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WHOLE LAKE CHEMICAL ADDITIONS IN THE EXPERIMENTAL LAKES AREA, 1990-1993

by

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ABSTRACT

Cruikshank, D.R. 1994. Whole lake additions in the Experimental Lakes Area, 1990-1993. Can. Data Rep. Fish. Aquat. Sci. 941: iv + 19 p.

Acid was added to three lake basins during the period 1990 to 1993. Sulfuric acid was added to Lake 223 and Lake 302S. Hydrochloric acid, sodium nitrate and sodium sulphate were added to Lake 302N. Beginning in 1993, phosphoric acid was also added to Lake 302N. Cadmium was added to Lake 382 during the period 1990 to 1992. Phosphoric acid only was added to Lake 227.

Key words: Acidification; fertilization; lake manipulations; trace metal.

RÉSUMÉ

Cruikshank, D.R. 1994. Whole lake additions in the Experimental Lakes Area, 1990-1993. Can. Data Rep. Fish. Aquat. Sci. 941: iv + 19 p.

De l'acide a été ajouté dans trois bassins lacustres entre 1990 et 1993. De l'acide sulfurique a été ajouté dans les lacs 223 et 302S. De l'acide chlorhydrique, du nitrate de sodium et du sulfate de sodium ont été ajoutés dans le lac 302N. À partir de 1993, de l'acide phosphorique a également été ajouté dans le lac 302N. Du cadmium a été ajouté dans le lac 382 pendant la période allant de 1990 à 1992. Enfin, de l'acide phosphorique seul a été ajouté dans le lac 227.

Mots-clés: Acidification; fertilisation; manipulations dans les lacs; métaux traces.

INTRODUCTION

This is the fourth in a series of reports on whole lake additions at the Experimental Lakes Area (ELA). For data on additions from 1969-1983 see Cruikshank (1984). For additions data during 1984 and 1985 see Cruikshank (1986). Additions made from 1986 to 1989 can be found in Cruikshank (1991). Summary data (1969-1993) for current experimental lakes are included in this report.

Lake 227 has received nutrients since 1969 (Table 1). Nitrogen and phosphorus were added in ratios of 15:1 respectively from 1969-1974 and 5:1 from 1975-1989. Beginning in 1990, phosphorus only was added to L227.

Lake 382 received small amounts of cadmium and cadmium^{109} during the period 1987-1992 (Table 2). These additions were made to test the Canadian Water Quality Guideline for cadmium in drinking water. Organisms in the lake trout food chain were examined for cadmium levels.

The L223 acidification experiment entered its third recovery phase in 1991 (Table 3). The target pH for the lake in 1991 was 6.1, up from 5.8 in 1990. The target pH of 6.1 was maintained during 1992 and 1993. The final recovery phase of L223 begins in 1994 with no planned acid additions for the future.

During 1990 and 1991 hydrochloric acid and sodium sulphate were added to L302N (Table 4) to maintain target levels of pH 5.1-5.3, sulphate concentrations of approximately 7.2 $mg \cdot L^{-1}$ and nitrate concentrations of 250 $\mu g \cdot L^{-1}$. These additions were made so that L302N would simulate pH, nitrate and sulfate concentrations found in Adirondack Mountain lakes. During 1992 and 1993, phosphoric acid was added. Additions of phosphoric acid were made to test the effect of adding the nutrient phosphorus would have on the phytoplankton communities. It was speculated that the addition of phosphorus would cause algal blooms to occur. These blooms may increase lake pH. The experiment during 1992 and 1993 changed from making additions to reach predetermined targets to a loading experiment. Once per week, from May to September, 10-11 carboys of hydrochloric acid, 5.5 L of phosphoric acid, three bags of sodium nitrate and 6.8 kg of sodium sulphate were added

The pH of L302S (Table 5) during 1990 and 1991 was maintained around the target pH of 4.5. During 1992, the recovery phase (pH = 5.1) for the L302S acidification experiment began and continued in 1993. Only small amounts of acid were required during 1992 and 1993, mostly during the spring and fall overturns to maintain the pH at 5.1.

