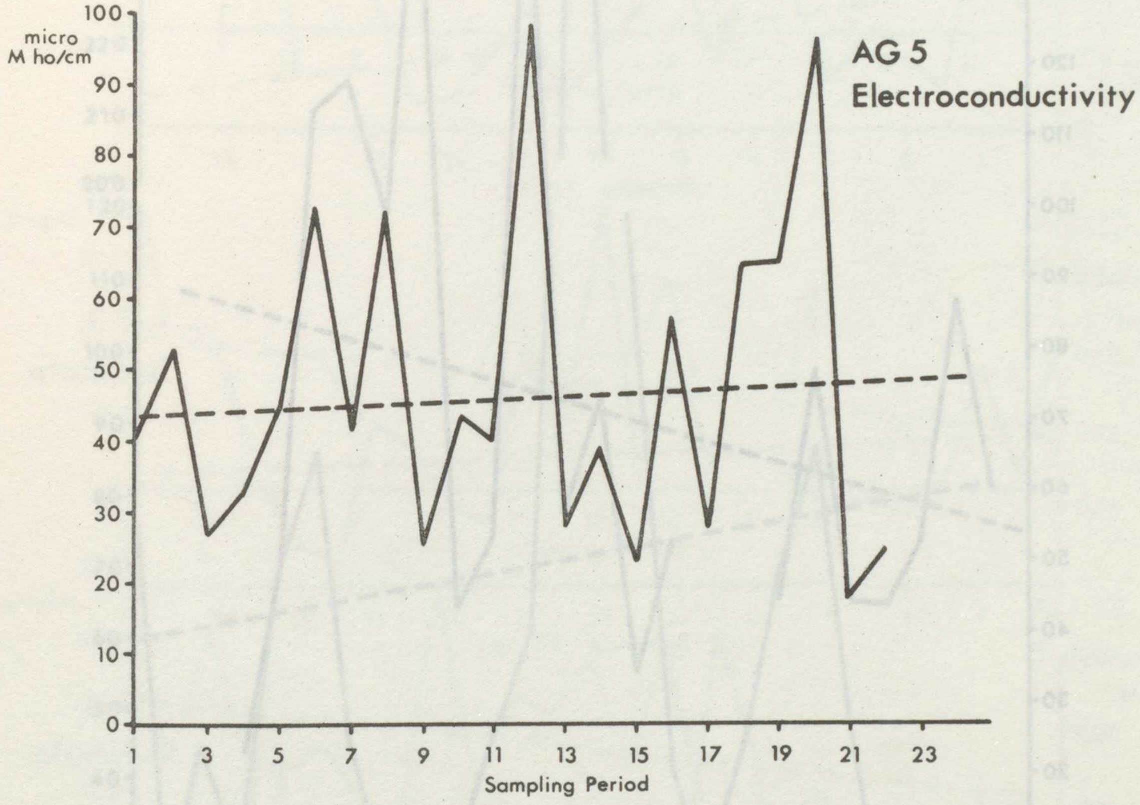

AG 5
Electroconductivity
micro
M ho/cm
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 8

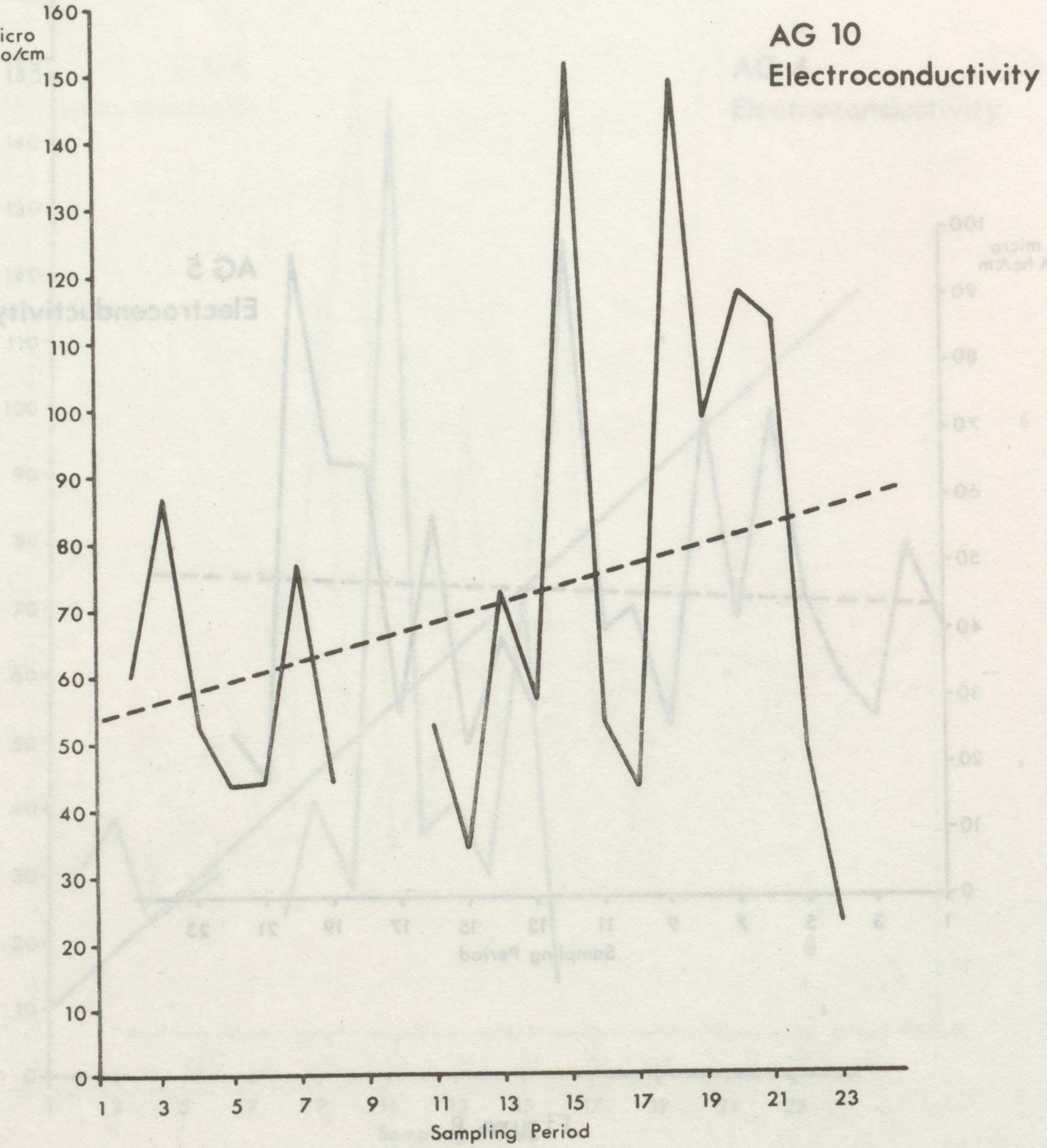

AG 10
Electroconductivity
micro
M ho/cm
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 9

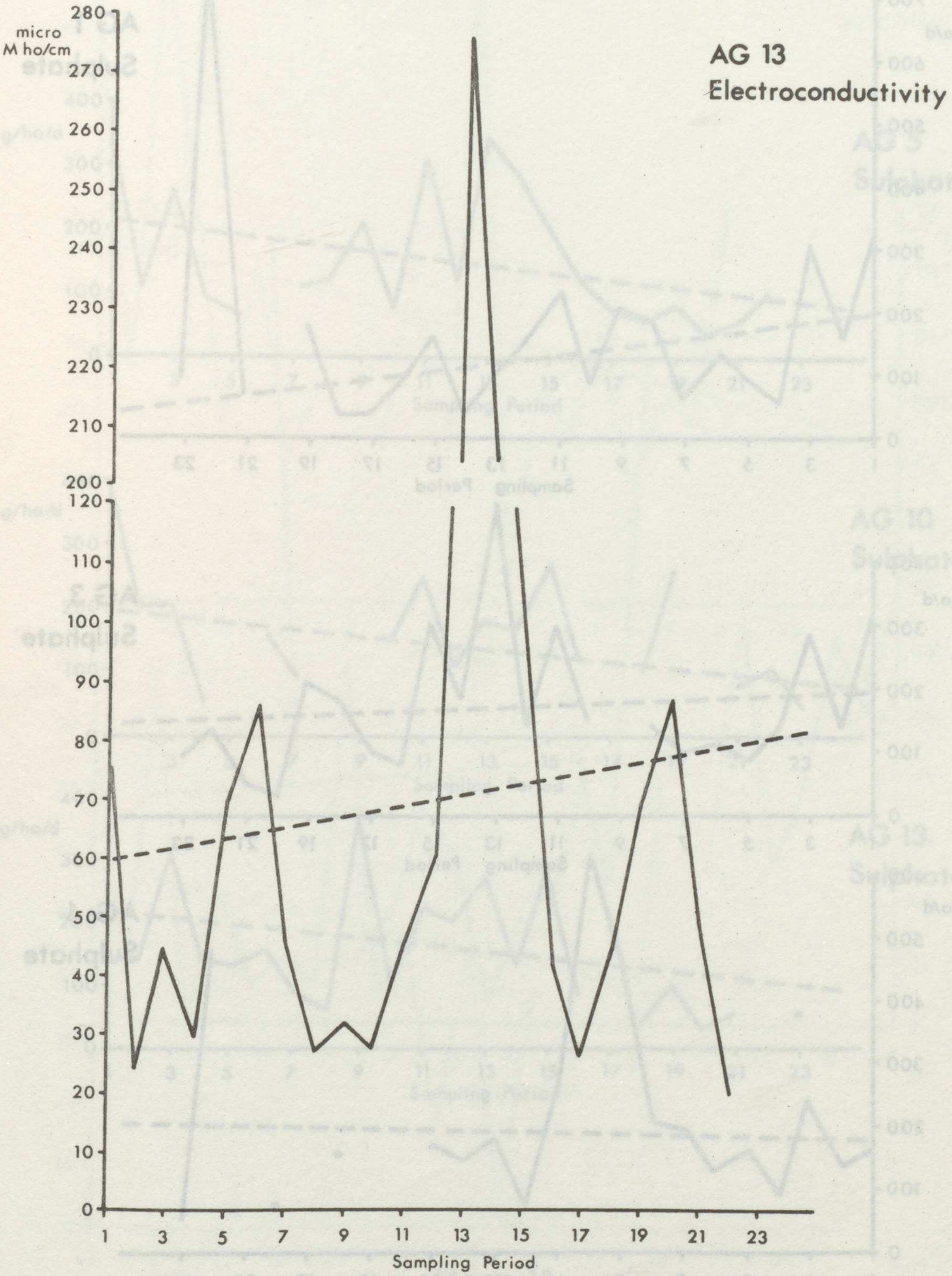

AG 13
Electroconductivity
micro
M ho/cm
280
270
260
250
240
230
220
210
200
120
110
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 10

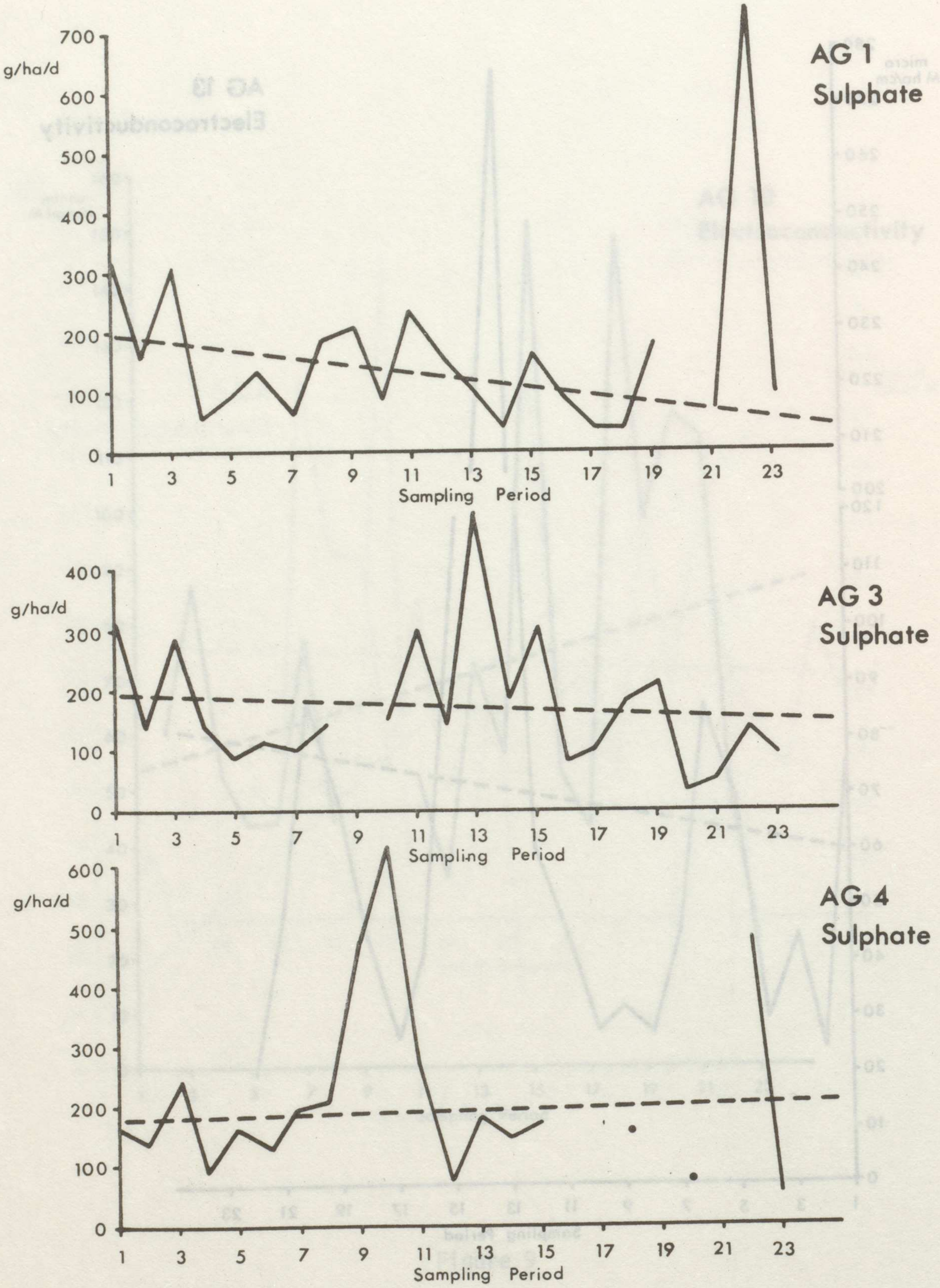

AG 1
Sulphate
g/ha/d
700
600
500
400
300
200
100
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 3
Sulphate
g/ha/d
400
300
200
100
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 4
Sulphate
g/ha/d
600
500
400
300
200
100
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 11

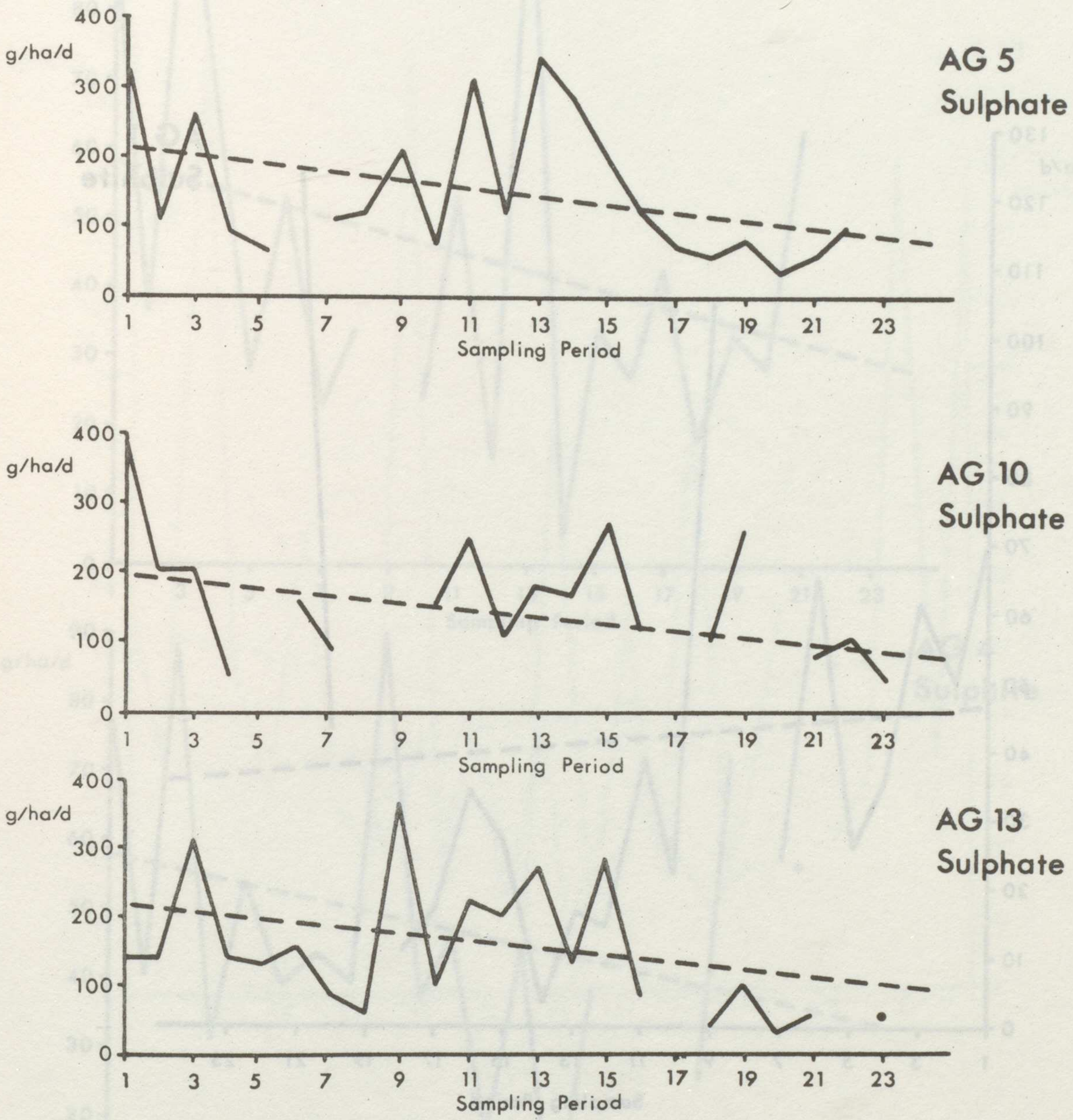

400
g/ha/d
300
200
100
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 5
Sulphate
400
g/ha/d
300
200
100
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 10
Sulphate
400
g/ha/d
300
200
100
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 13
Sulphate

Figure 12

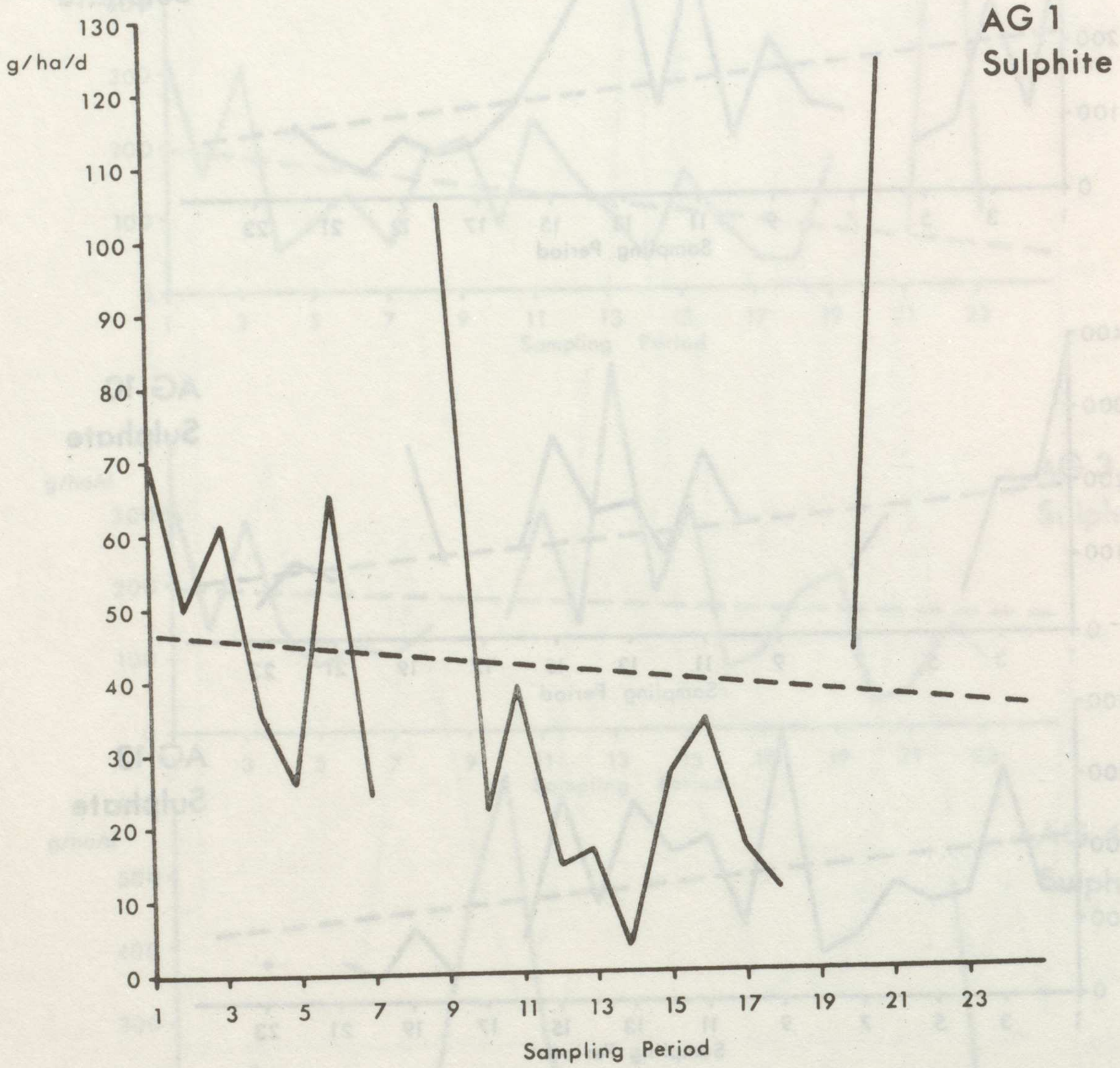

AG 1
Sulphite
g/ha/d
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 13

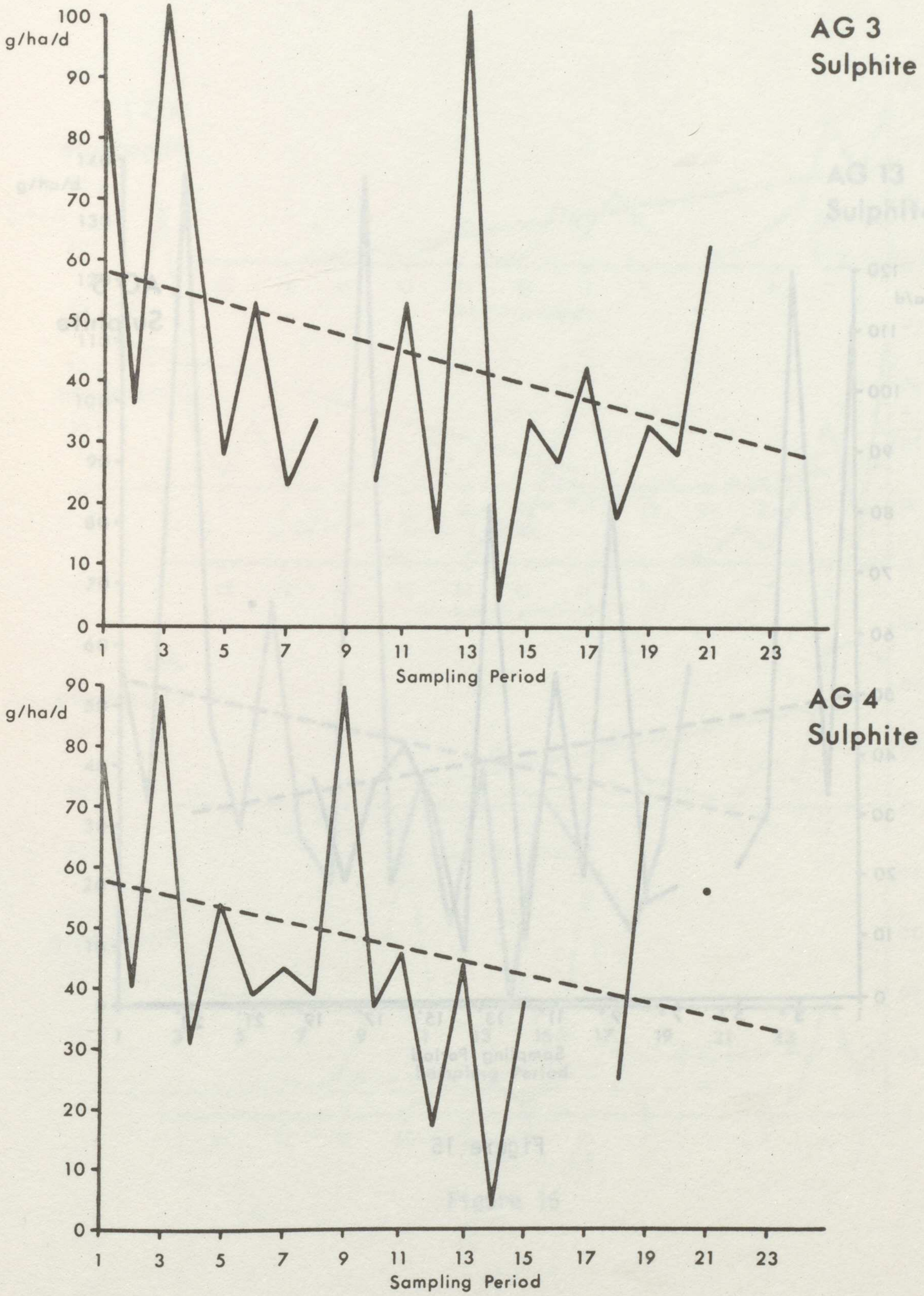

AG 3
Sulphite
g/ha/d
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 4
Sulphite
g/ha/d
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 14

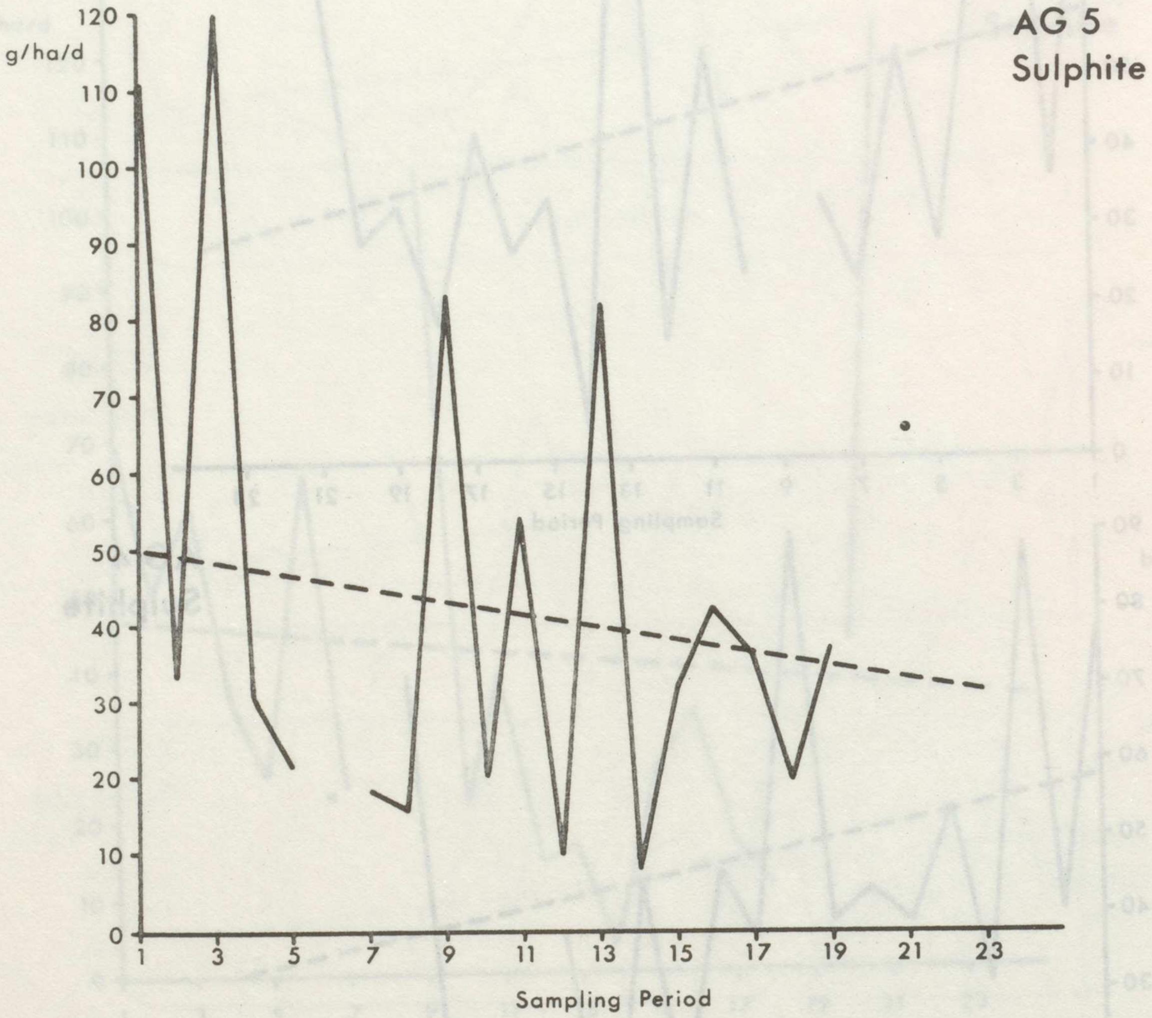

AG 5
Sulphite
g/ha/d
120
110
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 15

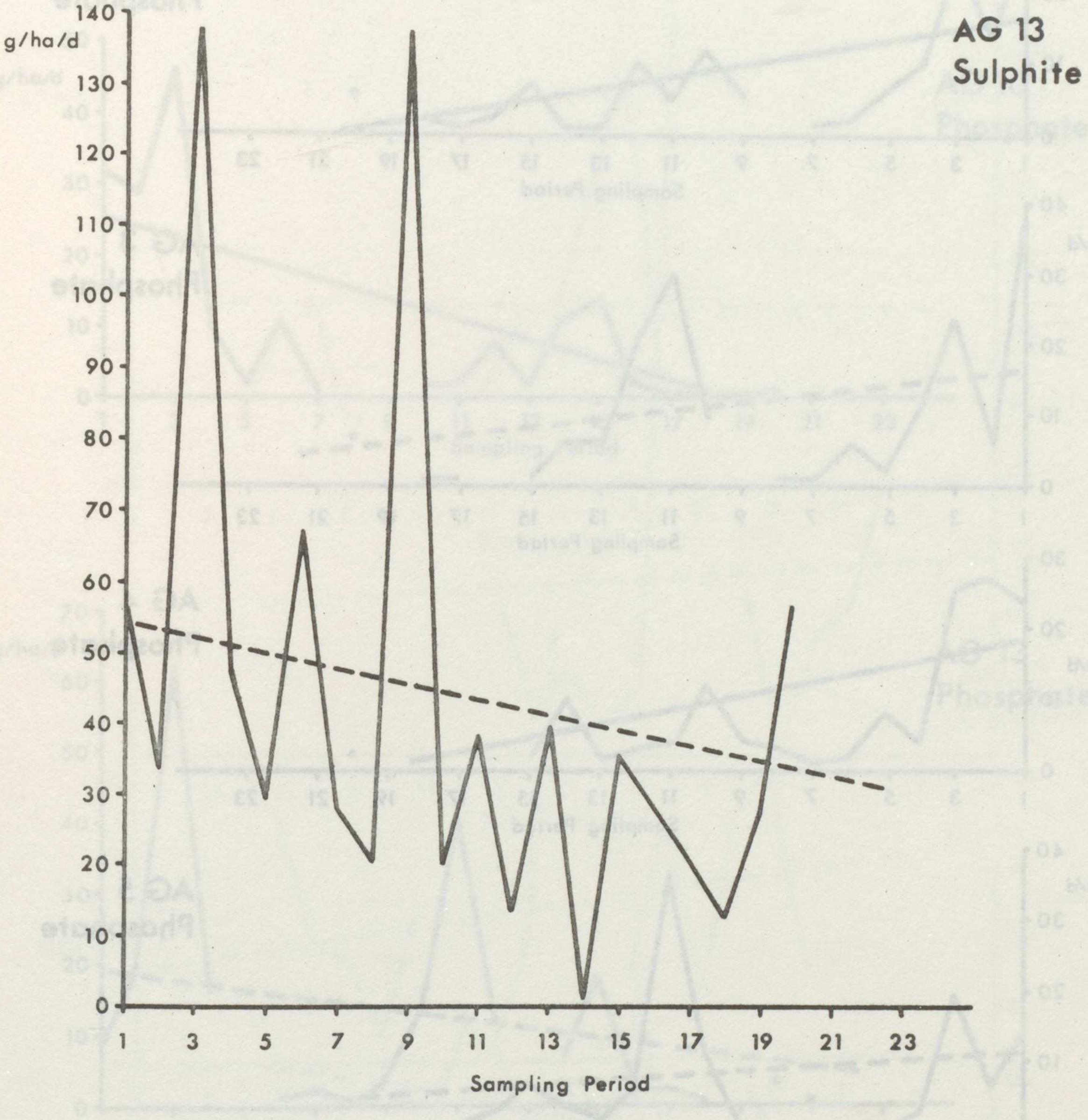

AG 13
Sulphite
g/ha/d
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 16

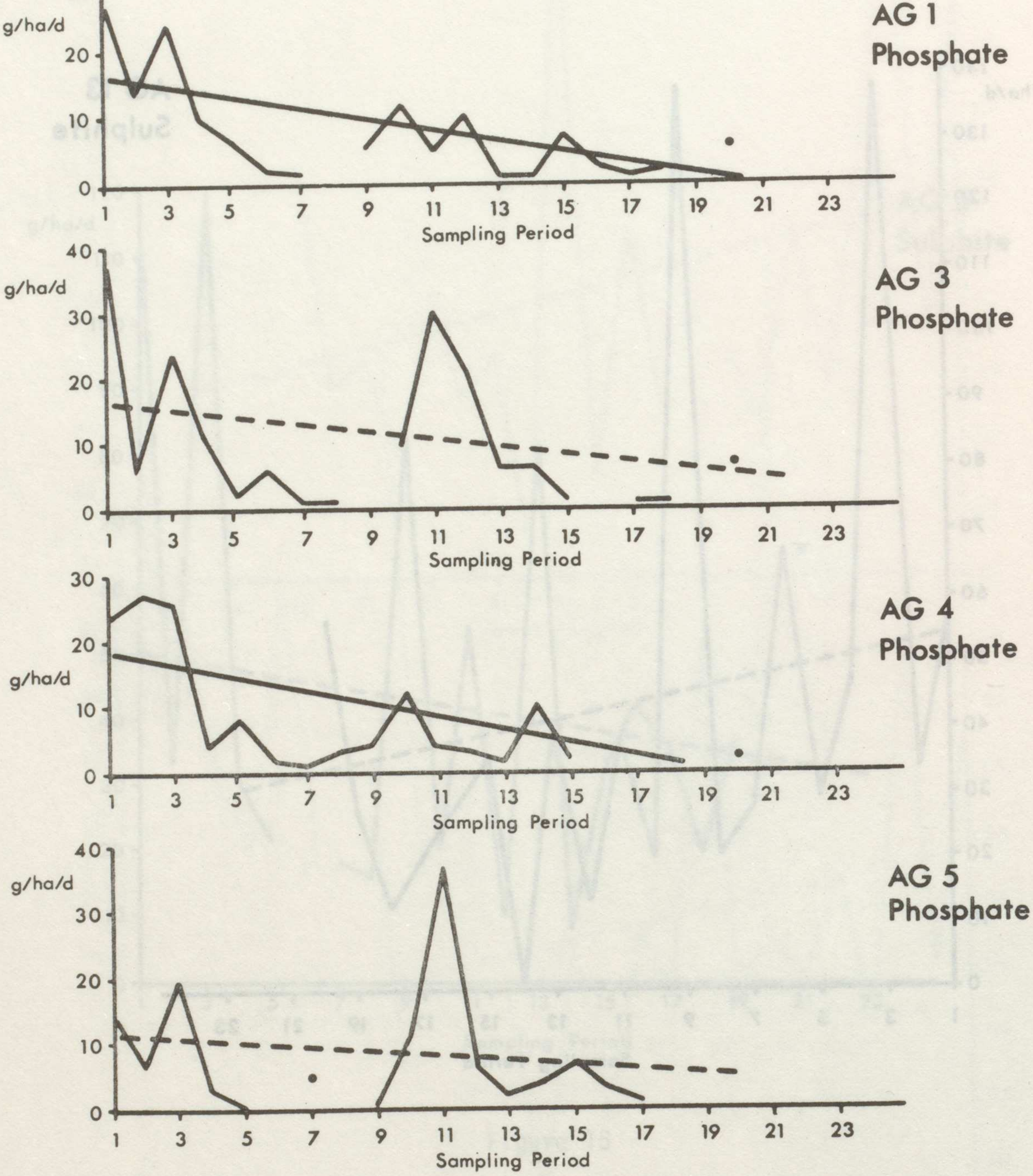

AG 1
Phosphate
g/ha/d
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 3
Phosphate
g/ha/d
40
30
20
10
0
Sampling Period
AG 4
Phosphate
g/ha/d
30
20
10
0
Sampling Period
AG 5
Phosphate
g/ha/d
40
30
20
10
0
Sampling Period

Figure 17

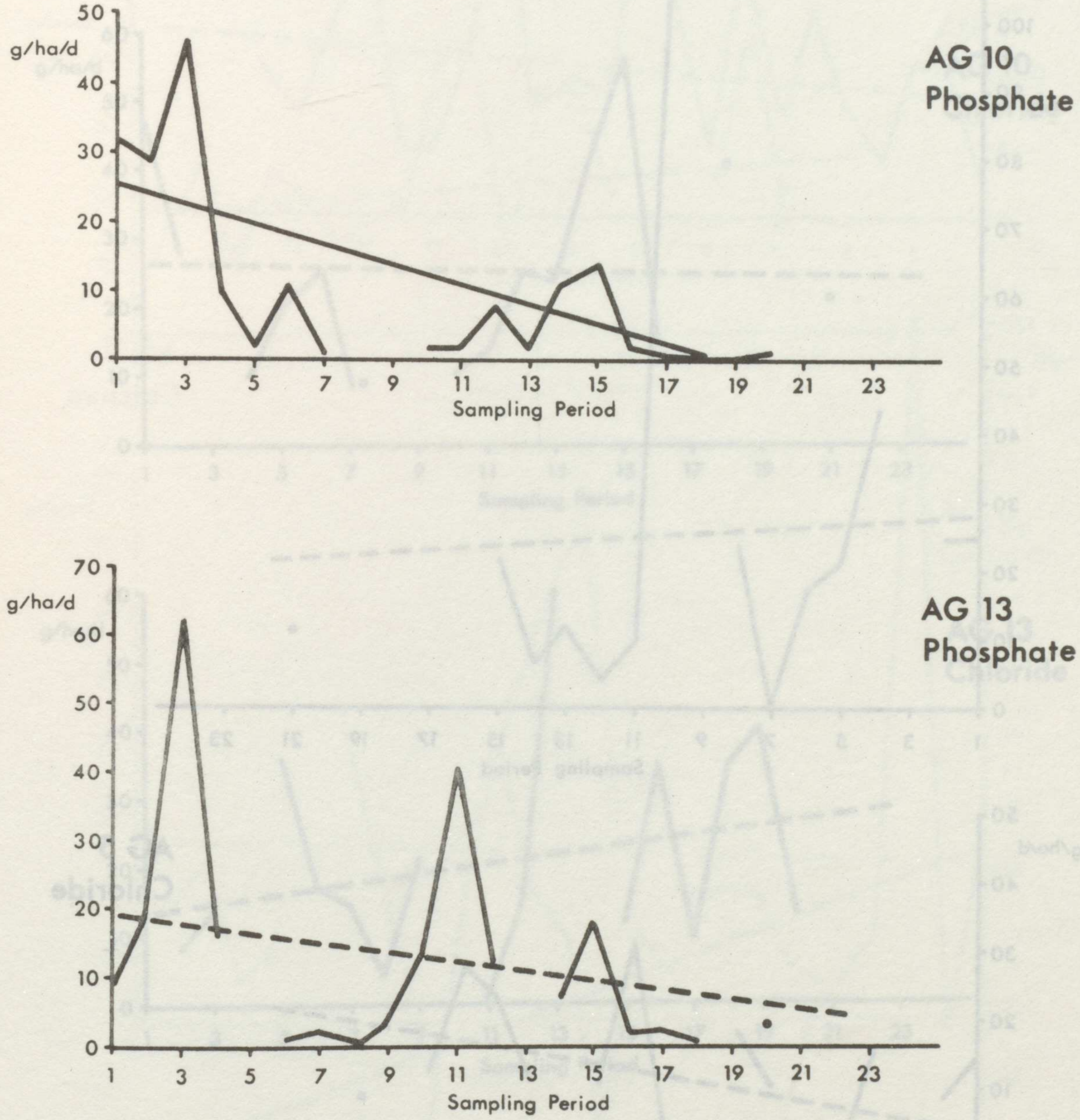

AG 10
Phosphate
g/ha/d
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 13
Phosphate
g/ha/d
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 18

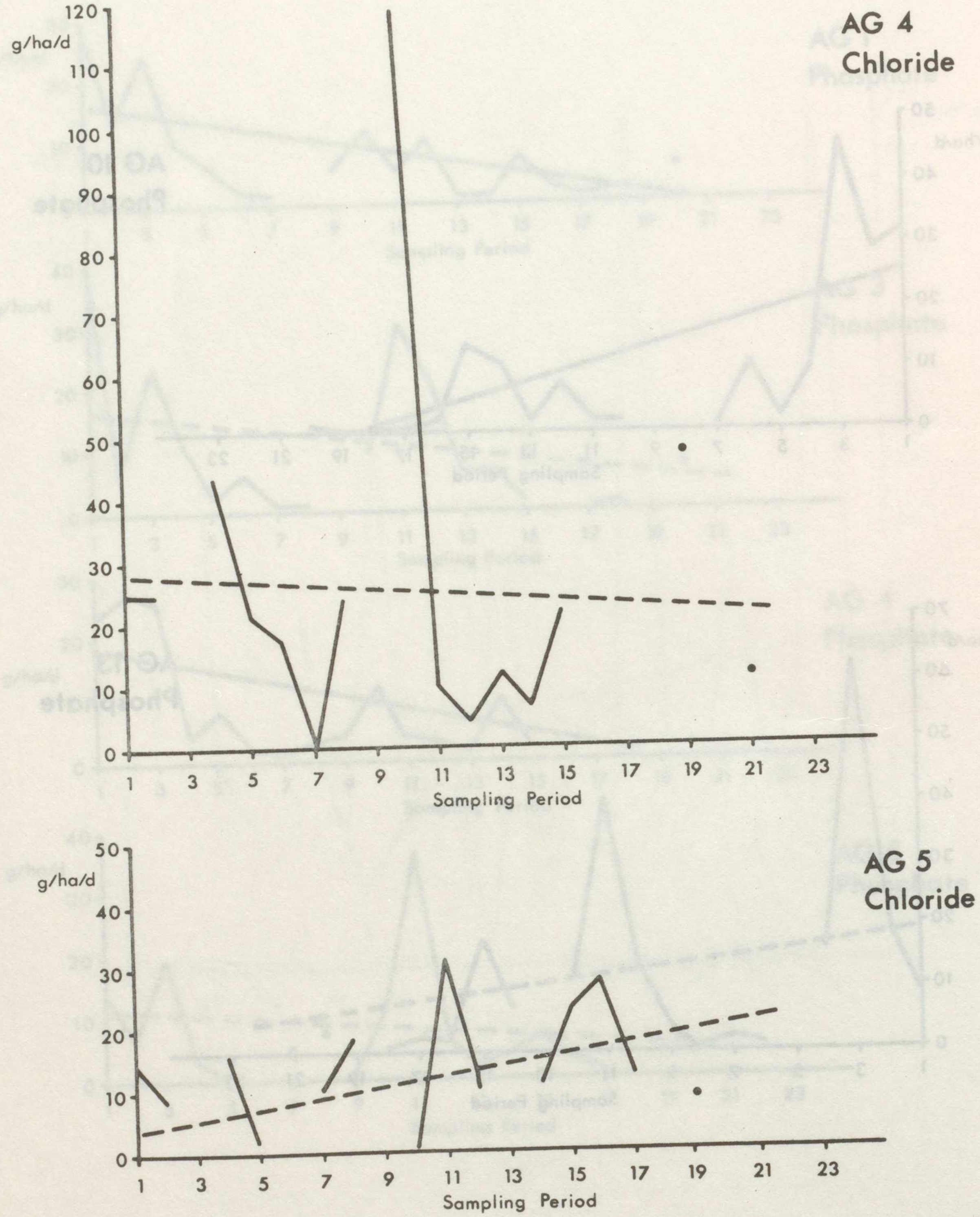

AG 4
Chloride
g/ha/d
120
110
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 5
Chloride
g/ha/d
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 19