METHODS

Additions of sulfuric acid to L223 and L302S as well as hydrochloric acid additions to L302N were made using the "prop-tube mix" method. The additions of phosphoric acid to L227 and L302N were made by mixing the acid with lake water in a barrel and letting it drain slowly into the lake. The "barrel method" and "prop-tube" method are described in more detail in Cruikshank (1984). Cadmium additions were made by injecting a cadmium chloride solution into the epilimnion from a raft near the centre of the lake (Cruikshank 1991).

Sodium sulphate was very difficult to dissolve, especially in cold water. Initial attempts to dissolve the sodium sulphate powder rapidly into a solution failed. Most of the powder, when introduced to water, turned into hard pellets. It was discovered that the pellets would gradually dissolve in water, over a period of one to two days. During 1990 and 1991, five cages were positioned around the lake and the sulphate powder divided between them. The frame of the cages were constructed using 5 cm by 5 cm spruce slats. The cages had dimensions of 1 m x 0.5 m x 0.5 m. The frame was covered in window screening to allow water to flow through. Each cage was weighted with rocks just beneath the surface. The waves and internal mixing of the lake created a fairly homogeneous concentration of sulphate across the lake after a period of one to two days.

The sodium nitrate was added using a variation of the "prop-tube" method. Two or three 202 L steel drums were filled with lake water using a gasoline powered pump. The sodium nitrate was added to the drums (1-1.5 bags per drum) and mixed until dissolved using an electric outboard motor. The sodium nitrate solution was then

pumped into two 202 L drums that were fastened on a rack between the seats of a 16 ft aluminum boat. The drums were positioned in a horizontal position with straight connectors and a 1 1/2" gate valve located between the drum and the side of the boat. A hole was cut into the side of the boat to allow the pipe from the gate valve to pass through the side of the boat and project about 0.5 m outside the boat hull. When the drums were full with the nitrate solution, the boat was driven around the lake with the valves open to allow the solution to drain from the drums. The nitrate solution was also mixed in the prop-wash of the boat as it criss-crossed the lake.

CHEMICAL SOURCES

The hydrochloric acid, sodium nitrate and sodium sulfate used in 1990 and in 1991 were purchased from STANCHEM in Winnipeg. These chemicals were purchased from PRAIRECHEM of Winnipeg during 1992 and 1993. All the sulfuric and phosphoric acid used from 1990 to 1993 were purchased from PRAIRECHEM. Table 6 summarizes chemical purities and prices for purchases made during the years 1990-1993. Chemicals which are not used in the year purchased are stockpiled at the lakes and are used the following year.

ACKNOWLEDGMENTS

I would like to thank my field assistants who did most of the chemical additions during 1990-1993. They are Scott Herron, John Embury, Murray MaCecharn, Cameron Grose, David Murray, and Craig Fazakas. Special thanks are extended to those who provided me with information for this report. Cadmium data for L382 was provided by Morris Holoka and Dr. Diane Malley. Ticia Lyng and Allison MacHutchon provide the pH data. Donna Laroque formatted the report.

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Table 1. L227 nutrient additions.

Years	Date	Sodium Nitrate				Phosphoric Acid				
		kg/wk	Total kg	kg N/wk	Total kg N	L/wk	Total Litres	Total kg	kg P/wk	Total kg P
1969 - 1974		90.7	11,067.2	15.0	1,829.5	2.5	262.5	376.2	1.14	24.0
1975 - 1989		34.0	10,206.0	5.61	1,683.0	2.5	750.0	1074.8	1.14	22.83
1990	May 16 - Sep 26 (20 additions)					2.5	50.0	71.7	1.14	22.83
1991	May 08 - Sep 18 (20 additions)					2.5	50.0	71.7	1.14	22.83
1992	May 14 - Sep 26 (20 additions)					2.5	50.0	71.7	1.14	22.83
1993	May 03 - Sep 15 (20 additions)					2.5	50.0	71.7	1.14	22.83

Table 2. L382 cadmium additions.

Year	Grams Cd added	mCi ^{109}Cd added	Target Epi [Conc] ng Cd/L	Mean Epi [Conc] ng Cd/L	Annual loading mg Cd/m^2
1987	975	96	100	83	2.6
1988	643	64	100	51	1.7
1989	778	77	120	110	2.1
1990	1435	142	160	150	3.9
1991	2143	211	200	180	5.8
1992	1117		200	177	3.0

Table 3. L223 sulfuric acid additions.