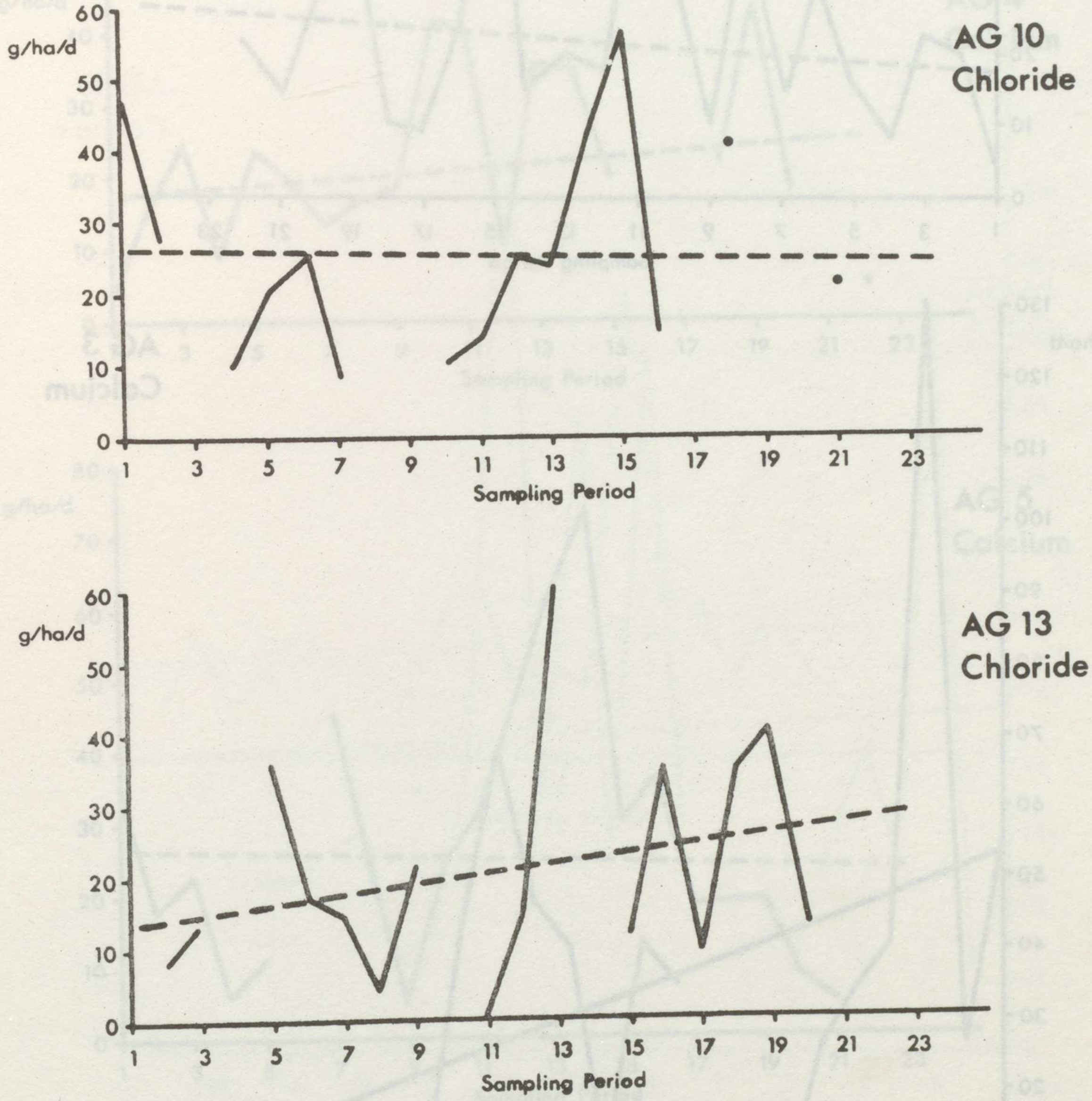

AG 10
Chloride
g/ha/d
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 13
Chloride
g/ha/d
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 20

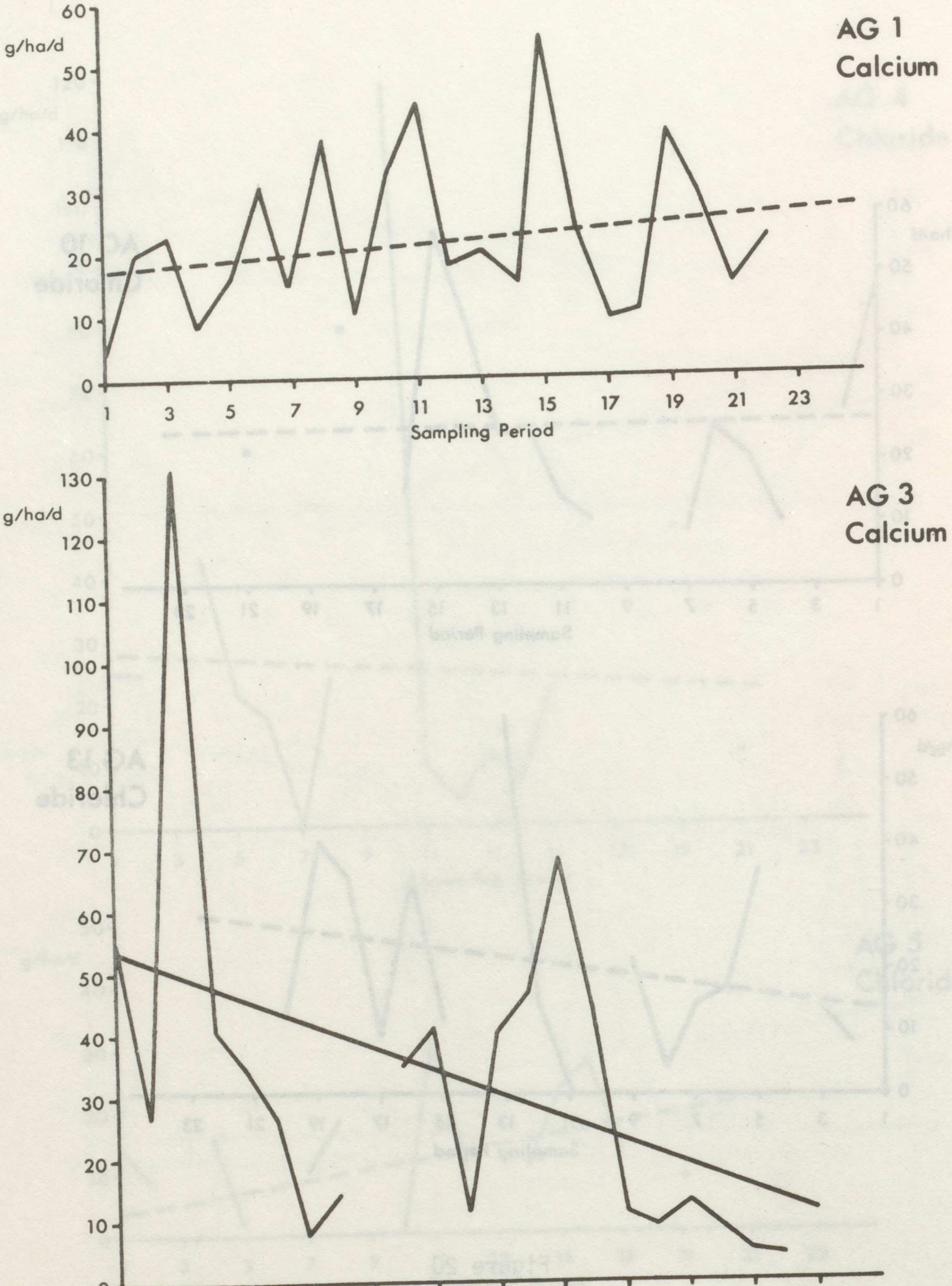

AG 1
Calcium
g/ha/d
0
10
20
30
40
50
60
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 3
Calcium
g/ha/d
0
10
20
30
40
50
60
70
80
90
100
110
120
130
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 21

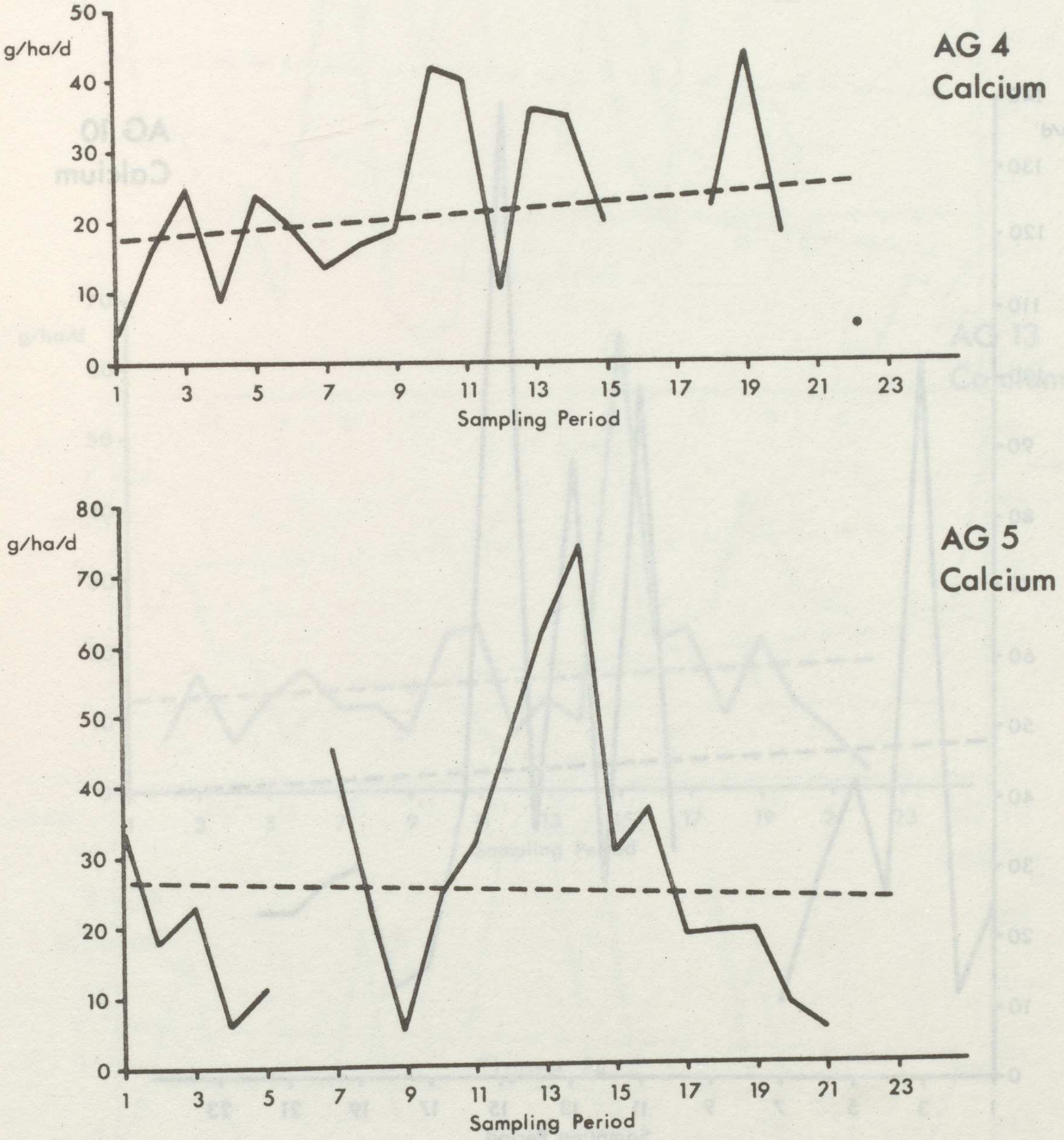

AG 4
Calcium
g/ha/d
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 5
Calcium
g/ha/d
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 22

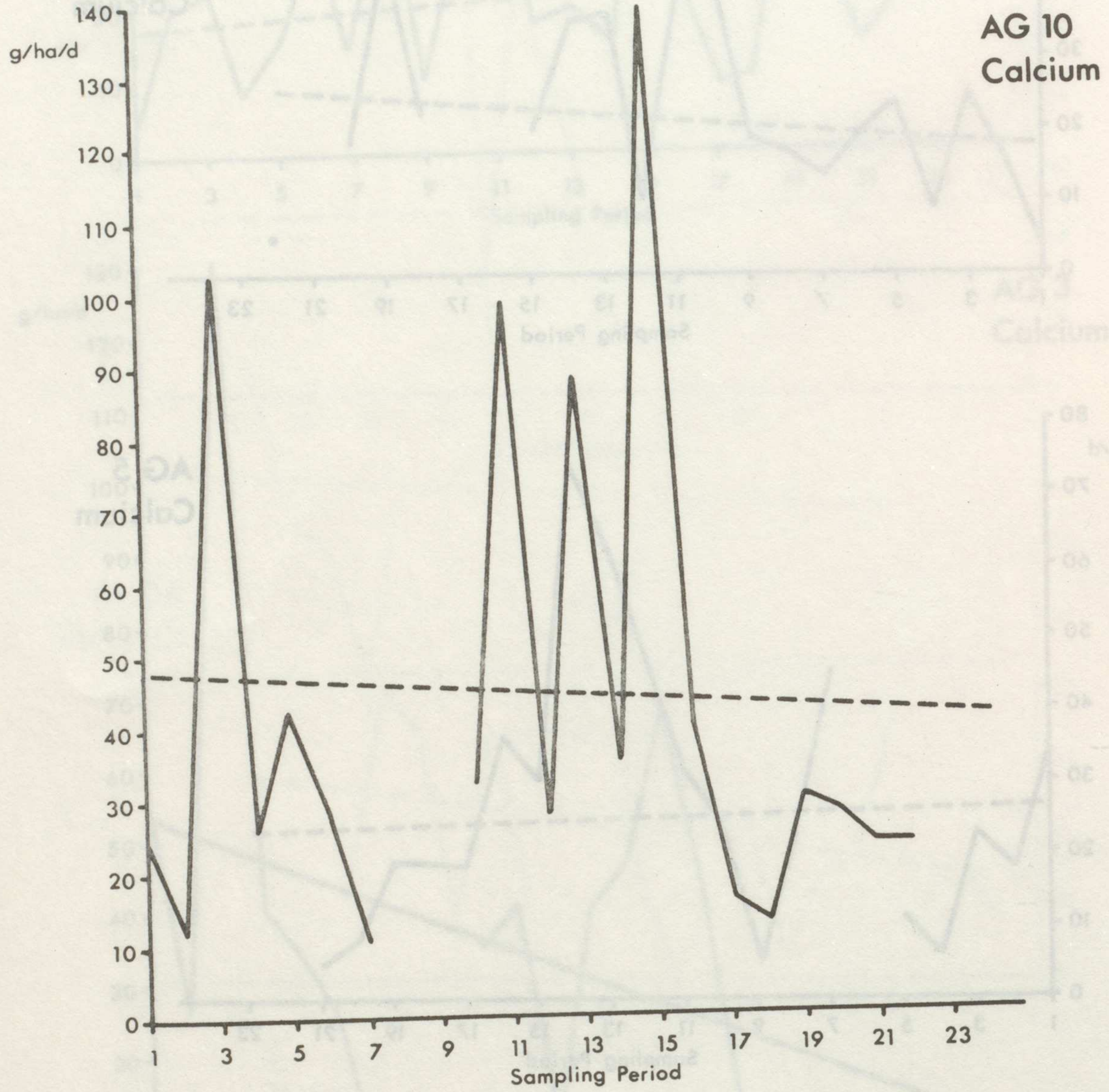

AG 10
Calcium
g/ha/d
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 23

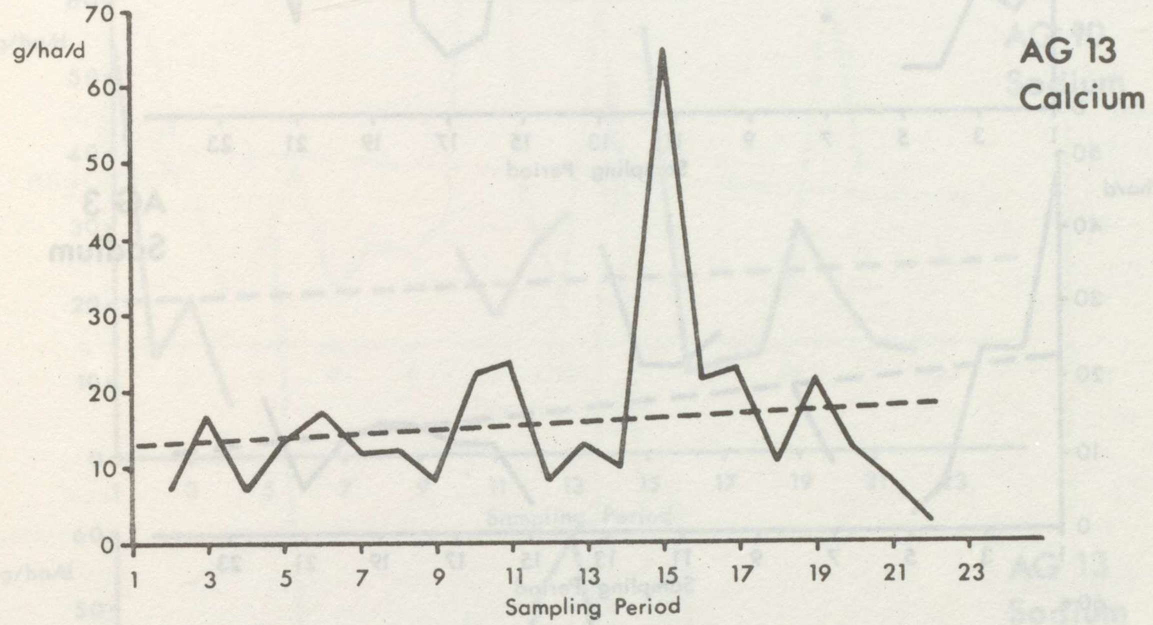

g/ha/d
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 13
Calcium

Figure 24

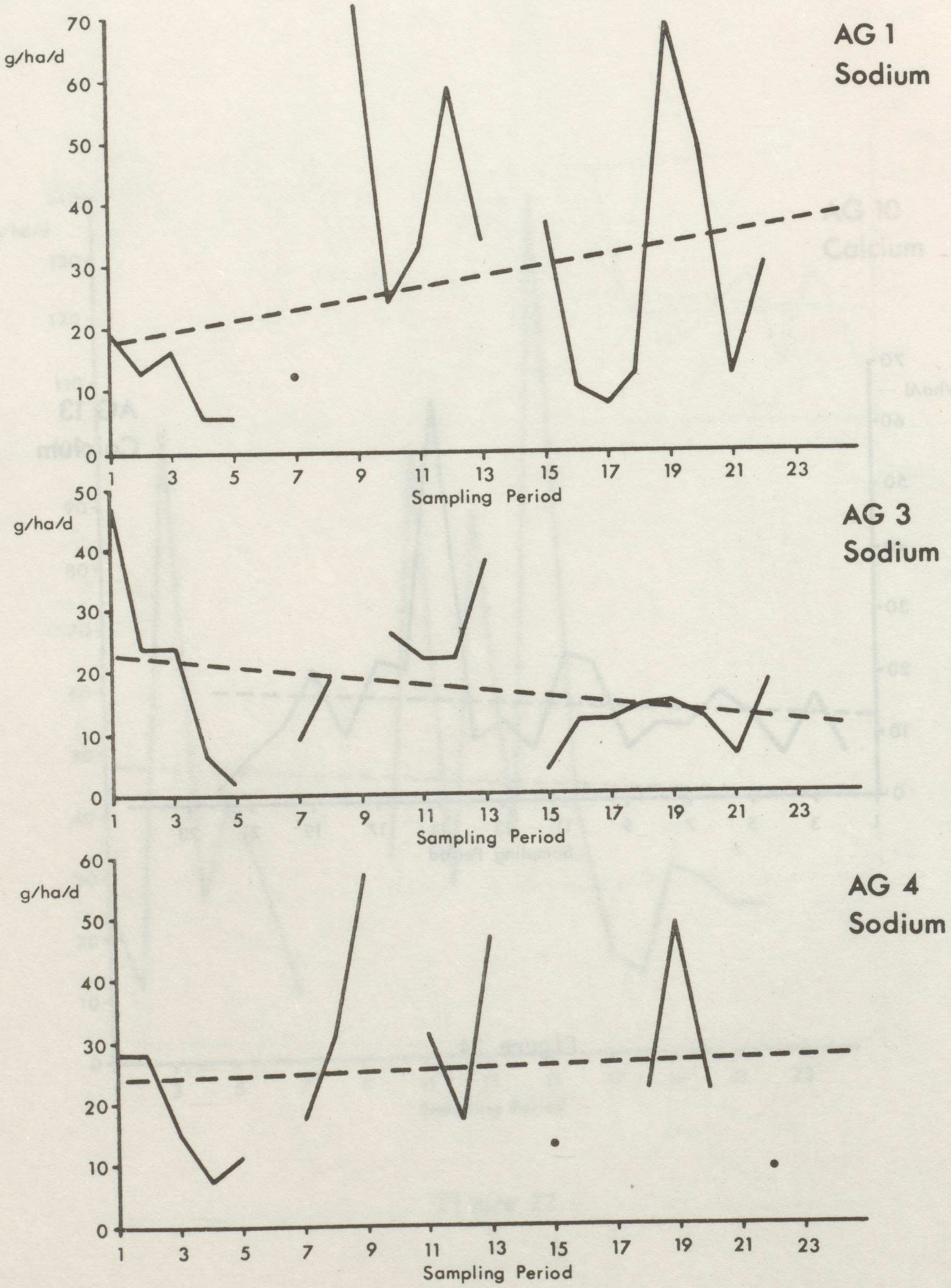

AG 1
Sodium
g/ha/d
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 3
Sodium
g/ha/d
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 4
Sodium
g/ha/d
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 25

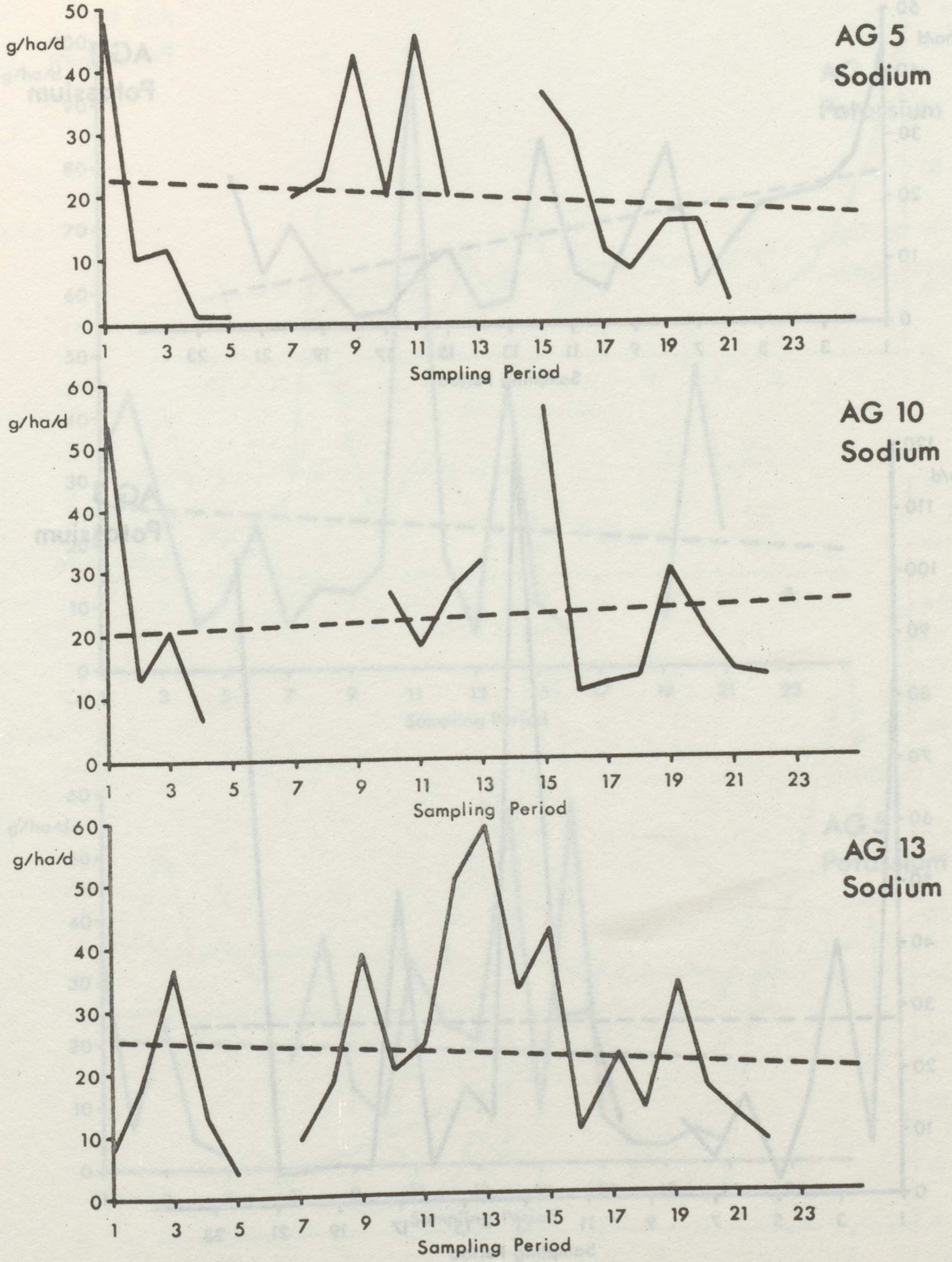

AG 5
Sodium
g/ha/d
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23
Sampling Period
AG 10
Sodium
g/ha/d
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23
Sampling Period
AG 13
Sodium
g/ha/d
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23
Sampling Period

Figure 26

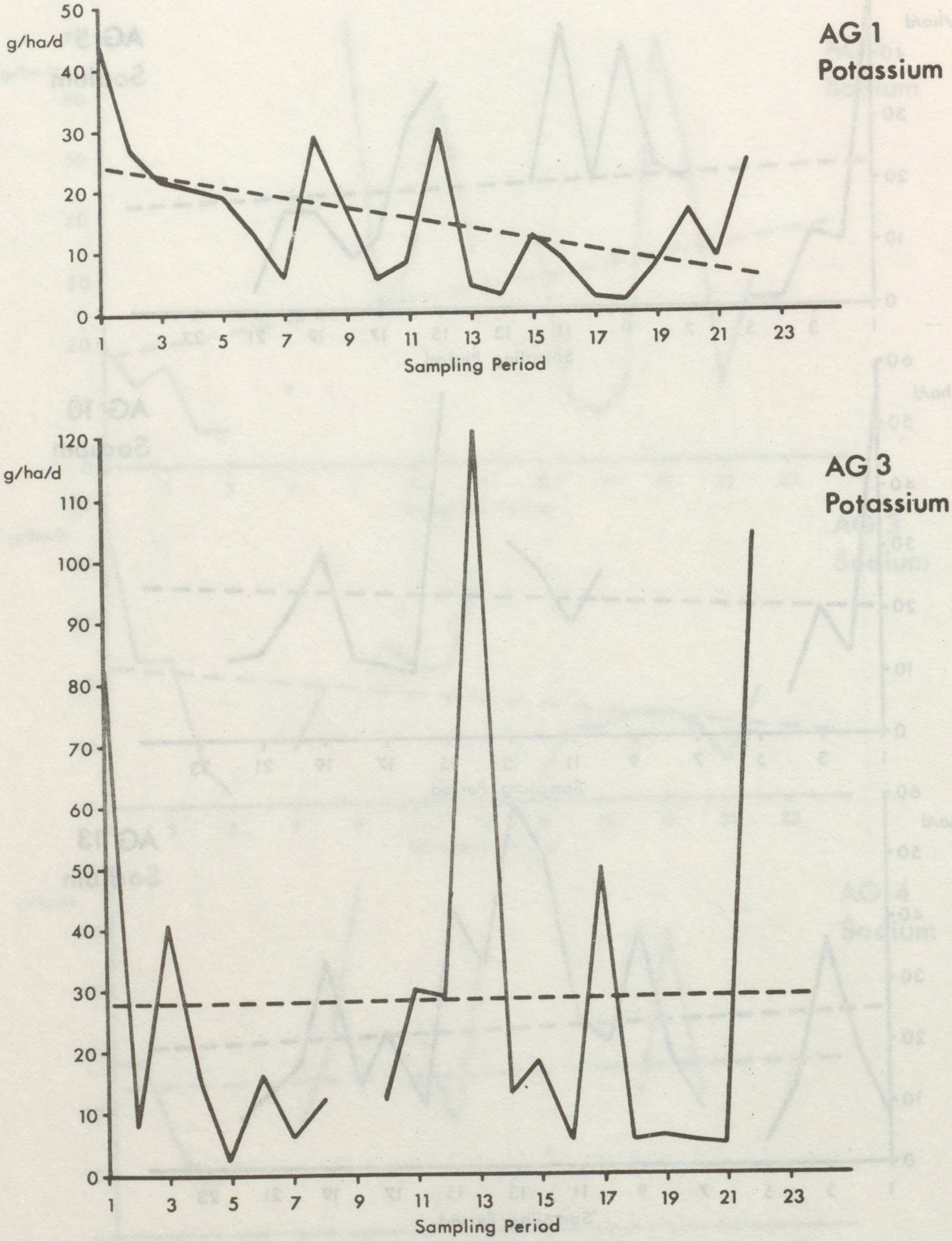
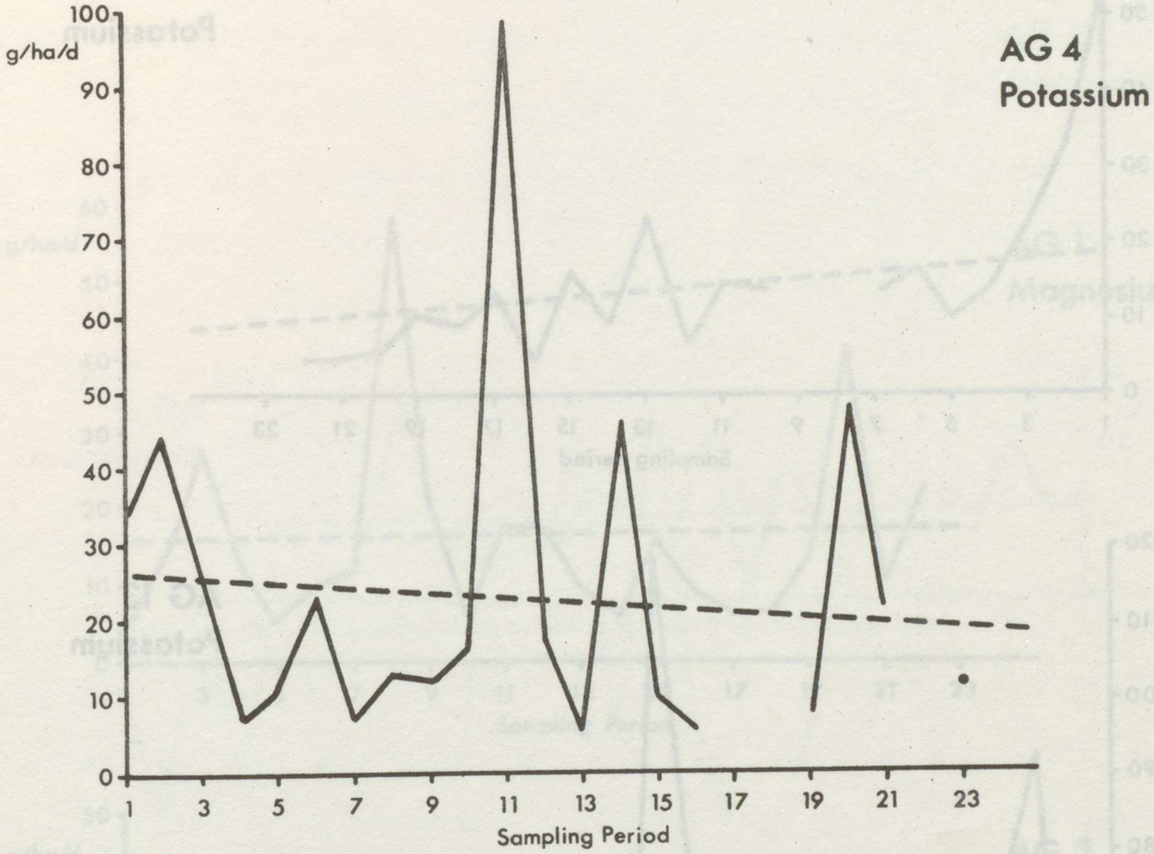

AG 1
Potassium
g/ha/d
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 3
Potassium
g/ha/d
120
110
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 27


AG 4
Potassium
g/ha/d
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

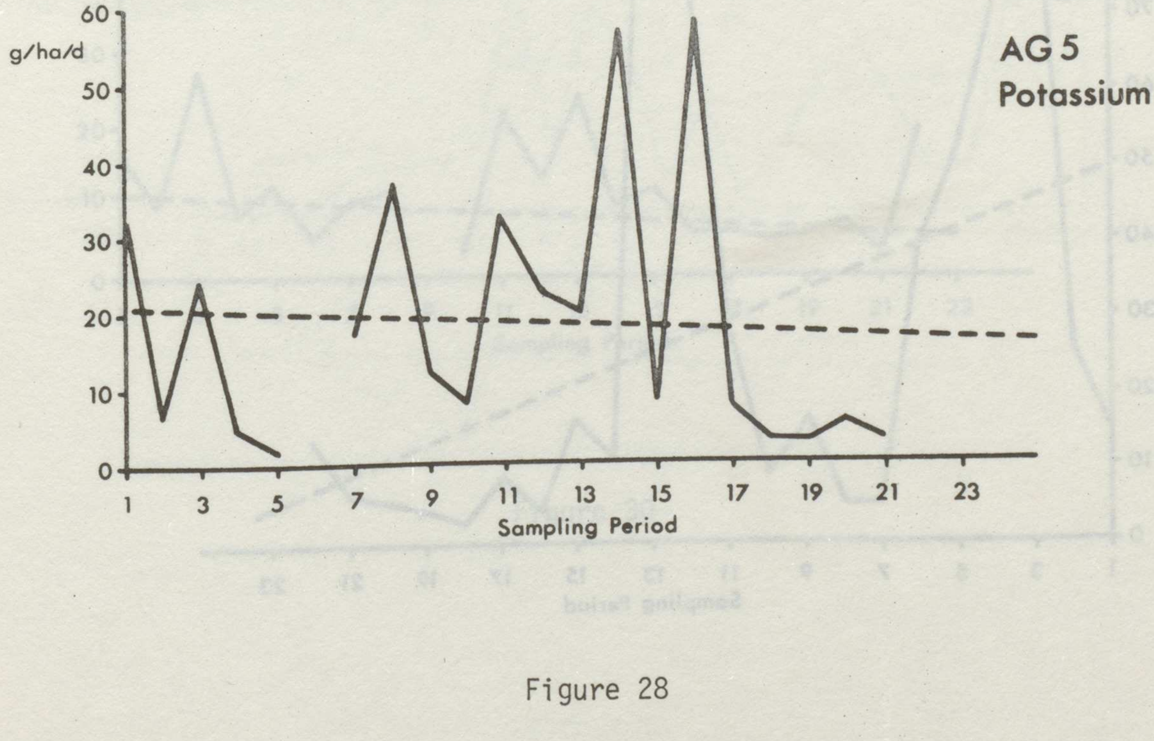

AG 5
Potassium
g/ha/d
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 28

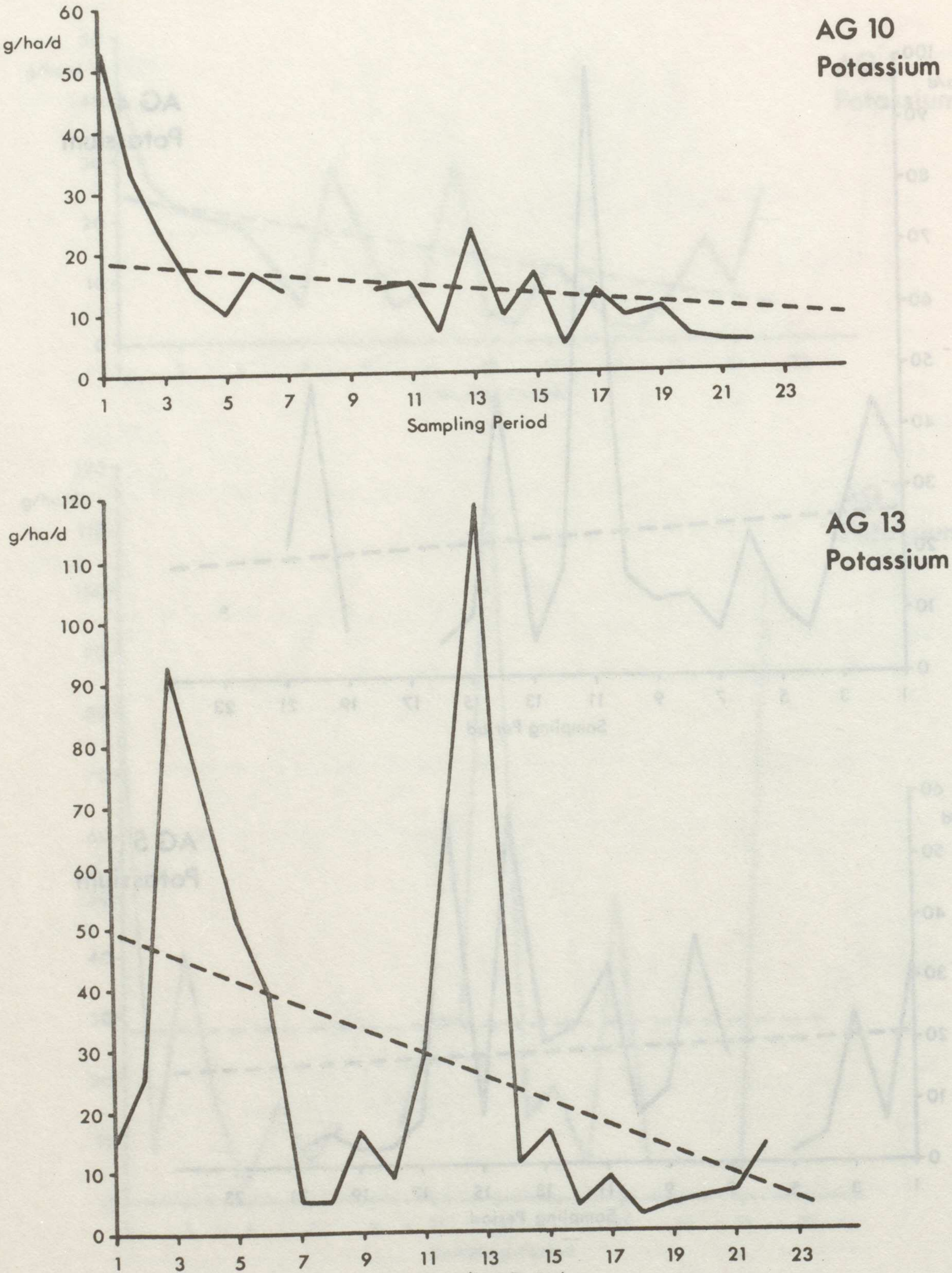
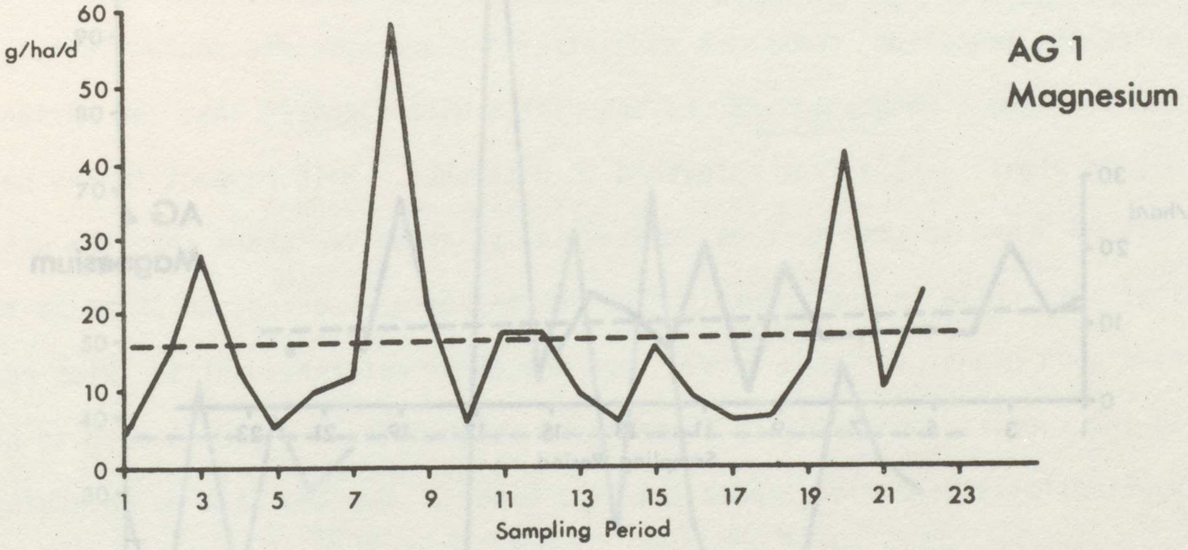

AG 10
Potassium
g/ha/d
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 13
Potassium
g/ha/d
120
110
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 29


60
g/ha/d
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 1
Magnesium

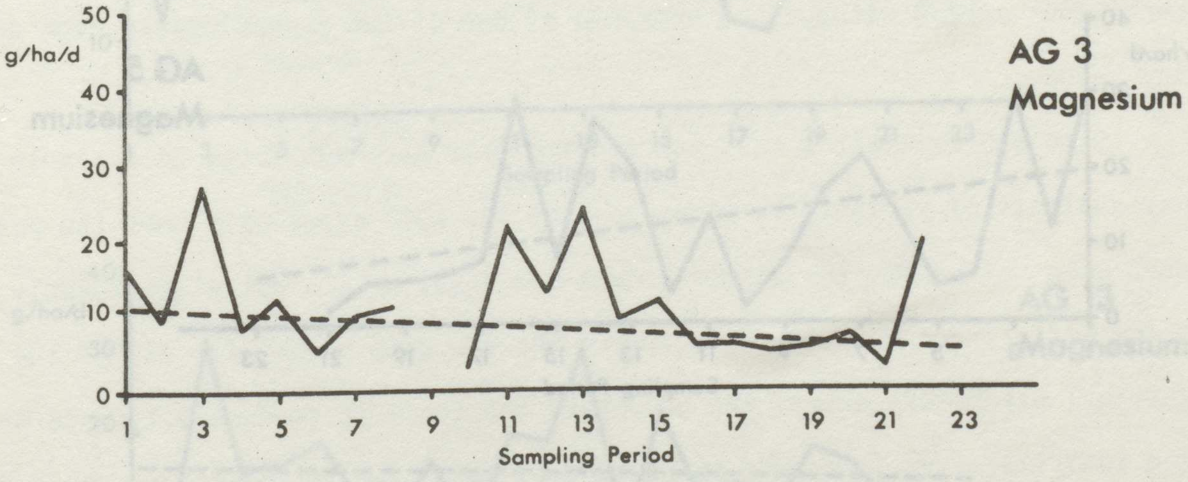
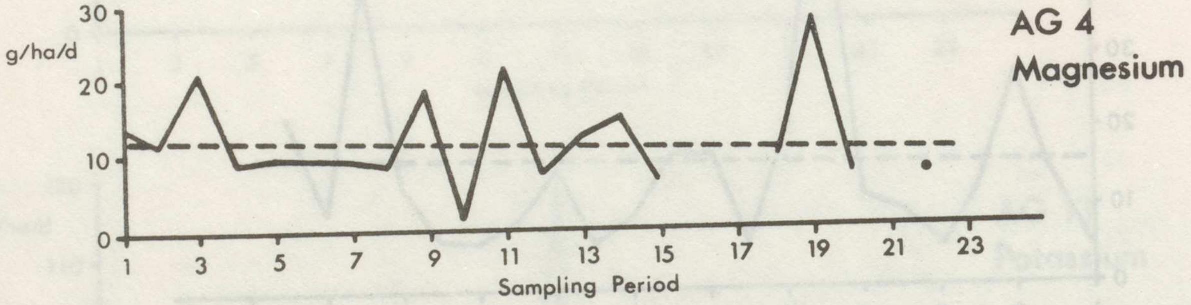