Year	Dates of additions	Number of additions	litres added	kg H_2SO_4 added	Kg H^+ added	Target pH	Mean Epi ph
1976			5537.8	9350.85	192.63		6.49
1977	May 04 - Oct 17	17	2910.6	4914.59	101.24	6.00	6.13
1978	May 08 - Oct 23	31	3377.4	5702.96	117.48	5.75	5.93
1979	May 21 - Oct 29	45	2816.1	4755.12	97.97	5.50	5.64
1980	May 05 - Oct 22	35	3099.6	5233.83	107.82	5.25	5.59
1981	May 06 - Oct 22	35	3553.2	5999.75	123.59	5.00	5.02
1982	May 05 - Oct 26	38	3458.7	5840.18	120.31	5.00	5.09
1983	May 10 - Oct 28	30	2230.2	3765.80	77.58	5.00	5.13
1984	May 21 - Oct 08	14	680.4	1148.89	23.67	5.40	5.44
1985	May 13 - Nov 06	34	3761.1	6350.80	130.83	5.40	5.53
1986	May 05 - Oct 22	19	2360.0	4036.12	83.14	5.40	5.45
1987	May 06 - Oct 12	18	1860.0	3181.01	65.53	5.40	5.42
1988	May 24 - Oct 13	15	1160.0	1983.86	40.87	5.80	5.81
1989	May 23 - Oct 24	22	1795.0	3069.85	63.24	5.80	5.81
1990	May 08 - Oct 26	18	1330.0	2274.59	46.86	5.80	5.84
1991	Jun 05 - Oct 28	13	480.0	820.91	16.91	6.10	6.11
1992	May 26 - Oct 07	15	1202.0	2055.68	42.35	6.10	6.19
1993	May 04 - Oct 22	21	1983.0	3391.4	69.9	6.10	6.20

N.B. A change of suppliers for the sulfuric acid occurred in 1986. Acid used from 1986 - 1992 was 93.2% pure and S.G.= 1.835. Sulfuric acid used prior to 1986 was 93.29 % pure and S.G. =1.81.

Table 4. L302N acid and fertilizer additions.

Year	Dates of additions	# of additions	Litres HNO_3 added	Kg HNO_3 added	Litres HCl added	Kg HCl added	Kg H^+ added	Kg $NaNO_3$ added	Kg Na_2SO_4 added	Litres H_3PO_4 added	Kg P added	Mean Epi pH
1982	Jun 29 - Oct 05	14	2282.9	1981.15			31.70					6.71
1983	May 23 - Oct 24	26	2463.3	2137.7			34.20					6.34
1984	May 09 - Sep 25	25	2804.4	2433.72			38.94					6.24
1985	May 15 - Oct 09	21	3050.4	2647.2			42.36					6.02
1986	May 06 - Oct 21	17	3247.2	2818.99			45.09					5.98
1987	Jun 04 - Oct 27	24			7320.0	2532.35	69.89					5.48
1988	May 23 - Oct 19	15			2660.0	920.23	25.40					5.32
1989	May 15 - Oct 30	26			3510.0	1214.28	33.04					5.04
1990	May 09 - Oct 26	12	10.0	8.68	2400.0	830.28	22.92	2281.99	2306.6			5.19
1991	May 08 - Oct 28	18			2760.0	954.82	26.35	858.81	90.5			5.32
1992	May 21 - Sep 28	15			3280.0	1134.72	31.3	1177.80	94.7	77.0	34.9	6.08
1993	May 03 - Aug 24	17			3549.9	1228.1	33.9	1251.4	115.0	93.5	42.4	4.96

Table 5. L302S sulfuric acid additions.