50
g/ha/d
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 3
Magnesium

Figure 30


AG 4
Magnesium
g/ha/d
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

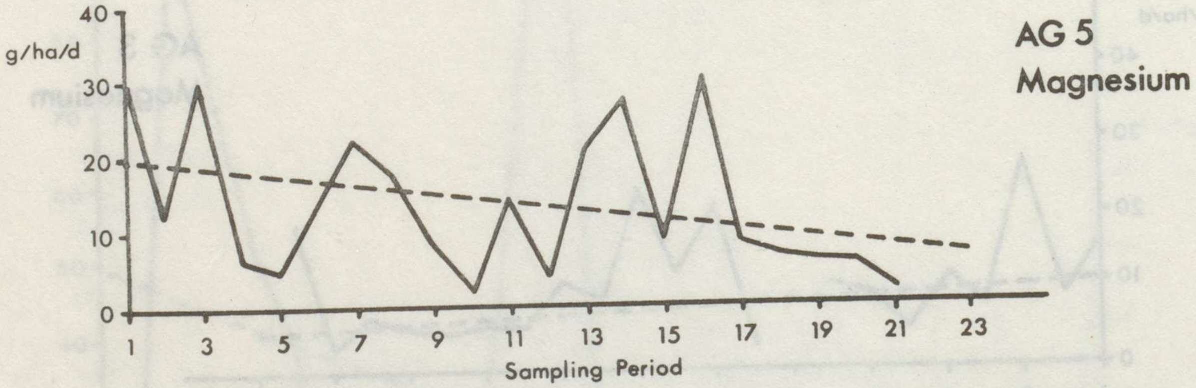

AG 5
Magnesium
g/ha/d
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 31

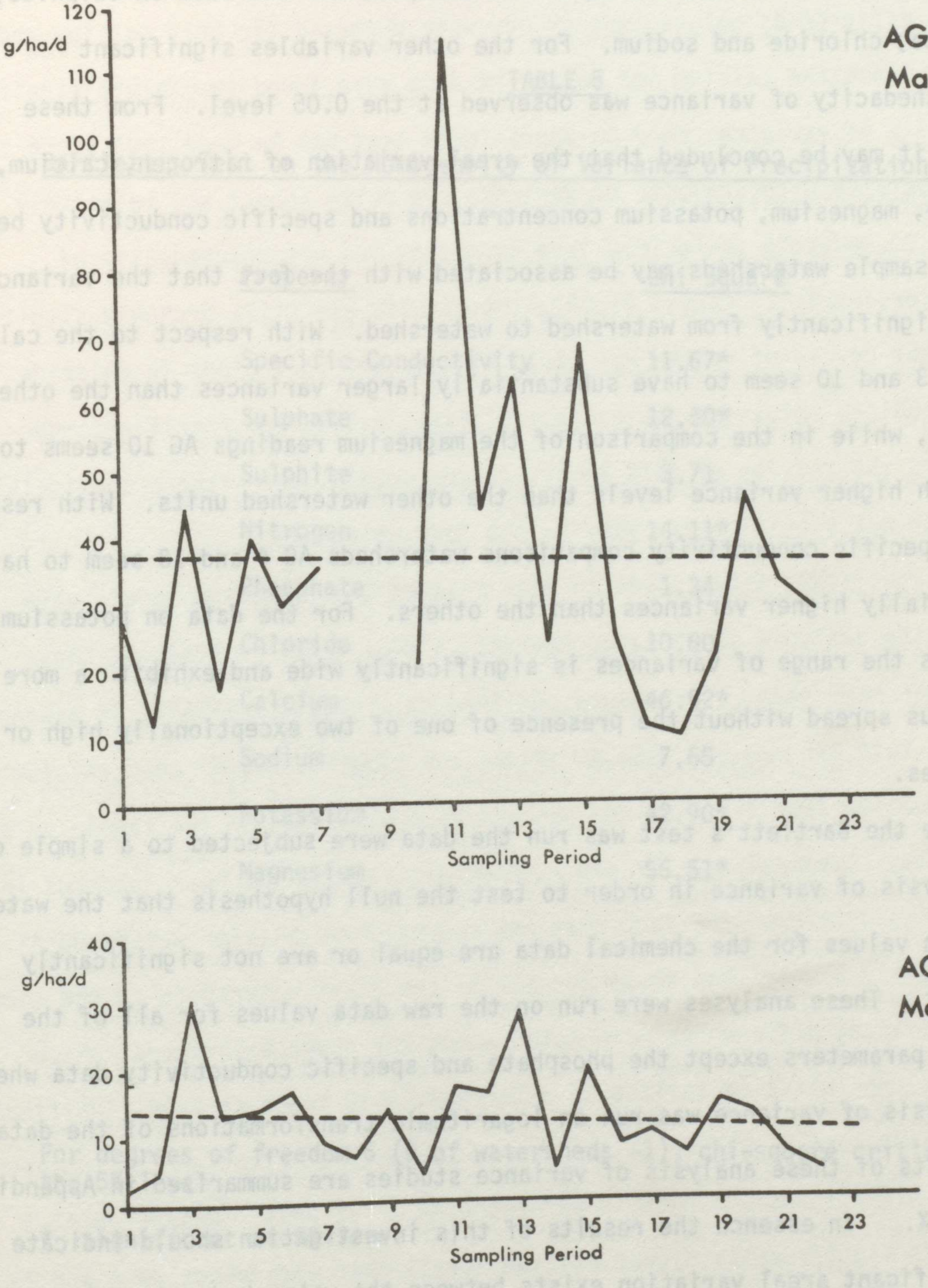

AG 10
Magnesium
g/ha/d
120
110
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period
AG 13
Magnesium
g/ha/d
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
Sampling Period

Figure 32

Table 5. Based on the results of the Bartlett's test the null hypothesis that the sample variances are equal was accepted for the data on sulphite, phosphate, chloride and sodium. For the other variables significant heteroschedacity of variance was observed at the 0.05 level. From these results it may be concluded that the areal variation of nitrogen, calcium, sulphate, magnesium, potassium concentrations and specific conductivity between the six sample watersheds may be associated with the fact that the variances differ significantly from watershed to watershed. With respect to the calcium data AG 3 and 10 seem to have substantially larger variances than the other stations, while in the comparison of the magnesium readings AG 10 seems to have much higher variance levels than the other watershed units. With respect to the specific conductivity comparisons watersheds AG 4 and 13 seem to have substantially higher variances than the others. For the data on potassium and sulphates the range of variances is significantly wide and exhibit a more continuous spread without the presence of one of two exceptionally high or low values.

Once the Bartlett's test was run the data were subjected to a simple one way analysis of variance in order to test the null hypothesis that the watershed mean values for the chemical data are equal or are not significantly different. These analyses were run on the raw data values for all of the chemical parameters except the phosphate and specific conductivity data where the analysis of variance was run on logarithmic transformations of the data. The results of these analysis of variance studies are summarized in Appendix VI Tables I-X. In essence the results of this investigation should indicate if any significant areal variation exists between the watershed units with respect to precipitation chemistry.

TABLE 5

Bartlett's Test on the Homogeneity of Variance of Precipitation Chemistry

Property	Chi Square
Specific Conductivity	11.67*
Sulphate	12.50*
Sulphite	3.71
Nitrogen	14.11*
Phosphate	1.34
Chloride	10.80
Calcium	46.52*
Sodium	7.68
Potassium	42.90*
Magnesium	55.51*

For degrees of freedom 5 (# of watersheds -1), chi-square critical = 11.07 at the 5% level

* significant at 5% level

Based on the results of the analysis of variance tests, relatively few significant differences were observed. In fact, at the 0.05 level of significance, significant differences between watersheds were observed for only calcium and magnesium. Since the calcium and magnesium data were found to exhibit significant heteorogeneity of variance, only an approximate test can be made, but since the F-tests associated with analysis of variance are quite robust and relatively insensitive to moderate deviations from normality and heteroschedacity of variance according to Lindquist (1956), the results are still probably significant. While a longer period of record may yield significant variations in chloride, phosphate, sodium, potassium, sulphate, sulphite, P.C.B. and specific conductivity means, the results of this investigation suggest that these chemicals' properties do not significantly vary in the test watersheds.

Since significant differences in mean calcium and magnesium levels were detected in the analysis of variance studies, a more detailed study of these variations was made using a procedure outlined by Lindquist (1956). In essence a modified t-test program was used to assess the significance of mean calcium and mean magnesium levels' variations between each watershed in the sample on a pairwise basis. Examination of Table X, Appendix VI, and the mean loadings in Table 6 (p. 66) discloses the fact that the magnesium levels for watershed AG 10 are significantly higher than those for all of the other watersheds in the sample. Also no significant differences were noted among the other watersheds, which suggests that precipitation falling in watershed AG 10 tends to have significantly higher magnesium levels. Using a similar procedure, precipitation calcium levels tended to be significantly higher in watershed AG 10 as well. Watershed AG 3 tended to have significantly higher calcium levels than watersheds AG 4 and 13. Watershed AG 13 also had a significantly lower mean calcium concentration than watershed AG 5, and had the lowest overall mean calcium level.

5.0 DISCUSSION OF SURFACE LOADINGS

The mean loadings, in grams per hectare per day for each element, by watershed, are shown in Table 6 in descending order of magnitude. They are discussed below in that order.

5.1 Sulphate

The analysis of variance test showed no significant differences among the watersheds in Southern Ontario with regard to sulphate loadings. Mean daily loadings ranged from 144 g/ha/d for AG 13 to 187 g/ha/d for AG 4. Shiomi (1973) found the average value for the Lake Ontario basin during 1970-71 was 140 g/ha/d. The Acres study of the atmospheric loadings of the upper Great Lakes (1976) showed values of 100 g/ha/d for the northern part of Southern Ontario for 1972-73. The higher loadings obtained in the present study may indicate more sulphur dioxide in the air above Southern Ontario or higher precipitation than during the earlier study periods. It can be concluded that for 1975-77 surface loadings of sulphate in Southern Ontario average 160 g/ha/d or approximately 60,000 grams per hectare per year based on the bulk precipitation sample.

5.2 Nitrogen

Table 6 shows nitrogen to have the next highest mean loadings, from 92 g/ha/d for AG 13 to 115 g/ha/d for AG 10. Of all the chemicals tested, nitrogen provided the most problems with the analyses and with extreme high values. Data for several months were discarded because of problems with testing procedures, and occasional extreme high values suggested that contamination of the sample had occurred. Consequently, less confidence can be placed on the nitrogen data than any of the other parameters. The analysis of variance test

TABLE 6

Watershed - Mean Loadings 1975-1977 (g/ha/d)

Parameter	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
Sulphate	163.8	172.3	210.4 186.6[1]	151.8	162.3	144.0
Nitrogen	93.9	108.0	110.9	105.6	115.1	91.5
Sulphite	41.6	42.9	47.0	41.6	42.6	42.9
Calcium	22.4	31.8	21.0	24.7	43.9	16.0
Sodium	28.0	17.5	25.3	20.3	22.1	23.4
Chloride	20.8	27.7	25.4	16.5	24.7	19.9
Potassium	15.3	27.8	23.5	18.3	15.0	28.3
Magnesium	15.7	11.2	11.7	13.1	36.6	11.9
Phosphate	7.5	10.1	8.2	7.9	9.9	12.6
Zinc[3]	1.19	1.23	3.46[2]	.62	1.99	.77
Lead[3]	.19	.20	.12	.15	.13	.18
Copper[3]	.17	.07	.26	.23	.06	.16
Cadmium[3]	.05	.03	.07	.03	.06	.02
P.C.B.s	.0016	.0026	.0021	.0013	.0017	.0023

(1) Omitting 1 extreme high value,

(2) Omitting 1 extreme high value.

(3) For heavy metals, values shown only for metals with at least 3 samples

again showed no significant differences among watersheds. Mean daily loading of nitrogen is estimated at 104 g/ha/d or 38,000 g/ha/yr. Brezonik (1975) stated that nitrogen fluxes in rural barnyard locations in Wisconsin have been reported at 30 kg/ha/yr while rural non-barnyard as well as urban fluxes were 13 kg/ha/yr. He attributes this to ammonia absorption from the air.

5.3 Sulphite

Surface loadings of sulphite showed no significant differences among the six watersheds studied. The mean loading was 43 g/ha/d or 16,000 g/ha/yr over the watersheds of Southern Ontario.

5.4 Calcium

Calcium appears to rank next in order of importance as far as surface loadings are concerned. Mean values ranged from 16 g/ha/d in AG 13 to 44 g/ha/d for AG 10. The analysis of variance test indicated that significant differences did exist among the watershed loadings. Calcium levels in precipitation were significantly higher in AG 10 and AG 3 than in the other watersheds, with the exception of no difference between AG 3 and AG 5. Calcium loadings have been thought to be related to road salting but all of the gauges were at least 400 ft. from the nearest road. It is not known why AG 10 and AG 3 have higher calcium loadings. Averaging the six calcium loadings gives a value of 27 g/ha/d or 10,000 g/ha/yr loading value for Southern Ontario. These values are lower than Shiomi's Lake Ontario basin values. However, the inter-laboratory comparisons which were carried out during the course of the study indicate that our analyses for calcium may be giving concentrations which are too low. Fifteen samples from the "precipitation only" gauges were analyzed and the concentrations averaged 60% of the bulk sampler concentrations.

5.5 Sodium

Sodium loadings appear to be similar to calcium loadings in the PLUARG watersheds, mean values ranging from 17 g/ha/d to 28 k/ha/d. The analysis of variance tests showed no significant differences in sodium loadings among the six watersheds. The mean loading was 23 g/ha/d or 8,400 g/ha/yr. This value is lower than Shiomi's value for Lake Ontario stations (11 kg/ha/yr) and similar to Kramer's values for Northern Ontario (8 kg/ha/yr). Fifteen samples from the "precipitation only" samplers were analyzed and concentrations averaged 50% of the bulk sampler concentrations.

5.6 Chloride

The surface loadings of chloride ranged from 16 to 28 g/ha/d for the six PLUARG watersheds. The analysis of variance test showed no significant difference among the watersheds. The mean loading was 22.5 g/ha/d. Shiomi reported similar average loadings of 16-21 g/ha/d for the Lake Ontario basin. The corresponding annual loading is approximately 8,300 g/ha/yr in Southern Ontario. Five "precipitation only" samples were anlayzed and these averaged 65% of the concentrations in the bulk precipitation samples.

5.7 Potassium

Mean potassium loadings ranged from 15 to 28 g/ha/d over the six watersheds. No significant differences were found in the loadings. The mean value for Southern Ontario is thus 21 g/ha/d or 7,700 g/ha/yr. The fifteen "precipitation only" samples yielded great differences in the concentrations of potassium compared to those in the bulk precipitation samples, from 1% to 900%. Consequently, no conclusion can be drawn with regard to potassium in the "precipitation only" samples.

5.8 Magnesium

Surface loadings of magnesium ranged from 11 to 37 g/ha/d in the six watersheds and the analysis of variance tests showed significant differences among the watersheds. The magnesium levels in watershed AG 10 were significantly higher than all the other watersheds. There is no obvious reason for this difference. Perhaps some local industry in the St. Catherines area may be causing the higher magnesium levels in AG 10. If AG 10 values are omitted, the mean loadings of magnesium in Southern Ontario were 11 g/ha/d or 4,000 g/ha/yr. Fifteen "precipitation only" samples were analyzed and the concentrations averaged 40% of the bulk precipitation concentrations.

5.9 Phosphate

Phosphate loadings ranged from 8 to 13 g/ha/d in the six PLUARG watersheds. The analysis of variance tests showed no significant differences among the watersheds. The mean loading value of phosphate for Southern Ontario is 9 g/ha/d or 3,000 g/ha/yr. This is equivalent to 1,000 g/ha/yr of total phosphorus. Brezonik (1975) stated that the range of phosphorus loadings in a Wisconsin study was from 0.1 to 1.0 kg/ha/yr. Shiomi did not give surface loading values and stated that there was little relationship between sample location and phosphorus concentration. There were six analyses of "precipitation only" samples and since the relationship between these concentrations and those in bulk precipitation samples ranged from 4% to 200%, no conclusion can be drawn concerning surface loadings of phosphorus from "precipitation only" samples in Southern Ontario.

5.10 Heavy Metals

Four samples from each station were analyzed for zinc concentrations. Of the heavy metals, zinc showed the greatest surface loadings, ranging from .66 to 1.99 g/ha/d for the six PLUARG watersheds. Shiomi's average loading for Lake Ontario stations was 1.4 g/ha/d. There were too few samples to test for significant differences among the watersheds, but there seemed to be no urban rural pattern in the data. The highest loading was at AG 4 which is furthest from an industrial centre. Averaging the six means gives a value of 1.55 g/ha/d for the PLUARG stations, or 565 g/ha/yr.

Average loadings of lead from four bulk precipitation samples ranged from <.12 to .20 g/ha/d. The Acres study showed values of .2 to .4 g/ha/d for the upper lakes and .4 to 1.0 g/ha/d for Southern Ontario stations. Our values are lower than both of these, averaging .16 g/ha/d overall. This would correspond to an annual loading of 58 g/ha/yr in Southern Ontario.

Average loadings of copper ranged from <.07 to .26 g/ha/d from four bulk precipitation samples with an overall mean value of .16 g/ha/d. Shiomi's average loadings were .11 g/ha/d while the Acres study showed values .10 to .20 g/ha/d for Southern Ontario stations. The corresponding annual loading for copper is the same as that for lead - 58 g/ha/yr in Southern Ontario.

Average loadings of cadmium ranged from 0.02 g/ha/d to 0.07g/ha/d from the four sets of six samples tested. In half of the samples, cadmium was not detectable within the limits of the testing procedure. The corresponding average loading of cadmium is .04 g/h/d or approximately 15 g/ha/yr in Southern Ontario.

Only two sets of nickel analyses were made. (Table XII Appendix I). Of the twelve samples, only five showed detectable concentrations of nickel, two at AG 1, two at AG 13 and one at AG 4. The presence of nickel at the two stations near leamington might be due to the presence of the automobile plants in Detroit-Windsor. For chromium, two sets of samples were also tested and only three had detectable concentrations; two at AG 1 and one at AG 4.

Eight "precipitation only" samples were analyzed for heavy metals, (two zinc, two lead, two copper and two cadmium). Strangely, all except one of these had higher concentrations than the bulk precipitation samples. No explanation can be offered for this result.

5.11 P.C.B.s

Seven sets of bulk precipitation samples (27 in number) were analyzed for P.C.B.s. In only three cases were P.C.B.s not detectable by the pesticide laboratory. Average loadings ranged from .0013 at AG 5 to .0026 g/ha/d at AG 3, with an average value of .0020 g/ha/d or .73 g/ha/yr.

Five "precipitation only" samples were anlayzed and these showed concentrations averaging 80% of those in the bulk samples. No comparable data on surface loadings of P.C.B.s have been found in the literature.

6.0 CONCLUSIONS

6.1 Precipitation Quantity

The precipitation quantity part of the study was undertaken to provide information for other PLUARG researchers and for the precipitation chemistry work.

Conclusion I

> It was found that precipitation during the first year of research, June 1975-May 1976, was considerably above normal at most of the stations and precipitation during the period June 1976-May 1977 was considerably below normal. This fact plays a significant role in explaining the surface loadings in the second part of the study.

6.2 Precipitation Quality

Twenty-three sets of precipitation samples from the bulk precipitation samplers at the six intensive watersheds were analyzed for most of the following: conductivity, suspended solids, sulphate, sulphite, phosphate, chloride, calcium, sodium, potassium and magnesium. Because of problems with the method of analysis, only twelve sets of samples were tested for nitrogen. Of the heavy metals, tests for zinc, lead, copper and cadmium were carried out on four sets of samples, chromium two, nickel two and arsenic one. Seven sets of samples were analyzed for P.C.B.s. "Precipitation only" samplers from two watersheds were analyzed for all parameters as often as the amount of sample permitted. The number of samples tested ranged from two for sulphite to fourteen for the metals.

The surface loadings for each parameter (with the exception of the heavy metals and P.C.B.s in which the sample sizes were too small) were subjected to statistical tests with the following results.

Conclusion II

Comparing surface loadings with precipitation amounts showed that in every case increased precipitation resulted in increased surface loadings. Correlation coefficients were significant for each parameter except sodium. This result added further proof to an earlier finding by Osborne (1976) that in individual rainstorms, precipitation amount explained 80% of the variation in surface loadings of sulphate.

Conclusion III

With a few exceptions, the parameters had normal distributions at each station. The few which did not conform to normality were found to have a log normal distribution.

Conclusion IV

The analysis of variance tests showed that with the exception of calcium and magnesium there was no significant difference in surface loadings at the six watersheds. For most parameters then, it is not possible to draw isoline maps of surface loadings in Southern Ontario, since all areas appear to have equally polluted precipitation.

Conclusion V

Although the period of analysis is perhaps too short, the statistical tests showed no seasonal variations in parameter loadings.

Conclusion VI

The trend lines fitted to the loading data showed downward trends with time for almost all parameters. In several cases the trend lines were statistically significant. Since it has been shown that surface loading is significantly related to precipitation amount, it is hypothesized that the decreasing trends are explained by decreased precipitation during the second year of the study. It would be unwise to assume decreased loadings to be a result of a decrease in air pollution.

Conclusion VII

Since one year of the study was one of above average precipitation and one year had below average precipitation, the mean loadings obtained in the present study probably approximate the mean precipitation situation. The loadings given below are those obtained from the bulk precipitation samples and expressed in grams per hectare per year. The parameters are arranged in descending order of magnitude.

Southern Ontario Surface Loadings kg/ha/year

(based on 1975-77 chemical analysis and precipitation data)

Parameter	Loading (g/ha/yr)
Sulphate	60,000
Nitrogen	38,000
Sulphite	16,000
Calcium	10,000
Sodium	8,400
Chloride	8,300
Potassium	7,700
Magnesium	4,000
Phosphate	3,000
Zinc	565
Lead	58
Copper	58
Cadmium	15
P.C.B.s	0.70

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APPENDIX I

CONCENTRATIONS OF CHEMICALS IN PRECIPITATION

(Note: dates for collection periods 1-23 listed in these tables are shown in Table 3, p. 26.)

APPENDIX I

TABLE I

Specific Conductivity (Micro MHo)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	28.7	65.9	30.6	40.0	59.8	24.0		
2	39.4	57.4	38.4	52.7	86.8	45.1		
3	26.5	56.8	23.3	25.7	52.6	28.7		
4	39.0	44.1	27.2	32.5	42.9	69.6		
5	49.0	45.4	30.4	44.7	43.3	85.8		
6	42.5	46.8	-	72.7	76.5	45.9		
7	32.0	41.6	24.4	41.1	43.5	27.7		
8	112.9	55.5	42.1	72.0	-	31.5		
9	32.2	-	28.4	25.4	-	27.8		
10	47.0	54.8	146.8	43.0	52.8	46.0		
11	35.3	41.3	36.3	41.3	34.3	60.5		
12	95.7	114.9	41.3	98.8	72.6	276.1		
13	46.2	66.8	29.8	27.7	55.5	244.5		
14	83.3	50.8	71.6	39.0	152.3	96.3	105.4	36.4
15	30.6	56.3	13.8	22.7	53.4	41.5	31.6	37.6
16	26.0	38.1	-	57.6	42.8	26.0	-	-
17	45.4	33.1	-	28.4	148.6	44.5	-	39.7
18	62.2	141.5	111.0	64.7	97.6	70.8	68.3(1)	40.3
19	167.0	117.0	-	64.0	115.0	88.0		
20	92.8	60.2	60.2	96.9	113.2	47.9	86.7	-
21	32.5	36.8	-	16.8	48.8	19.1	-	23.6
22	20.0	50.0	195.0	25.0	23.0	-	22.0	-
23	69.0	136.9	73.1	-	63.8	29.8	32.9	-

(1) 2 month sample

* Precipitation-only sample

\- No sample

APPENDIX I

TABLE II

Volatile Suspended Solids (mg/l)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	1.5	-	3.5	3.0	6.5	2.0		
2	1.0	-	2.5	2.0	1.0	1.5		
3	5.0	3.0	1.5	4.0	3.0	2.5		
4	2.7	1.8	1.1	0	2.2	-		
7	9.2	1.8	2.0	25.4	0.6	9.8		
9	0	-	.4	.8	-	1.6		
11	34	36	25	2	8	33		
15	1.2	-	.2	.3	.2	1.5	.5	.4

Total Suspended Solids (Mg/l)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	4.0		15.0	11.0	17.5	8.5		
2	3.0		5.5	6.0	6.0	6.5		
3	6.0	4.0	3.0	7.0	5.0	4.5		
4	6.5	3.0	2.5	0	4.8	-		
7	15.5	5.4	10.3	38.9	2.6	11.2		
9	0	-	1.0	1.2	-	2.3		
11	53	51	27	5	13	50		
15	1.5	-	0.3	0.4	0.5	2.4	.8	.9

* Precipitation-only sample

\- No sample

APPENDIX I

TABLE III

Sulphate (mg/l)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	9.3	7.3	6.0	3.3	9.0	4.7		
2	6.2	7.5	6.2	5.5	10.0	7.7		
3	5.1	6.4	5.5	4.6	4.0	4.5		
4	3.5	7.3	5.8	4.2	2.4	8.3		
5	8.5	6.5	5.0	7.6	-	13.0		
6	5.0	5.0	-	8.1	6.6	5.6		
7	4.5	6.6	7.8	6.0	5.6	5.0		
8	16.0	9.5	9.0	10.5	-	4.5		
9	3.5	-	8.0	4.2	-	5.0		
10	5.8	8.7	25.9	5.0	8.7	7.1		
11	7.5	8.0	8.5	7.5	5.0	7.5		
12	14.5	13.5	5.9	21.5	11.0	24.5		
13	8.0	10.5	6.7	6.0	7.0	17.0		
14	8.5	9.0	9.0	6.0	16.5	29.0		
15	4.2	8.4	4.2	5.0	6.0	6.7	5.5	5.0
16	5.0	5.5	-	5.0	6.3	5.0	-	-
17	6.3	5.1	-	4.0	-	-	-	-
18	7.5	20.3	13.5	7.5	10.0	7.5	-	-
19	24.5	19.0	-	8.5	17.0	11.5	-	-
20	14.8	9.6	2.0	5.0	18.0	6.8	13.4	
21	3.0	4.0	-	4.0	3.0	1.8	-	1.0
22	17.0	6.2	27.5	5.5	4.2	-	2.5	-
23	4.5	6.8	5.0	-	3.0	3.0	3.0	-

* Precipitation-only sample

\- No sample

APPENDIX I

TABLE IV

Sulphite (mg/l)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	2.0	2.0	1.9	1.8	1.9	2.0		
2	2.0	2.1	1.8	1.6	1.6	1.8		
3	1.0	2.2	2.5	1.8	2.0	2.0		
4	2.0	2.8	2.0	1.6	1.7	2.9		
5	2.6	2.0	1.5	2.5	2.5	3.0		
6	2.2	2.5	-	2.5	2.0	2.5		
7	1.5	1.5	1.8	1.0	1.8	1.8		
8	-	2.2	1.8	1.5	-	1.5		
9	1.8	-	1.5	1.6	-	1.9		
10	1.4	1.4	1.5	1.3	1.4	1.4		
11	1.2	1.4	1.4	1.3	1.5	1.4		
12	1.5	1.4	1.5	1.7	1.8	1.8		
13	1.4	2.2	1.6	1.4	1.6	2.6		
14	0.4	0.2	0.2	0.2	0.2	0.2		
15	0.7	1.0	1.0	0.8	0.8	0.8	0.8	0.9
16	2.0	1.8	-	1.8	1.5	1.7		
17	2.6	2.2	-	2.1	2.2	1.9		
18	2.1	2.0	2.3	2.5	2.3	2.3		
20	-	2.1	2.0	1.8	-	2.3		
21	1.9	2.1	-	-	2.1	1.9		3.0
22	2.8	2.8	3.2	3.6	3.3	-	4.3	

* Precipitation-only sample

\- No sample

APPENDIX I

TABLE V

Nitrogen (mg/l) - The total of kjeldahl, $NO_3 + NO_2$

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	4.9	11.5	4.2	6.2	5.8	2.1		
2	3.2	3.1	4.9	5.8	14.3	5.4		
3	2.6	0.3	1.4	2.7	1.8	2.8		
4	2.3	1.9	2.2	3.4	7.1	4.3		
5	-	-	2.7	-	1.8	-		
6	2.4	4.6	-	2.8	3.3	0.8		
7	3.4	5.8	2.7	3.8	4.7	2.0		
8	-	4.7	1.6	2.5	-	0.6		
9	1.9	-	8.4	2.0	-	2.3		
10	4.3	6.3	-	9.7	6.8	5.2		
11	4.2	3.2	1.6	3.7	1.7	6.0		
23	2.4	9.7	5.2	-	3.0	-	-	

* Precipitation-only sample

\- No sample

APPENDIX I

TABLE VI

Total Phosphate (mg/l)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	.75	.88	.24	.48	.72	.29		
2	.58	.34	.40	1.10	1.40	1.02		
3	.39	.54	.40	.50	.90	.90		
4	.55	.54	.11	.22	.48	.95		
5	.62	.16	.02	.36	.12	1.44		
6	.08	.27	-	.15	.26	.04		
7	.07	.04	.04	.25	.08	.10		
8	-	.04	.14	.80	-	.02		
9	.08	-	.06	.02	-	.02		
10	.77	.55	.50	.72	.13	.92		
11	.16	.80	.11	.89	.05	1.40		
12	.95	1.96	.30	.99	.80	1.73		
13	.02	.12	.03	.04	.07	2.00	.07	.03
14	.18	.29	.61	.08	1.06	1.54		
15	.18	.04	.06	.18	.32	.43	.07	.02
16	.14	-	-	.13	.11	.13		
17	.09	.07	-	.04	.17	.15		
21	.06	.08	-	-	.01	.04	-	ND
23	.22	.60	.20	-	.04	.14	.02	

* Precipitation-only sample

\- No sample

APPENDIX I

TABLE VII

Chloride (mg/l)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	.53	1.60	.26	.53	1.07	.26		
2	.56	.96	.51	1.01	1.37	.76		
3	4.84	4.31	2.69	3.77	1.61	1.61		
4	2.69	2.20	1.07	2.20	.50	2.16		
5	1.07	1.07	.10	.96	1.07	1.61		
6	.53	.53	-	1.07	1.07	.53		
7	.26	.53	ND	.53	.53	.26		
8	4.84	1.61	1.07	1.61	-	1.61		
9	.10	-	.10	.10	.10	.10		
10	.53	.53	4.84	ND	.53	ND		
11	.54	1.62	.32	.75	.27	.49		
12	ND	3.93	.38	1.78	2.37	7.33		
13	2.15	1.08	.43	.92	.97	-	1.40	0.32
14	2.05	.32	.43	.22	4.20	2.48		
15	.81	.92	.54	.59	1.29	.81	.65	.43
16	1.19	.66	-	1.19	.81	.54		
17	1.35	.54	-	.70	-	2.96		
19	-	2.40	-	-	2.70	4.70	-	-
20	-	1.00	1.30	.40	-	1.10	-	
21	ND	.50	-	-	ND	ND	ND	
22	.53	1.15	.62	-	.89	-	-	
23	2.49	5.49	1.99	-	0.49	-	-	-

* Precipitation-only sample

\- No sample

APPENDIX I

TABLE VIII

Calcium (mg/l)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	.08	1.25	.57	.09	.57	ND		
2	.79	1.48	.98	.64	.58	.39		
3	.37	2.90	.49	.49	2.20	.25		
4	.42	2.00	.37	.44	1.35	.39		
5	1.58	2.50	.80	1.12	2.25	1.35		
6	1.05	1.22	-	1.29	1.15	.63		
7	.92	.50	.50	2.55	.62	.71		
8	3.20	.92	.75	2.00	-	.88		
9	.16	-	.32	.10	-	.10		
10	2.15	2.00	1.70	1.60	1.80	1.60		
11	1.40	1.08	1.30	.74	2.20	.83		
12	1.75	1.00	.87	.76	2.65	1.00		
13	1.60	.84	1.31	1.05	3.50	.84	1.25	1.15
14	3.35	2.25	2.10	1.55	3.50	2.25	3.00	1.55
15	1.38	1.90	0.50	0.75	3.35	1.55	0.75	0.66
16	1.40	2.85	-	1.55	2.40	1.30	0.54	0.42
17	1.73	0.59	-	1.05	3.00	1.93	-	0.63
18	2.10	0.95	2.00	2.40	1.40	1.90	1.25(1)	0.72
19	5.30	0.95	2.90	2.10	1.95	2.60		
20	1.57	0.60	0.50	0.39	1.68	1.05	2.05	-
21	.58	.35	-	.28	1.10	.26	-	.17
22	.36	.12	.18	.34	.48	-	.14	-
23	1.05	0.36	0.50	-	1.60	0.16	0.38	-

(1) 2 month sample

* Precipitation-only sample

\- No sample

APPENDIX I

TABLE IX

Sodium (mg/l)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	.56	1.10	.84	.59	1.22	.32		
2	.53	1.33	.53	1.12	.62	.98		
3	.25	.52	.25	.29	.40	.54		
4	.29	.29	.10	.37	.37	.76		
5	.50	.15	.15	.50	.08	.36		
6	11.00	12.80	-	32.50	25.00	16.80		
7	.76	.58	.71	1.12	.52	.55		
8	20.00	1.30	1.40	2.10	-	1.30		
9	1.21	-	.96	.82	-	.54		
10	1.55	1.55	22.50	1.25	1.50	1.45		
11	1.05	.59	.98	1.10	.36	.83		
12	5.90	2.05	1.55	3.40	2.58	6.20		
13	2.80	.80	1.70	2.15	1.25	3.80	1.75	0.88
14	35.50	8.10	6.50	5.50	17.00	7.40	14.50	8.75
15	1.20	0.10	0.32	0.94	1.28	1.00	0.34	0.16
16	0.57	0.75	-	1.30	0.66	0.61	0.20	0.20
17	1.23	0.61	-	0.64	2.15	1.86	-	0.72
18	2.45	1.55	2.03	1.15	1.35	2.30	3.00 (1)	1.00
19	9.40	1.35	3.15	1.72	1.90	4.00		
20	2.65	.80	.74	.80	1.25	1.38	2.70	-
21	.52	.45	-	.21	.54	.39		.36
22	.33	.36	.53	.70	.56	-	.30	
23	1.46	1.46	0.97	-	.84	0.46	.32	-

(1) 2 month sample

* Precipitation-only sample

\- No sample

APPENDIX I

TABLE X

Potassium (mg/l)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	1.25	1.90	.61	.72	1.25	.50		
2	1.08	.44	.34	1.80	1.62	1.35		
3	.36	.90	.51	.51	.45	1.35		
4	1.10	.78	.30	.33	.71	4.30		
5	1.80	.24	.13	.44	.50	5.20		
6	.44	.75	-	1.51	.72	1.45		
7	.39	.39	.28	.91	.81	.28		
8	2.45	.78	.60	3.40	-	.34		
9	.28	-	.20	.23	-	.23		
10	.42	.68	4.02	.50	.75	.62		
11	.26	.80	.50	.80	.30	1.00		
12	3.00	2.70	.49	3.80	.70	9.40		
13	.43	2.55	.16	.34	.90	7.60	0.22	0.24
14	.72	.63	.63	1.20	.90	2.60	.24	.05
15	.32	.50	.16	.20	.36	.40	.30	.16
16	.55	.34	-	2.50	.26	.24	.24	.08
17	.48	.26	-	.43	2.35	.76	-	.36
18	.41	.54	.59	.34	.90	.48	3.20 (1)	.18
19	1.05	.50	3.15	.24	.62	.44		
20	.90	.30	.62	.28	.36	.36	1.03	-
21	.36	.36	-	.22	.28	.18	-	.26
22	.37	.71	.38	.25	.12	-	.31	-
23	1.2	8.3	1.2	-	0.34	0.75	0.42	-

(1) 2 month sample

* Precipitation-only sample

\- No sample

APPENDIX I

TABLE XI

Magnesium (mg/l)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	.12	.38	.51	.29	.64	.06		
2	.55	.52	.63	.45	.57	.26		
3	.46	.60	.63	.41	.87	.45		
4	.66	.41	.41	.43	.87	.80		
5	.50	.83	.34	.44	2.05	1.45		
6	.33	.22	-	.59	1.26	.63		
7	.75	.66	.38	1.20	2.10	.62		
8	4.90	.75	.36	1.55	-	.47		
9	.34	-	.32	.16	-	.19		
10	.41	.16	.05	.13	1.70	.30		
11	.56	.58	.67	.35	2.35	.58		
12	1.75	1.15	.65	.75	4.20	2.00		
13	.75	.51	.45	.36	2.55	1.85	.50	.42
14	1.20	.43	.88	.57	2.45	1.05	1.00	.26
15	.42	.32	.14	.21	1.55	.46	.16	.10
16	.50	.40	-	1.30	1.55	.48	.15	.12
17	.95	.33	-	.45	2.25	.84	-	.47
18	1.18	.57	.82	.80	1.04	1.19	.50	.24
19	1.85	.50	1.82	.58	1.41	1.80		
20	2.21	.52	.19	.25	2.75	1.05	1.50	
21	.42	.19	-	.09	1.25	.22		.12
22	.23	,32	.29	.30	.51	-	.15	-
23	1.1	1.6	0.76	-	1.9	0.24	0.34	-

* Precipitation-only sample

\- No sample

APPENDIX I

TABLE XII

Heavy Metals (mg/l)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
Nickel								
10	.003	<.002	.007	<.002	<.002	.002		
13	.300	<.002	<.002	<.002	<.002	.003		
Zinc								
10	.096	.076	.760	.041	.160	.057		
12	.063	.044	.340	.130	.072	.045		
13	.030	.025	.110	.160	.092	.062		
21	.096	.068	-	.040	.072	.032	.190	.071
Lead								
10	.027	.016	.009	.008	<.002	.018		
12	.036	.025	.002	.010	.016	.032		
13	<.002	.004	.004	.007	.014	.010		
21	<.002	.004	-	<.002	<.002	<.002	.025	.008
Cadmium								
10	<.001	<.001	.007	<.001	<.001	<.001		
12	<.001	<.001	.002	.001	.001	.002		
13	<.01	<.001	.001	.001	<.001	<.001		
21	.002	.003	-	.002	.007	.001	.031	.060
Copper								
10	.016	.008	.017	.002	.002	.011		
12	.007	.009	.003	.004	.005	.007		
13	.030	.009	.012	.014	.006	.028		
21	<.001	<.001	-	<.001	<.001	<.001	.024	<.001
Chromium								
10	.003	<.002	.002	<.002	<.002	<.002		
13	.06	<.002	<.002	<.002	<.002	<.002		
Arsenic								
10	.002	.001	.003	<.001	<.001	.007		

* Precipitation-only sample   - No sample

APPENDIX I

TABLE XIII

P.C.B.s (ppb)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	0.06	0.04	0.05	0.01	0.02	0.03		
3	0.05	0.10	0.10	0.07	0.05	0.07		
6	0.02	0.10	0.03	-	0.08	0.09		
9	ND	-	0.01	ND	-	ND		
13	0.27					0.11	-	0.12
14	0.13					0.32	0.15	0.11
16	0.09					0.15	0.10	0.07

* Precipitation-only sample

\- No sample

APPENDIX II

SURFACE LOADINGS FOR EACH COLLECTION PERIOD

(Note: dates for collection periods 1-23 listed in these tables are shown in Table 3, p. 26.)

APPENDIX II

TABLE I

Sulphate Loadings (kg/ha)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	9.34	8.81	7.86	5.45	10.90	3.78		
2	5.63	4.88	5.52	3.63	7.41	5.09		
3	11.28	10.44	10.12	7.91	7.41	11.13		
4	2.21	5.04	4.06	2.23	1.67	4.82		
5	3.40	3.58	4.20	4.25	-	4.95		
6	4.20	3.10	-	5.35	4.63	4.37		
7	2.30	3.17	6.17	3.48	3.03	2.60		
8	5.93	4.37	6.22	3.57	-	1.89		
9	4.20	-	9.53	4.38	-	7.26		
10	3.66	6.18	26.19	3.20	6.44	4.05		
11	6.61	8.41	7.57	8.71	6.96	6.08		
12	4.06	4.05	1.83	3.44	3.19	5.64		
13	2.64	13.45	4.96	9.49	4.76	7.15		
14	1.28	6.04	4.78	9.13	5.29	4.06		
15	3.62	6.64	3.70	4.35	5.83	6.24	4.73	4.65
16	2.85	2.75	-	3.80	3.47	2.80		
17	1.26	3.06	-	2.12	-	-		
18	1.13	5.28	4.32	1.73	2.80	1.20		
19	5.89	7.99	-	2.89	10.04	3.22		
20	8.00	3.56	1.72	2.45	7.21	2.38	7.24	
21	1.92	1.44	-	1.56	2.16	1.46		0.81
22	21.78	4.03	14.03	2.92	2.98	-	3.20	
23	3.92	3.65	1.95	-	1.89	2.28	2.61	

* Precipitation-only sample

\- No sample

APPENDIX II

TABLE II

Sulphite Loadings (kg/ha)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	2.00	2.40	2.49	2.92	2.30	1.62		
2	1.80	1.37	1.60	1.06	1.19	1.19		
3	2.21	3.67	4.60	3.10	3.70	4.95		
4	2.21	5.04	1.40	0.85	1.16	1.68		
5	1.02	1.10	1.26	1.40	1.88	1.14		
6	1.89	1.55	-	1.65	1.40	1.95		
7	0.77	0.72	1.21	0.58	0.95	0.91		
8	-	1.04	1.79	0.51	-	0.63		
9	2.10	-	1.52	1.65	-	2.76		
10	0.88	0.99	1.25	0.83	1.04	0.80		
11	1.10	1.47	0.47	1.51	2.09	1.10		
12	0.42	0.42	1.19	0.27	0.51	0.40		
13	0.45	2.76	0.13	2.21	1.09	1.09		
14	0.07	0.13	0.84	0.27	0.06	0.03		
15	0.60	0.75	-	0.70	0.73	0.79	0.69	0.84
16	1.14	0.88	-	1.37	0.83	0.95		
17	0.52	1.32	-	1.11	0.37	0.69		
18	0.32	0.52	0.74	0.58	0.65	0.37		
20	-	0.78	1.72	0.88	-	0.81		
21	1.16	0.76	-	-	1.51	1.54		2.43
22	3.59	1.82	1.63	1.91	2.35	-	5.51	

* Precipitation-only sample

\- No sample

APPENDIX II

TABLE III

Nitrogen Loadings (kg/ha)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	4.97	13.79	5.51	10.05	7.01	2.10		
2	2.85	2.78	4.37	3.82	10.60	3.56		
3	5.74	.49	2.58	4.65	3.36	6.95		
4	1.46	1.30	1.53	1.79	4.93	2.50		
5	-	-	2.30	-	1.37	-		
6	2.00	2.85	-	1.85	2.32	0.62		
7	1.71	2.78	2.13	2.20	2.58	1.05		
8	-	2.16	1.11	0.84	-	0.25		
9	2.26	-	9.98	2.06	-	3.36		
10	2.64	4.48	-	6.10	5.04	3.00		
11	3.70	3.38	1.44	4.30	2.35	4.85		
23	2.06	5.24	2.03	-	1.88	-	-	

* Precipitation-only sample

\- No sample

APPENDIX II

TABLE IV

Phosphate Loadings (kg/ha)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	0.75	1.06	0.31	0.79	0.87	0.24		
2	0.52	0.22	0.36	0.73	1.04	0.67		
3	0.86	0.88	0.74	0.86	1.67	2.23		
4	0.35	0.37	0.08	0.12	0.33	0.55		
5	0.25	0.09	0.02	0.20	0.09	0.55		
6	0.07	0.17	-	0.10	0.18	0.03		
7	0.04	0.02	0.03	0.15	0.04	0.05		
8	-	0.02	0.10	0.27	-	0.01		
9	0.10	-	0.07	0.02	-	0.04		
10	0.49	0.39	0.51	0.46	0.10	0.53		
11	0.14	0.84	0.10	1.03	0.07	1.14		
12	0.27	0.59	0.09	0.16	0.23	0.40		
13	0.01	0.15	0.02	0.06	0.05	0.84	0.02	0.01
14	0.03	0.19	0.32	0.12	0.34	0.22		
15	0.16	0.03	0.05	0.16	0.31	0.40	0.06	0.02
16	0.08	-	-	0.10	0.06	0.07		
17	0.02	0.04	-	0.02	0.03	0.05		
21	0.04	0.03	-	-	0.01	0.03		
23	0.19	0.32	0.08	-	0.03	0.11	0.02	

* Precipitation-only sample

\- No sample

APPENDIX II

TABLE V

Chloride Loadings (kg/ha)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	0.53	1.92	0.34	0.88	1.30	0.21		
2	0.51	0.62	0.45	0.67	1.02	0.50		
3	10.71	7.03	4.95	6.49	2.98	3.98		
4	1.70	1.52	0.75	1.17	0.34	1.25		
5	0.43	0.59	0.08	0.54	0.80	0.61		
6	0.45	0.33	-	0.71	0.75	0.41		
7	0.13	0.26	ND	0.31	0.29	0.14		
8	1.79	0.74	0.74	0.55	-	0.68		
9	0.12	-	0.12	0.10	0.11	0.15		
10	0.33	0.38	4.89	ND	0.39	0.01		
11	0.48	1.70	0.29	0.87	0.38	0.40		
12	ND	1.18	0.12	0.29	0.69	1.69		
13	0.71	1.38	0.32	1.46	0.66	-	0.46	0.13
14	0.31	0.22	0.23	0.34	1.35	0.35		
15	0.70	0.73	0.48	0.51	1.25	0.75	0.56	0.40
16	0.68	0.33	-	0.91	0.45	0.30		
17	0.27	0.32	-	0.37	-	1.07		
19	-	1.01	-	-	1.59	1.32		
20	-	0.37	1.12	0.20	-	0.39		
21	ND	0.18	-	-	-	-		
22	0.68	0.75	0.32	-	0.63	-		
23	2.17	2.97	0.78	-	0.31	-		

* Precipitation-only sample

\- No sample

APPENDIX II

TABLE VI

Calcium Loadings (kg/ha)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	0.08	1.50	0.75	0.14	0.69	ND		
2	0.71	0.96	0.87	0.42	0.43	0.26		
3	0.82	4.73	0.90	0.84	4.07	0.62		
4	0.27	1.38	0.26	0.23	0.92	0.23		
5	0.63	1.38	0.67	0.63	1.69	0.51		
6	0.88	0.76	-	0.85	0.81	0.49		
7	0.47	0.24	0.40	1.48	0.34	0.37		
8	1.19	0.42	0.52	0.68	-	0.37		
9	0.19	-	0.38	0.10	-	0.15		
10	1.36	1.42	1.72	1.03	1.33	0.91		
11	1.23	1.14	1.16	0.86	3.06	0.67		
12	0.49	0.30	0.27	0.12	0.77	0.23		
13	0.53	1.08	0.97	1.66	2.38	0.35	0.41	0.48
14	0.50	1.51	1.11	2.36	1.12	0.32	0.45	0.22
15	1.19	1.50	0.44	0.65	3.25	1.44	0.65	0.61
16	0.80	1.43	-	1.18	1.32	0.73	0.31	0.24
17	0.35	0.35	-	0.56	0.51	0.70	-	0.23
18	0.32	0.25	0.64	0.55	0.39	0.31	0.44	0.12
19	1.27	0.40	1.68	0.71	1.15	0.73		
20	0.85	0.22	0.43	0.19	0.67	0.37	1.11	-
21	0.37	0.13	-	0.14	0.79	0.21	-	0.14
22	0.46	0.08	0.09	0.18	0.36	-	0.19	-
23	0.91	0.19	0.20	-	1.01	0.12	0.34	-