Year	Dates of additions	Number of additions	litres added	kg H_2SO_4 added	Kg H^+ added	Target pH	Mean Epi ph
1981							6.75
1982	Jun 29 - Oct 05	14	1228.5	2074.38	42.73		6.25
1983	May 23 - Oct 24	26	1107.7	1870.41	38.53	5.80	5.86
1984	May 09 - Oct 08	24	1152.9	1946.73	40.10	5.50	5.60
1985	May 14 - Oct 08	21	1247.4	2106.30	43.39	5.30	5.31
1986	May 06 - Oct 21	18	1292.3	2207.0	44.82	5.00	5.02
1987	May 05 - Oct 28	19	1450.0	2479.82	51.08	4.75	4.80
1988	May 09 - Oct 19	29	2020.0	3454.64	71.17	4.50	4.58
1989	May 15 - Oct 30	23	1220.0	2086.47	43.02	4.50	4.53
1990	May 09 - Oct 26	14	875.0	1496.44	30.83	4.50	4.53
1991	Jun 05 - Oct 28	13	480.0	820.91	16.90	4.50	4.59
1992	May 13 - Sep 02	03	220.0	376.25	7.75	5.10	4.85
1993	May 04 - Sep 24	07	290.0	495.96	10.30	5.10[†]	4.98

N.B. A change of suppliers for the sulfuric acid occurred in 1986. Acid used from 1986 - 1992 was 93.2% pure and S.G.= 1.835. Sulfuric acid used prior to 1986 was 93.29 % pure and S.G. =1.81.

[†] Includes 0.08 kg H^+ added through a spill of HCl (8L on June 01).

Table 6. Chemical purities and costs.

Chemical used	Year	% purity	Specific gravity	Cost per kg
$NaNO_3$	1990	98.615		$ 0.62
	1991	98.615		
	1992	98.615		
	1993	98.615		$ 1.03
Na_2SO_4	1990	99.5		$ 0.52
	1991	99.5		
	1992	99.5		
	1993	99.5		
H_2SO_4	1990	93.2	1.835	$ 0.52
	1991	93.2	1.835	$ 0.52
	1992	93.2	1.835	$ 0.44
	1993	93.2	1.835	
H_3PO_4	1990	85.0	1.686	$ 1.63
	1991	85.0	1.686	$ 2.08
	1992	85.0	1.686	
	1993	85.0	1.686	$ 2.22
HCl	1990	31.45	1.10	$ 0.55
	1991	31.45	1.10	
	1992	32.5	1.18	$ 0.62

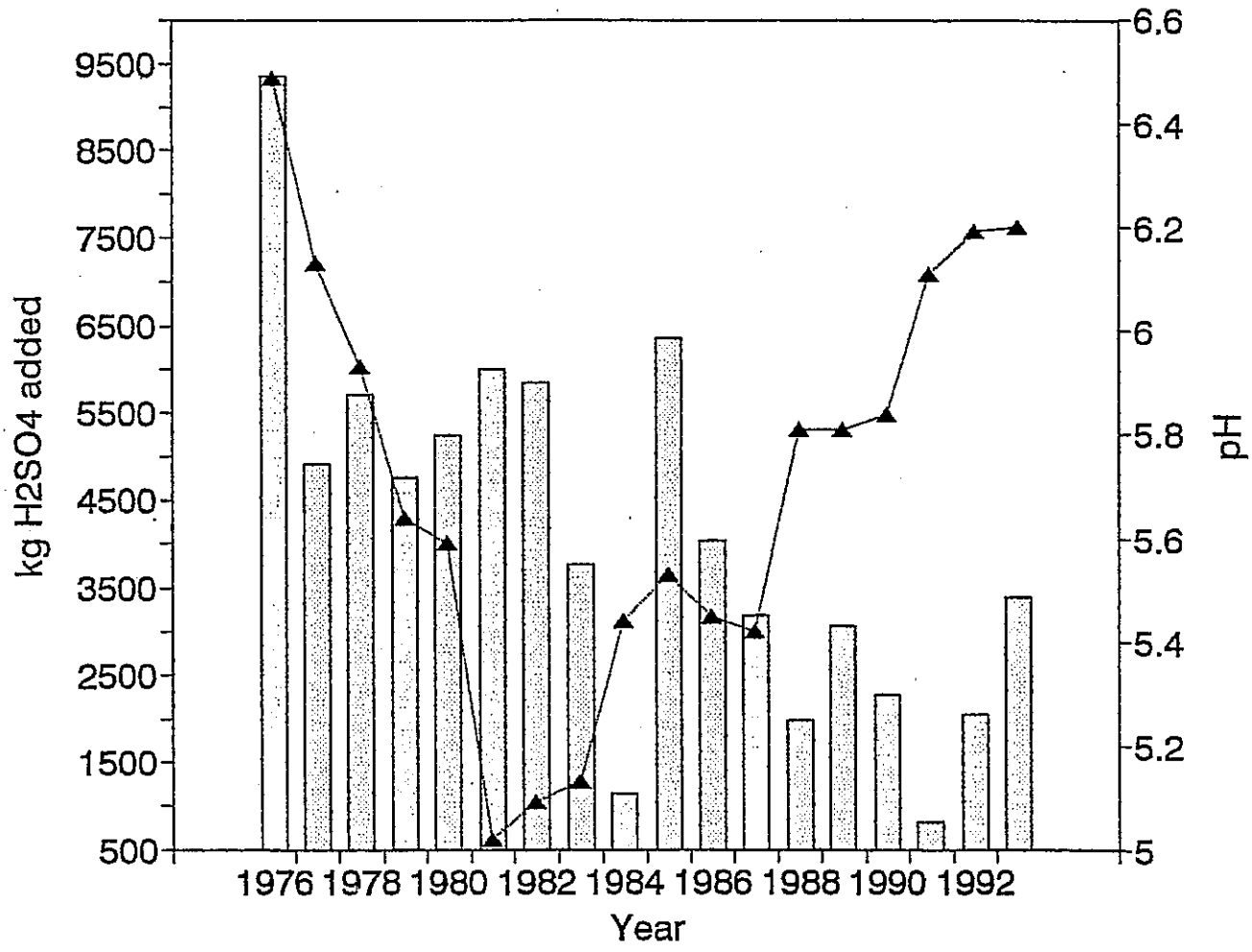

Fig. 1. L223 annual mean pH and sulfuric acid additions.