* Precipitation-only sample

\- No sample

APPENDIX II

TABLE VII

Sodium Loadings (kg/ha)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	0.56	1.32	1.10	0.97	1.48	0.26		
2	0.48	0.87	0.47	0.74	0.46	0.65		
3	0.56	0.85	0.46	0.50	0.74	1.34		
4	0.18	0.20	0.07	0.20	0.25	0.44		
5	0.20	0.08	0.13	0.28	0.06	0.14		
6	9.25	7.94	-	21.47	17.52	13.12		
7	0.39	0.28	0.56	0.65	0.28	0.29		
8	7.41	0.60	0.97	0.71	-	0.55		
9	1.45	-	1.14	0.85	-	0.78		
10	0.98	1.10	22.75	0.80	1.11	0.83		
11	0.92	0.62	0.87	1.28	0.50	0.67		
12	1.65	0.62	0.48	0.54	0.75	1.43		
13	0.92	1.03	1.26	3.40	0.85	1.60	0.58	0.37
14	5.33	5.43	3.45	8.37	5.45	1.04	2.18	1.23
15	1.03	0.08	0.28	0.82	1.24	0.93	0.29	0.15
16	0.34	0.38	-	0.99	0.36	0.34	0.11	0.11
17	0.25	0.37	-	0.34	0.37	0.67		0.26
18	0.37	0.40	0.65	0.26	0.38	0.37	1.05	0.16
19	2.26	0.57	1.83	0.59	1.12	1.12		
20	1.43	0.30	0.64	0.39	0.50	0.48	1.46	-
21	0.33	0.16	-	0.08	0.39	0.32		0.29
22	0.42	0.23	0.27	0.37	0.40	-	0.38	-
23	1.27	0.79	0.38	-	0.53	0.35	0.27	-

* Precipitation-only sample

\- No sample

APPENDIX II

TABLE VIII

Potassium Loadings (kg/ha)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	1.25	2.28	0.80	1.19	1.51	0.41		
2	0.97	0.29	0.30	1.19	1.20	0.89		
3	0.80	1.47	0.94	0.88	0.83	3.34		
4	0.69	0.54	0.21	0.18	0.48	2.50		
5	0.72	0.13	0.11	0.25	0.38	1.98		
6	0.37	0.47	-	1.00	0.50	1.13		
7	0.20	0.19	0.22	0.53	0.44	0.15		
8	0.91	0.36	0.41	1.16	-	0.14		
9	0.34	-	0.24	0.24	-	0.33		
10	0.26	0.48	4.06	0.32	0.58	0.35		
11	0.23	0.84	0.45	0.93	0.42	0.81		
12	0.84	0.81	0.15	0.61	0.20	2.16		
13	0.14	3.27	1.15	0.54	0.61	3.20	0.07	0.10
14	0.11	0.42	0.33	1.83	0.29	0.36	0.03	0.01
15	0.28	0.40	0.14	0.18	0.35	0.37	0.26	0.15
16	0.31	0.17	-	1.90	0.14	0.13	0.14	0.04
17	0.10	1.53	-	0.23	0.40	0.27		0.13
18	0.06	0.14	0.19	0.08	0.25	0.08	1.12	0.03
19	0.25	0.21	1.83	0.08	0.37	0.12		
20	0.49	0.11	0.53	0.14	0.14	0.13	0.56	
21	0.23	0.13	-	0.09	0.13	0.15		0.21
22	0.47	0.46	0.19	0.13	0.09	-	0.40	-
23	1.05	4.49	0.47	-	0.22	0.57	0.37	

* Precipitation-only sample

\- No sample

APPENDIX II

TABLE IX

Magnesium Loadings (kg/ha)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	0.13	0.46	0.67	0.47	0.78	0.05		
2	0.50	0.34	0.56	0.30	0.42	0.17		
3	1.02	0.98	1.16	0.71	1.61	1.11		
4	0.42	0.28	0.30	0.22	0.59	0.46		
5	0.20	0.46	0.29	0.25	1.54	0.55		
6	0.28	0.14	-	0.39	0.88	0.49		
7	0.38	0.32	0.30	0.70	1.14	0.32		
8	1.81	0.35	0.25	0.53	-	0.20		
9	0.41	-	0.38	0.17	-	0.28		
10	0.26	0.11	0.05	0.08	1.26	0.17		
11	0.49	0.61	0.60	0.41	3.27	0.47		
12	0.49	0.35	0.20	0.12	1.22	0.46		
13	0.25	0.65	0.33	0.56	1.74	0.78	0.17	0.18
14	0.18	0.29	0.47	0.87	0.78	0.15	0.15	0.04
15	0.36	0.26	0.13	0.18	1.51	0.43	0.14	0.09
16	0.29	0.20	-	0.99	0.85	0.27	0.09	0.07
17	0.19	0.20	-	0.24	0.38	0.30		0.17
18	0.18	0.15	0.26	0.18	0.29	0.19	0.18	0.04
19	0.44	0.21	1.06	0.20	0.83	0.50		
20	1.19	0.19	0.16	0.12	1.10	0.37	0.81	
21	0.27	0.07	-	0.04	0.90	0.18		0.10
22	0.29	0.21	0.15	0.16	0.36	-	0.19	-
23	0.96	0.86	0.30	-	1.20	0.18	0.30	

* Precipitation-only

\- No sample

APPENDIX II

TABLE X

Heavy Metal Loadings (kg/ha)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
Nickel								
10	0.0019	<0.0014	0.0071	<0.0013	<0.0015	0.0011		
13	0.0991	<0.0026	<0.0015	<0.0032	<0.0014	0.0013		
Zinc								
10	0.061	0.054	0.768	0.026	0.119	0.033		
12	0.018	0.013	0.106	0.021	0.021	0.010		
13	0.010	0.032	0.081	0.253	0.063	0.026		
21	0.062	0.025	-	0.016	0.052	0.026	0.122	0.058
Lead								
10	0.017	0.011	0.009	0.005	<0.0015	0.010		
12	0.010	0.008	0.0001	0.002	0.005	0.007		
13	<0.0007	0.005	0.003	0.011	0.010	0.004		
21	<0.0013	0.001	-	<0.0008	<0.0014	<0.0016	0.016	0.006
Cadmium								
10	<0.0006	<0.0007	0.007	<0.0006	<0.0007	<0.0007		
12	<0.0003	<0.0003	0.0006	0.0002	0.0003	0.0005		
13	<0.0033	<0.0013	0.0007	0.0016	<0.0007	<0.0004		
21	0.0013	0.0011	-	0.0008	0.0050	0.0008	0.020	0.049
Copper								
10	0.010	0.006	0.017	0.0013	0.0015	0.006		
12	0.002	0.003	0.001	0.001	0.0015	0.002		
13	0.010	0.012	0.009	0.022	0.004	0.012		
21	<0.0006	<0.0004	-	<0.0004	<0.0007	<0.0008	0.015	<0.0008
Chromium								
10	0.002	<0.0014	0.002	<0.0013	<0.0015	<0.0011		
13	0.020	<0.0026	<0.0015	<0.0032	<0.0014	<0.0008		
Arsenic								
10	0.001	0.0007	0.003	<0.0006	<0.0007	0.004		

* Precipitation-only sample - No sample

APPENDIX II

TABLE XI

P.C.B.s (kg/ha)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	.00006	.00005	.00007	.00002	.00002	.00002		
3	.00011	.00016	.00018	.00012	.00009	.00017		
6	.00002	.00006	.00001	-	.00006	.00007		
9	ND		.00001	ND		ND		
13	.00009					.00005		.00005
14	.00002					.00004	.00002	.00002
16	.00005					.00008	.00006	.00004

* Precipitation-only sample

\- No sample

APPENDIX III

SURFACE LOADINGS OF PARAMETERS (g/ha/d)

(Note: Dates for collection periods 1-23 listed in these tables are shown in Table 3, p. 26.)

APPENDIX III

TABLE I

Sulphate Loadings (g/ha/d)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	333.6	314.6	163.8	113.5	389.3	135.0		
2	156.4	135.6	153.3	100.8	205.1	141.4		
3	313.3	290.0	281.1	219.7	205.8	309.2		
4	63.1	144.0	116.0	63.7	47.7	137.7		
5	87.2	91.8	107.7	109.0	-	126.9		
6	144.8	106.9	-	184.5	159.7	150.7		
7	71.9	99.1	192.8	108.8	94.7	81.2		
8	191.3	141.0	200.6	115.2	-	61.0		
9	210.0	-	476.5	219.0	-	363.0		
10	89.7	150.7	638.8	78.0	157.1	98.8		
11	236.1	300.4	270.4	311.1	248.6	217.1		
12	145.0	144.6	65.4	122.9	113.9	201.4		
13	97.8	498.2	183.7	351.4	176.3	264.8		
14	40.0	188.7	149.4	285.3	165.3	126.9		
15	164.6	301.8	168.2	197.7	265.0	283.6	215.0	211.4
16	86.4	83.3	-	115.2	105.2	84.8		
17	40.6	98.7	-	68.4	-	-		
18	38.9	182.1	149.0	59.7	96.6	41.4		
19	178.5	210.3	-	76.1	264.2	166.2		
20	279.9	148.3	71.7	102.1	300.4	82.1	249.7	
21	71.1	53.3	-	57.8	80.0	27.9		30.0
22	751.0	139.0	483.8	100.7	102.8	-	110.3	
23	93.3	84.9	45.3	-	45.0	54.3	62.1	-

* Precipitation-only sample

\- No sample

APPENDIX III

TABLE II

Sulphite Loadings (g/ha/d)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	71.4	85.7	51.9	60.8	82.1	57.9		
2	50.0	36.1	44.4	29.4	33.1	33.1		
3	61.4	101.9	127.8	86.1	102.8	137.5		
4	63.0	54.3	40.0	24.3	33.1	48.0		
5	26.2	28.2	32.3	35.9	48.2	29.2		
6	65.2	53.4	-	56.9	48.3	67.2		
7	24.1	22.5	43.1	18.1	29.7	28.4		
8	-	33.6	39.0	16.4	-	20.3		
9	105.0	-	89.5	82.5	-	138.0		
10	21.5	24.2	37.1	20.2	25.4	19.5		
11	39.3	52.5	44.6	53.9	74.6	39.3		
12	15.0	15.0	16.8	9.6	18.2	14.3		
13	16.7	102.2	44.1	81.8	40.4	40.4		
14	2.2	4.1	4.1	8.4	1.9	0.9		
15	27.3	34.1	38.2	31.8	33.2	35.9	31.4	38.2
16	34.6	26.7	-	41.5	25.1	28.8		
17	16.8	42.6	-	35.8	11.9	22.3		
18	11.0	17.9	25.5	20.0	22.4	12.7		
20	-	32.5	71.7	36.7	-	27.9		
21	43.0	28.1	-	-	55.9	57.0		90.0
22	123.8	62.8	56.2	65.9	81.0	-	190.0	

* Precipitation-only sample

\- No sample

APPENDIX III

TABLE III

Nitrogen Loadings (g/ha/d)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	177.5	344.8	114.8	209.4	175.3	75.0		
2	79.2	77.2	121.4	106.1	294.4	98.9		
3	159.4	13.6	71.7	129.2	93.3	193.1		
4	41.7	37.1	43.7	51.1	140.9	71.4		
5	-	-	59.0	-	35.1	-		
6	69.0	98.3	- -	63.8	80.0	21.4		
7	53.4	86.9	66.6	68.8	80.6	32.8		
8	-	69.7	35.8	27.1	-	8.1		
9	113.0	-	499.0	103.0	-	168.0		
10	64.4	109.3	-	148.3	122.9	73.2		
11	132.1	120.7	51.4	153.6	83.9	173.2		
23	49.1	121.9	47.2	-	44.8	-		
MEAN	93.9	108.0	110.9	105.6	115.1	91.5		

\- No sample

APPENDIX III

TABLE IV

Phosphate Loadings (g/ha/d)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	26.8	37.9	6.5	16.5	31.1	8.6		
2	14.4	6.1	10.0	20.3	28.9	18.6		
3	23.9	24.4	20.6	23.9	46.4	61.9		
4	10.0	10.6	2.3	3.4	9.4	15.7		
5	6.4	2.3	0.5	5.1	2.3	-		
6	2.4	5.9	-	3.4	6.2	1.0		
7	1.2	0.6	0.9	4.7	1.2	1.6		
8	-	0.6	3.2	-	-	0.3		
9	5.0	-	3.5	1.0	-	2.0		
10	11.9	9.5	12.4	11.2	2.4	12.9		
11	5.0	30.0	3.6	36.8	2.5	40.7		
12	9.6	21.1	3.2	5.7	8.2	14.3		
13	0.4	5.6	0.7	2.2	1.8	-	0.8	-
14	0.9	5.9	10.0	3.8	10.6	6.9		
15	7.3	1.4	2.3	7.3	14.1	18.2	2.7	0.8
16	2.4	-	-	3.0	1.8	2.1		
17	0.6	1.3	-	0.6	1.0	1.6		
21	1.5	1.1	-	-	0.4	1.1		
23	4.5	7.4	1.9	-	0.7	2.6	0.5	

* Precipitation-only sample

\- No sample

APPENDIX III

TABLE V

Chloride Loadings (g/ha/d)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	18.9	68.6	7.1	18.3	46.4	7.5		
2	14.2	17.2	12.5	18.6	28.3	13.9		
3	-	-	-	-	-	-		
4	48.6	43.4	21.4	33.4	9.7	35.7		
5	11.0	15.1	2.1	13.8	20.5	15.6		
6	15.5	11.4	-	24.5	25.9	14.1		
7	4.1	8.1	0	9.7	9.1	4.4		
8	57.7	23.9	23.9	17.7	-	21.9		
9	6.0	-	6.0	5.0	5.5	7.5		
10	8.0	9.3	119.3	0	9.5	0		
11	17.4	60.7	10.4	31.1	13.6	14.3		
12	0	42.1	4.3	10.4	24.6	60.4		
13	26.3	51.1	11.8	54.1	24.4	-	17.0	4.8
14	9.7	6.9	7.2	10.6	42.2	10.9		
15	31.8	33.2	21.8	23.2	56.8	34.1	25.5	18.2
16	20.6	10.0	-	27.6	13.6	9.1		
17	8.7	10.3	-	11.9	-	34.5		
19	-	26.6	-	-	41.8	40.0		
20	-	15.4	46.7	8.3	-	13.4		
21	-	6.7	-	-	-	-		
22	23.4	25.9	11.0	-	21.7	-		
23	51.7	69.1	18.1	-	7.4	-		

* Precipitation-only sample

\- No sample

APPENDIX III

TABLE VI

Calcium Loadings (g/ha/d)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	2.9	53.6	15.6	2.9	24.6	-		
2	19.7	26.7	24.2	11.7	11.9	7.2		
3	22.8	131.4	25.0	23.3	113.1	17.2		
4	7.7	39.4	7.4	6.6	26.3	6.6		
5	16.2	35.4	17.2	16.2	43.3	13.1		
6	30.3	26.2	-	29.3	27.9	16.9		
7	14.7	7.5	12.5	46.2	10.6	11.6		
8	38.4	13.6	16.8	21.9	-	11.9		
9	9.5	-	19.0	5.0	-	7.5		
10	33.2	34.6	42.0	25.1	32.4	22.2		
11	43.9	40.7	41.4	30.7	109.3	23.9		
12	17.5	10.7	9.6	4.3	27.5	8.2		
13	19.6	40.0	35.9	61.5	88.2	13.0	15.2	17.8
14	15.6	47.2	34.7	73.8	35.0	10.0	14.0	6.7
15	54.1	68.2	20.0	29.6	147.7	65.4	29.0	28.2
16	24.2	43.3	-	35.8	40.0	22.1	9.2	7.0
17	11.3	11.3	-	18.1	16.4	22.6	-	7.3
18	11.0	8.6	22.1	19.0	13.4	10.7	7.2	-
19	38.5	10.5	44.2	18.7	30.3	22.1		
20	29.3	9.2	17.9	7.9	27.9	12.8	38.3	-
21	13.7	4.8	-	5.2	29.3	7.8	-	5.2
22	15.9	2.8	3.1	6.2	12.4	-	6.6	-
23	21.7	4.4	4.7	-	24.1	2.9	8.1	-

* Precipitation-only sample

\- No sample

APPENDIX III

TABLE VII

Sodium Loadings (g/ha/d)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	20.0	47.1	22.9	20.2	52.9	9.3		
2	13.3	24.2	13.1	20.6	12.8	18.0		
3	15.6	23.6	12.8	13.9	20.6	37.2		
4	5.1	5.7	2.0	5.7	7.1	12.6		
5	5.1	2.0	3.3	7.2	-	3.6		
6	-	-	-	-	-	-		
7	12.2	8.8	17.5	20.3	8.7	9.1		
8	-	19.4	31.3	22.9	-	17.7		
9	72.5	-	57.0	42.5	-	39.0		
10	23.9	26.8	-	19.5	27.1	20.2		
11	32.9	22.1	31.1	45.7	17.9	23.9		
12	58.9	22.1	17.1	19.3	26.8	51.1		
13	34.1	38.2	46.7	-	31.5	59.3	20.6	13.4
14	-	-	-	-	-	32.5		37.8
15	46.8	3.6	12.7	37.3	56.4	42.3	13.1	6.7
16	10.3	11.5	-	30.0	10.9	10.3	3.4	3.4
17	8.1	11.9	-	10.9	11.9	21.6	-	16.9
18	12.8	13.8	22.4	9.0	13.1	12.8	35.0	5.3
19	68.5	15.0	48.2	15.5	29.5	33.9		10.7
20	49.3	12.5	26.7	16.3	20.8	16.6	50.3	
21	12.2	5.9	-	3.0	14.4	11.9		
22	14.5	7.9	9.3	12.8	13.8	-	13.1	-
23	30.2	18.4	8.8	-	12.6	8.3	6.4	

* Precipitation-only sample

\- No sample

APPENDIX III

TABLE VIII

Potassium Loadings (g/ha/d)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	44.6	81.4	16.7	24.8	53.9	14.6		
2	26.9	8.1	8.3	33.1	33.3	24.7		
3	22.2	40.8	26.1	24.4	23.1	92.8		
4	19.7	15.4	6.0	5.1	13.7	71.4		
5	18.5	3.3	2.8	6.4	9.7	50.8		
6	12.8	16.2	-	34.5	17.2	39.0		
7	6.2	5.9	6.9	16.6	13.8	4.7		
8	29.4	11.6	13.2	37.4	-	4.5		
9	17.0	-	12.0	12.0	-	16.5		
10	6.3	11.7	99.0	7.8	14.2	8.5		
11	8.2	30.0	16.1	33.2	15.0	28.9		
12	30.0	28.9	5.4	21.8	7.1	77.1		
13	5.2	121.1	45.6	20.0	22.6	118.5	2.6	3.7
14	3.4	13.1	10.3	57.2	9.1	11.2	1.1	<0.2
15	12.7	18.2	6.4	8.2	15.9	16.8	12.0	6.6
16	9.4	5.1	-	57.6	4.2	3.9	4.1	1.21
17	3.2	49.4	-	7.4	12.9	8.7	-	4.2
18	2.1	4.8	6.6	2.8	8.6	2.7	18.4	1.0
19	7.6	5.5	48.2	2.1	9.7	3.6		
20	16.9	4.6	22.1	5.8	5.8	4.5	19.3	
21	8.5	4.8	-	3.3	4.8	5.6		7.8
22	16.2	15.9	6.6	4.5	3.1	-	13.8	-
23	25.0	104.4	10.9	-	5.2	13.6	8.8	

* Precipitation-only sample

\- No sample

APPENDIX III

TABLE IX

Magnesium Loadings (g/ha/d)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	4.6	16.4	14.0	9.8	27.9	1.8		
2	13.9	9.4	15.6	8.3	11.7	4.7		
3	28.3	27.2	32.2	19.7	44.7	30.8		
4	12.0	8.0	8.6	6.3	16.9	13.1		
5	5.1	11.8	7.4	6.4	39.5	14.1		
6	9.7	4.8	-	13.4	30.3	16.9		
7	11.9	10.0	9.4	21.9	35.6	9.4		
8	58.4	11.3	8.1	17.1	-	6.4		
9	20.5	-	19.0	8.5	-	14.0		
10	6.3	2.7	1.2	1.9	30.7	4.2		
11	17.5	21.8	21.4	14.6	116.8	16.8		
12	17.5	12.5	7.1	4.3	43.6	16.4		
13	9.3	24.1	12.2	20.7	64.4	28.9	5.9	6.5
14	5.6	9.1	14.7	27.2	24.4	4.7	4.6	1.1
15	16.4	11.8	5.9	8.2	68.6	19.6	6.2	4.2
16	8.8	6.1	-	30.0	25.7	8.2	2.6	2.0
17	6.1	6.4	-	7.7	12.2	9.7	-	5.3
18	6.2	5.2	9.0	6.2	10.0	6.6	3.0	1.3
19	13.3	5.5	27.9	5.3	21.8	15.2		
20	41.0	7.9	6.7	5.0	45.8	12.8	27.9	-
21	10.0	2.6	-	1.5	33.3	6.7	-	3.7
22	10.0	7.2	5.2	5.5	12.4	-	6.6	-
23	22.9	20.0	7.0	-	28.6	4.3	7.1	-

* Precipitation-only sample

\- No sample

TABLE X

Heavy Metal Loadings (g/ha/d)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
Nickel								
10	.04	<.03	.17	<0.03	<.03	.03		
13	3.70	<.03	<.03	<.03	<.03	.05		
Zinc								
10	1.45	1.31	(18.90)	0.64	2.88	0.80		
12	0.63	0.47	3.80	.74	0.71	0.38		
13	0.37	1.22	3.12	(9.70)	2.44	0.92		
21	2.30	.93	-	.59	1.93	.96	4.52	2.15
Lead								
10	.40	.27	.22	.12	<.03	.25		
12	.36	.27	.02	.06	.16	.26		
13	<.03	.20	.11	.42	.37	.16		
21	<0.05	.05	-	<0.03	<0.05	0.06	0.59	0.22
Cadmium								
10	<.02	<.02	.17	<.02	<.02	<.01		
12	<.01	<.01	.02	.01	.01	.02		
13	<.12	<.05	.03	.06	<.02	<.02		
21	.05	.04	-	.03	.19	.03	.74	1.81
Copper								
10	.24	.14	.41	.03	.03	.15		
12	.07	.10	.03	.02	.05	.06		
13	.37	.04	.34	.84	.16	.45		
21	<0.02	<0.02	-	.02	<0.03	<0.03	0.56	<0.03
Chromium								
10	.05	<.03	.05	<.03	<.03	<.03		
13	.73	<.09	<.06	<.11	<.05	<.03		
Arsenic								
10	.03	.02	.07	<.02	<.02	.10		

* Precipitation-only sample   - No sample

APPENDIX III

TABLE XI

P.C.B. Loadings (g/ha/d)