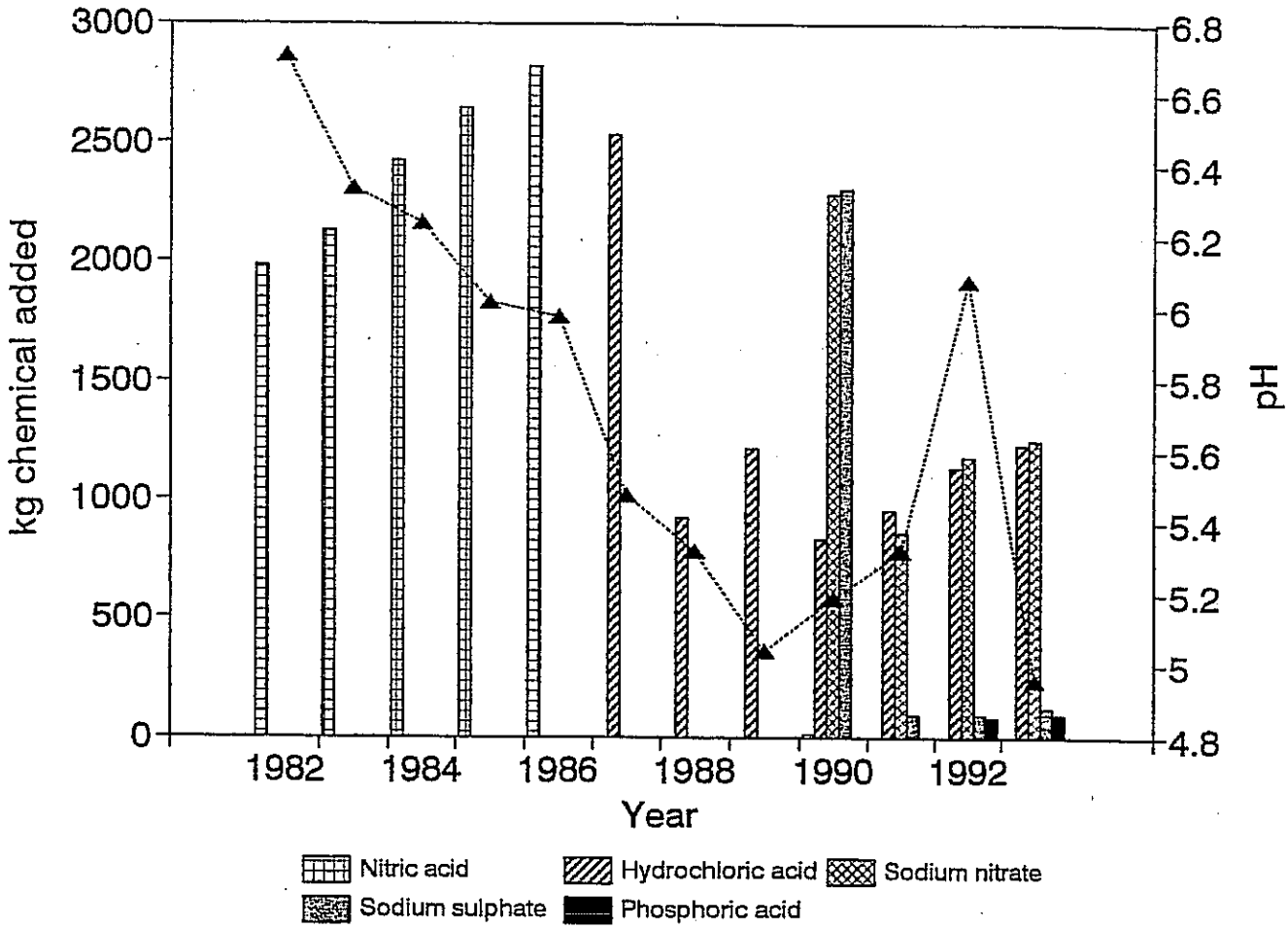

Fig. 2. L302N annual mean ph and chemical additions.