Collection Period	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 1*	AG 13*
1	.0022	.0013	.0023	.0006	.0005	.0009		
3	.0031	.0045	.0051	.0033	.0026	.0048		
6	.0006	.0021	.0003		.0021	.0024		
9	ND		.0006	ND		ND		
13	.0032					.0019		.0019
14	.0006					.0012	.0007	.0005
16	.0016					.0025	.0017	.0011

* Precipitation-only sample

APPENDIX IV

KOLMOGOROV-SMIRNOV ONE SAMPLE TEST FOR NORMALITY

APPENDIX IV

TABLE I

Kolmogorov-Smirnov Test for Normality of Conductivity

Theoretical Cumulative Proportion		Observed Cumulative Proportion by Watershed					
(z value)		AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
<-2z	.023	.000	.000	.000	.000	.000	.000
<-1z	.159	.087	.000	.000	.091	.050	.045
< 0	.500	.696	.767	.705	.636	.600	.636
<+1z	.841	.783	.857	.824	.818	.800	.909
<+2z	.977	.913	.952	.941	.909	.900	.909
>+2z	1,000	1.000	1.000	1.000	1.000	1.000	1.000
Sample Size		23	21	17	22	20	22
Mean		51.2	60.7	55.9	47.1	70.8	69.2
Standard Deviation		24.8	28.6	49.6	23.0	36.9	66.0
D_{max}		.196*	.262*	.205*	.136	0.100	.136

Theoretical Cumulative Proportion		Logarithmic Transformed Cumulative Proportions					
(z value)		AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
<-2z	.023	.000	.000	.000	.000	.050	.000
<-1z	.159	.173	.143	.058	.227	.100	.136
< 0	.500	.521	.521	.588	.545	.600	.545
<+1z	.841	.782	.854	.824	.727	.800	.909
<+2z	.977	.913	.952	.941	.909	1.000	.909
>+2z	1,000	1.000	1.000	1.000	1.000	1.000	1.000
Mean		1.667	1.749	1.632	1.625	1.797	1.722
Standard Deviation		0.190	0.166	0,304	0.208	0.216	0.299
D_{max}		.064	.021	.093	.117	.100	.068

* Significant at 0.05 level

APPENDIX IV

TABLE II

Kolmogorov-Smirnov Test for Normality of Sulphate Concentrations

Theoretical Cumulative Proportions		Observed Cumulative Proportions by Station							
(z value)		AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 7a	AG 4b
<-2z	.023	.000	.000	.000	.000	.000	.000	.000	.052
<-1z	.159	.000	.091	.053	.048	.111	.091	.050	.210
< 0	.500	.636	.636	.736	.619	.555	.636	.600	.526
<+1z	.841	.909	.772	.789	.714	.833	.864	.900	.842
<+2z	.977	.954	.954	.948	1.000	.945	.954	.900	.947
>+2z	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sample Size		22	22	19	21	18	21	20	21
Mean		163.8	172.3	210.4	151.8	162.3	144.0	186.6	2.256
Standard Deviation		155.1	109.5	157.2	102.2	89.3	92.2	121.5	0.243
D_{max}		.159	.136	.236*	.128	.055	.136	.109	.051

* Significant at 0.05 level

a AG 4 without extreme high value

b log of AG 4 measurements

APPENDIX IV

TABLE III

Kolmogorov-Smirnov Test for Normality of Sulphite Data

Theoretical Cumulative Proportions (z value)		AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 13a	AG 13b
		Observed Cumulative Proportions by Watershed							
<-2z	.023	.000	.000	.000	.000	.000	.000	.000	.055
<-1z	.159	.053	.100	.111	.105	.111	.050	.000	.055
< 0	.500	.631	.600	.667	.631	.611	.700	.736	.500
<+1z	.841	.894	.850	.778	.842	.833	.850	.897	.977
<+2z	.977	.947	.950	1.000	.947	.944	.900	1.000	1.000
>+2z	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sample Size		19	20	18	19	18	20	19	20
Mean		41.6	42.9	47.0	41.6	42.6	42.9	42.1	1.4646
Standard Deviation		31.9	27.3	23.5	29.4	27.2	36.3	32.9	0.4729
D_{max}		.131	.100	.167	.131	.111	.200*	.236*	.104

a AG 13 less extreme value

b AG 13 after log transformation

* Significant at 0.05 level

APPENDIX IV

TABLE IV

Kolmogorov-Smirnov Test for Normality of Nitrogen Data

Watershed	Theory	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
				(cumulative proportions)			
p less than $-2z$	.023	.000	.000	.000	.000	.000	.000
$-2z < p < -z$	.159	.111	.125	.000	.222	.000	.222
$-z < p < 0$	.500	.667	.500	.625	.444	.667	.556
$0 < p < +z$	.841	.888	.750	.875	.778	.889	.667
$+z < p < +2z$	.977	1.000	1.000	1.000	1.000	.889	1.000
$p > +2z$	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Mean ($\bar{x}$)		86	91	62	95	108	93
Standard Deviation (s)		41	27	26	44	78	71
D_{max}		.167	.099	.159	.064	.167	.174

* Significant at 0.05 level

z $x-\bar{x}/s$

Note: all D_{max} are also less than .223 the critical value for the 0.20 level of significance as well.

APPENDIX IV

TABLE V

Kolmogorov-Smirnov Test for Normality of Phosphate Data

Theoretical Cumulative Proportions (z value)		Observed Cumulative Proportions by Watershed AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
<-2z	.023	.000	.000	.000	.000	.000	.000
<-1z	.159	.000	.000	.000	.000	.000	.000
< 0	.500	.667	.706	.687	.733	.706	.588
< +1z	.841	.888	.823	.812	.867	.823	.882
< +2z	.977	.888	1.000	.937	.933	.941	.941
> +2z	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sample Size		18	17	16	15	17	17
Mean		7.46	10.10	8.21	7.90	9.94	12.55
Standard Deviation		7.71	11.31	9.00	9.62	13.24	16.45
D_{max}		.167	.206*	.187	.233*	.206*	.188

Theoretical Cumulative Proportions (z value)		Logarithmic Transformed Cumulative Proportions AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
<-2z	.023	.000	.000	.000	.067	.000	.058
<-1z	.159	.167	.176	.125	.200	.235	.176
< 0	.500	.388	.352	.625	.667	.529	.471
<+1z	.841	.875	.764	.812	.800	.823	.882
<+2z	.977	1.000	1.000	1.000	1.000	1.000	1.000
>+2z	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Mean		.614	.692	.697	.605	.675	.732
Standard Deviation		.553	.597	.491	.517	.597	.661
D_{max}		.112	.148	.125	.167	.076	.041

* Significant at 0.05 level

APPENDIX IV

TABLE VI

Kolmogorov-Smirnov Test for Normality of Chloride Data

Theoretical Cumulative Proportions (z value)		Observed Cumulative Proportions by Watershed AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 4a	AG 4b
<-2z	.023	.000	.000	.000	.000	.000	.000	.000	.050
<-1z	.159	.055	.050	.000	.133	.250	.063	.133	.176
< 0	.500	.511	.600	.812	.667	.625	.625	.466	.471
<+1z	.841	.833	.800	.937	.933	.750	.813	.866	.882
<+2z	.977	.944	.950	.937	.933	.938	.938	.933	.941
>+2z	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sample Size		18	20	16	15	16	16	15	16
Mean		20.8	27.7	25.4	16.5	24.7	19.9	19.1	1.2792
Standard Deviation		16.8	21.0	28.1	13.5	15.0	15.6	13.1	0.3719
D_{max}		0.111	.100	.312*	.167	.125	.125	.047	.042

a AG 4 less extreme high value

b AG 4 after log transformation

* significant at 0.05 level

APPENDIX IV

TABLE VII

Kolmogorov-Smirnov Test for Normality of Calcium Data

Theoretical Cumulative Proportions		Observed Cumulative Proportions by Watershed							
(z value)		AG 1	AG 3	AG 4	AG 5	AG 10	AG 13	AG 10a	AG 10b
<-2z	.023	.000	.000	.000	.000	.000	.000	.000	.000
<-1z	.159	.136	.000	.210	.200	.000	.048	.000	.150
< 0	.500	.591	.523	.578	.600	.800	.619	.578	.650
<+1z	.841	.818	.904	.736	.850	.800	.952	.842	.800
<+2z	.977	.954	.952	1.000	.950	.950	.952	1.000	1.000
>+2z	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sample Size		22	21	19	20	20	21	19	20
Mean		22.4	31.8	22.0	24.7	43.9	16.0	38.2	1.328
Standard Deviation		12.9	29.3	12.4	18.7	38.4	12.9	30.6	0.326
D_{max}		.091	.159	.105	.100	.300*	.119	.159	.150

* Significant at 0.05 level

a AG 10 less extreme value

b AG 10 after log transformation

APPENDIX IV

TABLE VIII

Kolmogorov-Smirnov Test for Normality of Sodium Data

Theoretical Cumulative Proportions (z value)		Observed Cumulative Proportions by Watershed AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
<-2z	.023	.000	.000	.000	.000	.000	.000
<-1z	.159	.105	.210	.125	.167	.059	.048
< 0	.500	.579	.526	.500	.611	.647	.619
<+1z	.841	.842	.894	.813	.778	.882	.809
<+2z	.977	.947	.947	.938	1.000	.882	.952
>+2z	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sample Size		19	19	16	18	17	21
Mean		28.0	17.5	25.5	20.3	22.1	23.4
Standard Deviation		21.6	11.6	14.8	14.9	14.3	15.4
D_{max}		.079	.051	.044	.111	.147	.119

All D_{max} are not significant at 0.05 level

APPENDIX IV

TABLE IX

Kolmogorov-Smirnov Test for Normality of Potassium Data

Theoretical Cumulative Proportions (z value)		Observed Cumulative Proportions by Watershed AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
<-2z	.023	.000	.000	.000	.000	.000	.000
<-1z	.159	.181	.000	.000	.000	.000	.000
< 0	.500	.500	.667	.684	.600	.650	.681
<+1z	.841	.818	.857	.894	.900	.900	.818
<+2z	.977	.954	.904	.947	.900	.950	.954
>+2z	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sample Size		22	21	19	20	20	22
Mean		15.3	27.8	23.5	18.3	15.0	28.3
Standard Deviation		10.9	34.1	23.1	17.6	11.7	33.1
D_{max}		.028	.167	.184	.159	.159	.181

None of the observed D_{max} are significant at 0.05 level

APPENDIX IV

TABLE X

Kolmogorov-Smirnov Test for Normality of Magnesium Data

Theoretical Cumulative Proportions		Observed Cumulative Proportions by Watershed					
(z value)		AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
<-2z	.023	.000	.000	.000	.000	.000	.000
<-1z	.159	.000	.095	.052	.050	.100	.048
< 0	.500	.636	.571	.631	.600	.650	.476
<+1z	.841	.909	.809	.789	.800	.850	.904
<+2z	.977	.954	.952	.947	1.000	.950	.904
>+2z	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sample Size		22	21	19	20	20	21
Mean		15.7	11.2	11.7	13.1	36.6	11.9
Standard Deviation		12.9	7.0	6.5	10.0	24.6	7.8
D_{max}		.159	.071	.131	.109	.130	.111

None of the D_{max} are significant at 0.05 level

APPENDIX V

TIME SERIES TESTS

APPENDIX V

TABLE I

Least Squares Trend Line Statistics by Watershed for Specific Conductivity

Statistic		AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
Slope	m	1.11	0.89	4.63	0.20	1.41	1.09
Standard Error Slope	S_m	0.82	0.95	1.06	0.79	1.24	2.26
Intercept	a	54.90	60.17	59.46	46.88	69.64	69.76
Correlation	r	0.21	0.20	0.58	0.06	0.26	0.11
t-test	t_r	1.01	0.92	2.80*	0.25	1.13	0.48
t-test	t_m	1.35	0.90	2.78*	0.25	1.13	0.48
N		21	19	15	20	18	20
Runs Test Significance		no	no	no	no	no	no

$$t_m = \frac{m-0}{S_m} \qquad t_r = \frac{r\sqrt{N-2}}{\sqrt{1-r^2}}$$

Trend Equation Format $Y = a \pm mx$ x = time interval

* Significant at 0.05 level

APPENDIX V

TABLE II

Least Squares Trend Line Statistics by Watershed for Sulphate

Statistic		AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
Slope	m	-6.5	-3.8	1.0	-5.7	-5.2	-5.1
Standard Error Slope	S_m	4.7	3.6	5.7	3.3	2.6	2.0
Intercept	a	130.3	172.9	187.8	150.5	141.9	162.6
Correlation	r	-0.49	-0.23	0.05	-0.36	-0.36	-0.40
t-test	t_r	-2.46*	-1.10	0.23	-1.71	-1.72	-1.96
t-test	t_m	-1.39	-1.06	+0.18	-1.70	-61.78	-1.96
N		22	22	19	21	19	22
Runs Test Significance **		no	no	no	no	no	no

$$t_m = \frac{m-0}{S_m} \qquad t_r = \frac{r\sqrt{N-2}}{\sqrt{1-r^2}}$$

Trend Equation Format $Y = a \pm mx$ x = time interval

* Significant at 0.05 level

** Yes = signficant at 0.05 level

APPENDIX V

TABLE III

Least Squares Trend Line Statistics by Watershed for Sulphite

Statistic		AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
Slope	m	-0.53	-1.42	1.01	-0.79	-2.28	-1.17
Standard Error Slope	S_m	1.13	0.95	0.95	1.15	0.97	1.32
Intercept	a	41.46	43.06	45.86	41.40	41.79	42.37
Correlation	r	-0.10	-0.33	0.25	-0.16	-0.32	-0.27
t-test	t_r	-0.42	-1.48	1.07	-0.68	-1.70	-1.14
t-test	t_m	-0.46	-1.48	1.06	-0.68	-1.72	-1.20
N		19	20	18	19	18	20
Runs Test Significance**		no	no	no	no	*no	no

$$t_m = \frac{m-0}{S_m} \qquad t_r = \frac{r\sqrt{N-2}}{\sqrt{1-r^2}}$$

Trend Equation Format $Y - a \pm mx$ x = time interval

* Significant at 0.05 level

** Yes = significant at 0.05 level

APPENDIX V

TABLE IV

Least Squares Trend Line Statistics by Watershed for Phosphate

Statistic		AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
Slope	m	-0.90	-0.77	-1.10	-0.32	-1.41	-1.01
Standard Error Slope	S_m	0.23	0.46	0.37	0.49	0.45	0.69
Intercept	a	7.59	9.87	6.76	7.66	10.19	12.48
Correlation	r	-0.67	-0.39	-0.62	-0.18	-0.63	-0.36
t-test	t_r	3.64*	-1.64	-3.00*	-0.66	-3.17*	-1.49
t-test	t_m	-3.62	-1.64	-2.98*	-0.64	-3.13*	-1.47
N		18	17	16	15	17	17
Runs Test Significance		no	no	no	no	no	no

$$t_m = \frac{m-0}{S_m} \qquad t_r = \frac{r\sqrt{N-2}}{\sqrt{1-r^2}}$$

Trend Equation Format $Y = a \pm mx$ x = time interval

* Significant at 0.05 level

APPENDIX V

TABLE V

Least Squares Trend Line Statistics by Watershed for Chloride

Statistic		AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
Slope	m	-0.43	-0.21	-0.30	0.53	-0.04	0.76
Standard Error Slope	S_m	0.61	0.73	1.08	0.64	0.59	0.63
Intercept	a	21.26	27.80	25.00	17.33	24.69	21.79
Correlation	r	-0.16	-0.07	-0.07	0.22	-0.02	0.28
t-test	t_r	-0.66	-0.29	0.28	0.83	-0.07	1.10
t-test	t_m	-0.70	-0.29	-0.28	0.83	-0.07	1.10
N		18	20	16	15	16	16
Runs Test Significance**		no	no	no	no	no	no

$$t_m = \frac{m-0}{S_m} \qquad t_r = \frac{r\sqrt{N-2}}{\sqrt{1-r^2}}$$

Trend Equation Format $Y = a \pm mx$ x = time interval

* Significant at 0.05 level

** Yes = significant at 0.05 level

APPENDIX V

TABLE VI

Least Squares Trend Line Statistics by Watershed for Calcium

Statistic		AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
Slope	m	0.41	-2.09	0.46	-0.05	-0.32	0.23
Standard Error Slope	S_m	0.43	0.89	0.46	0.68	1.34	0.41
Intercept	a	22.49	32.12	22.52	24.70	44.06	15.86
Correlation	r	0.20	-0.47	0.23	-0.01	-0.05	0.11
t-test	t_r	0.94	-2.35*	1.00	-0.07	-0.24	0.50
t-test	t_m	0.94	-2.34*	1.00	-0.07	-0.24	0.48
N		22	21	19	20	20	21
Runs Test Significance**		no	no	no	no	no	no

$$t_m = \frac{m-0}{S_m} \qquad t_r = \frac{r\sqrt{N-2}}{\sqrt{1-r^2}}$$

Trend Equation Format $Y = a \pm mx$ x = time interval

* Significant at 0.05 level

** Yes = significant at 0.05 level

APPENDIX V

TABLE VII

Least Squares Trend Line Statistics by Watershed for Sodium

Statistic		AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
Slope	m	0.88	-0.53	0.23	-0.26	-0.14	0.16
Standard Error Slope	S_m	0.74	0.39	0.58	0.60	0.53	0.54
Intercept	a	27.69	17.67	25.75	20.18	22.80	23.30
Correlation	r	0.29	0.33	0.12	-0.12	-0.07	0.07
t-test	t_r	0.29	-1.44	0.44	-0.49	-0.28	0.31
t-test	t_m	1.19	-1.36	0.40	-0.43	-0.30	0.26
N		19	19	16	18	17	21
Runs Test Significance		no	no	no	no	no	no

$$t_m = \frac{m-0}{S_m} \qquad t_r = \frac{r\sqrt{N-2}}{\sqrt{1-r^2}}$$

Trend Equation Format $Y = a \pm mx$ x = time interval

* Significant at 0.05 level

** Yes = significant at 0.05 level

APPENDIX V

TABLE VIII

Least Squares Trend Line Statistics By Watershed for Potassium

Statistic		AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
Slope	m	-0.84	-0.27	-0.30	-0.31	-0.26	-1.94
Standard Error Slope	S_m	1.33	1.23	.84	.66	.40	1.05
Intercept	a	15.26	27.80	23.18	18.16	15.34	28.30
Correlation	r	-0.50	-0.04	-0.08	-0.11	-0.15	-0.38
t-test	t_r	2.51*	-0.17	-0.33	-0.48	-0.64	-1.83
t-test	t_m	2.51*	-0.15	-0.33	-0.47	-0.64	-1.84
N		20	19	17	18	18	20
Runs Test Significance		no	no	no	no	no	no

$t_m = \frac{m-0}{S_m}$ $\quad$ $t_r = \frac{r\sqrt{N-2}}{\sqrt{1-r^2}}$

Trend Equation Format $Y = a \pm mx$ $\quad$ x = time interval

* Significant at 0.05 level

** Yes = significant at 0.05 level

APPENDIX V

TABLE IX

Least Squares Trend Line Statistics by Watershed for Magnesium

Statistic		AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
Slope	m	0.08	-0.27	0.04	-0.59	0.02	-0.14
Standard Error Slope	S_m	0.44	0.24	0.25	0.35	0.86	0.27
Intercept	a	15.70	11.20	11.67	13.00	36.61	12.05
Correlation	r	0.04	-0.26	-0.04	-0.37	0.01	-0.12
t-test	t_r	0.17	-1.15	0.17	-1.68	0.02	-0.57
t-test	t_m	0.18	-1.13	0.16	-1.68	0.02	-0.51
N		22	21	19	20	20	21
Runs Test Significance		no	no	no	no	no	no

$$t_m = \frac{m-0}{S_m} \qquad t_r = \frac{r\sqrt{N-2}}{\sqrt{1-r^2}}$$

Trend Equation Format $Y = a \pm mx$ x = time interval

* Significant at 0.05 level

APPENDIX VI

ANALYSIS OF VARIANCE TESTS

APPENDIX VI

ANALYSIS OF VARIANCE BETWEEN WATERSHEDS

TABLE I - Specific Conductivity(1)

Source	Sum of Squares	df	Mean Square	F-Ratio
Between Watersheds	0.4794	5	0.0959	1.75
Within Watersheds	0.5060	119	0.0547	

TABLE II- Sulphate

Source	Sum of Squares	df	Mean Square	F-Ratio
Between Watersheds	53385	5	10677	0.73
Within Watersheds	1724483	118	14614	

TABLE III - Sulphite

Source	Sum of Squares	df	Mean Square	F-Ratio
Between Watersheds	366	5	73	0.08
Within Watersheds	95019	113	879	

TABLE IV - Nitrogen

Source	Sum of Squares	df	Mean Square	F-Ratio
Between Watersheds		5	1962	0.70
Within Watersheds		46	2806	

TABLE V - Phosphate (1)

Source	Sum of Squares	df	Mean Square	F-Ratio
Between Watersheds	0.1975	5	0.0395	0.1168
Within Watersheds	30.0904	89	0.3381	

TABLE VI - Chloride

Source	Sum of Squares	df	Mean Square	F-Ratio
Between Watersheds	1461	5	292	0.80
Within Watersheds	34652	95	365	

(1) Based on a logarithmic transformation

* Significant at 0.05 level

APPENDIX VI

ANALYSIS OF VARIANCE BETWEEN WATERSHEDS

TABLE VII - Calcium

Source	Sum of Squares	df	Mean Square	F-Ratio
Between Watersheds	9779	5	1956	3.72*
Within Watersheds	61429	117	525	

Matrix of ε Tests for Individual Watershed Differences

	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
AG 1	-	2.34*	0.11	0.55	5.33*	1.63
AG 3		-	2.36*	1.74	2.99*	3.93*
AG 4			-	0.64	5.25*	1.47
AG 5				-	4.67*	2.14*
AG 10					-	6.86*

TABLE VIII - Sodium

Source	Sum of Squares	df	Mean Square	F-Ratio
Between Watersheds	1286	5	257	1.04
Within Watersheds	25848	104	249	

TABLE IX - Potassium

Source	Sum of Squares	df	Mean Square	F-Ratio
Between Watersheds	3842	5	768	1.36
Within Watersheds	66849	118	567	

(1) Based on a logarithmic transformation

* Significant at 0.05 level

APPENDIX VI

ANALYSIS OF VARIANCE BETWEEN WATERSHEDS

TABLE X - Magnesium

Source	Sum of Squares	df	Mean Square	F-Ratio
Between Watersheds	9821	5	1964	11.59*
Within Watersheds	19831	117	169	

Matrix of t-Tests for Individual Watershed Differences

	AG 1	AG 3	AG 4	AG 5	AG 10	AG 13
AG 1	-	1.13	0.97	0.63	5.21*	0.97
AG 3		-	0.13	0.49	6.25*	0.17
AG 4			-	0.34	5.97*	0.03
AG 5				-	5.76*	0.32
AG 10					-	6.08*

TABLE XI - PCBs

Source	Sum of Squares	df	Mean Square	F-Ratio
Between Watersheds	.000002	5	.0000004	0.28
Within Watersheds	.000030	23	.0000013	

* Significant at 0.05 level

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