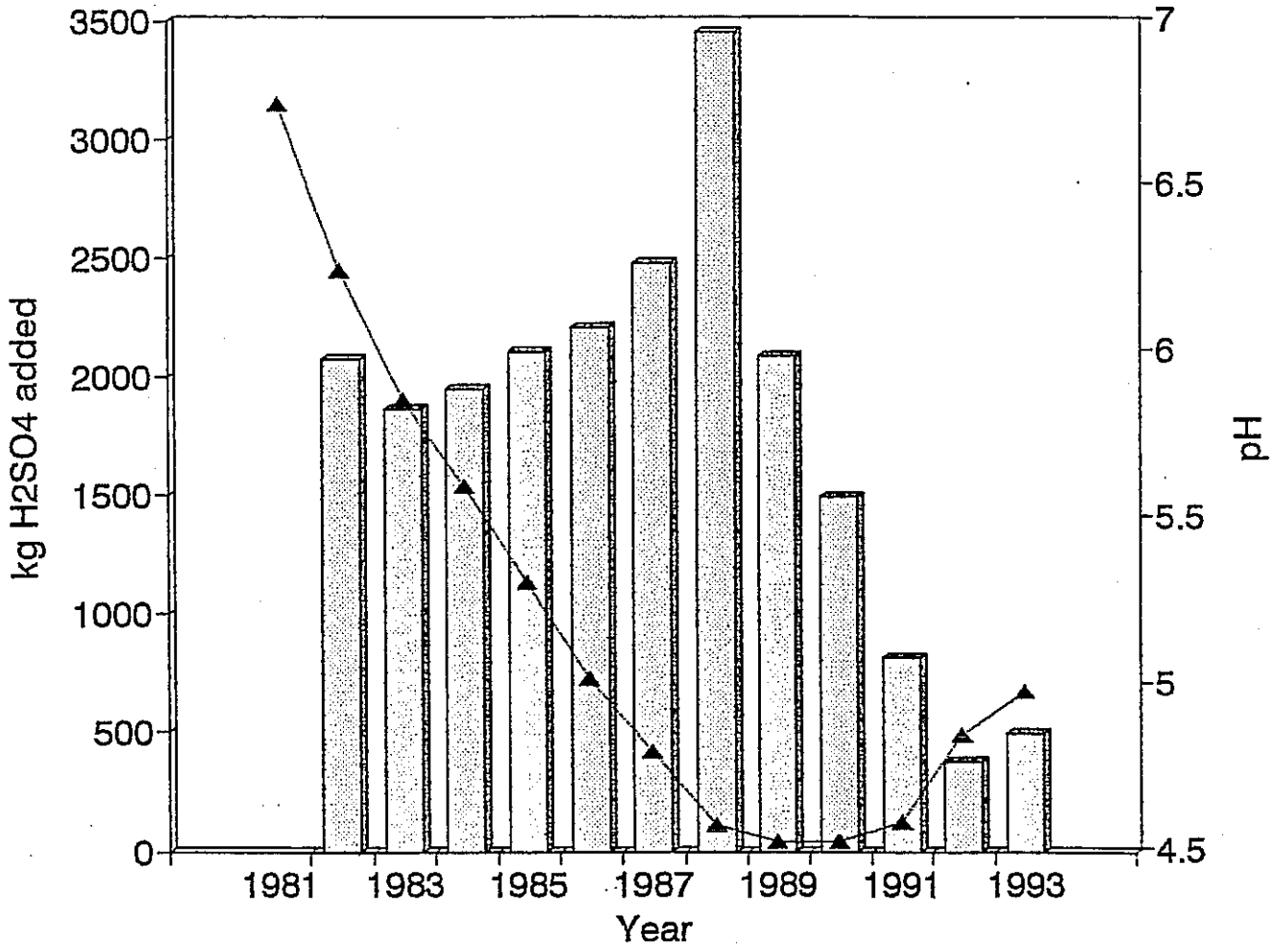

Fig. 3. L302S annual mean pH and sulfuric acid additions.

Appendix 1. L223 daily pH and sulfuric acid additions.

Date of addition	pH	kg H_2SO_4 added	Date of addition	ph	kg H_2SO_4 added	Date of addition	pH	kg H_2SO_4 added	Date of addition	ph	kg H_2SO_4 added
05/07/1990	5.89		08/07/1990	5.84		10/25/1990	5.83		07/15/1991	6.15	
05/08/1990	5.87	102.6	08/08/1990	5.81		10/26/1990		68.4	07/16/1991	6.14	
05/09/1990		256.5	08/13/1990	5.8		10/29/1990	5.74		07/22/1991	6.15	
05/10/1990	5.91		08/20/1990	5.87	51.3	11/01/1990	5.75		07/23/1991	6.20	
05/15/1990	5.82		08/21/1990	5.81					07/30/1991	6.28	
05/16/1990		68.4	08/27/1990	6.05		05/08/1991	5.82		08/02/1991		51.3
05/22/1990	5.89		08/29/1990		205.2	05/09/1991	5.72		08/06/1991	6.20	
05/23/1990	5.86		08/30/1990	5.6		05/16/1991	5.92		08/08/1991		34.2
05/28/1990	5.84		09/04/1990	5.72		05/21/1991	6.03		08/13/1991	6.17	
05/29/1990	5.79		09/05/1990	5.81		05/22/1991	6.16		08/27/1991	6.32	
05/30/1990	5.81		09/06/1990	5.85		05/27/1991	6.13		08/30/1991		51.3
06/04/1990	5.84		09/10/1990	5.83		05/29/1991	6.01		09/03/1991	6.23	
06/05/1990	5.81		09/11/1990	5.82		06/03/1991	6.30		09/04/1991	6.30	
06/11/1990	5.94		09/12/1990		68.4	06/04/1991	6.31		09/06/1991		51.3
06/13/1990	5.89		09/18/1990	5.89		06/05/1991		85.5	09/09/1991	6.20	
06/14/1990		68.4	09/19/1990		136.8	06/11/1991	6.26		09/11/1991	6.21	68.4
06/26/1990	5.97		09/21/1990	5.84		06/14/1991		136.8	09/17/1991	6.01	
07/04/1990		136.8	09/24/1990	5.88	119.7	06/18/1991	6.15		09/18/1991	6.02	
07/05/1990	5.93		09/25/1990	5.74		06/20/1991		51.3	09/23/1991	5.98	
07/06/1990		136.8	09/27/1990	5.92		06/24/1991	6.06		10/07/1991	6.07	
07/10/1990	5.91		09/28/1990		102.6	06/25/1991	6.17		10/15/1991	6.10	
07/11/1990		171.0	10/01/1990	5.8		06/26/1991		51.3	10/23/1991	6.15	68.4
07/12/1990	5.74		10/04/1990	5.8		07/02/1991	6.16		10/28/1991	6.20	68.4
07/16/1990	5.85		10/10/1990		102.6	07/03/1991	6.20				
07/17/1990	5.8		10/11/1990	5.83		07/04/1991		34.2	05/13/1992	5.93	
07/23/1990	6.02	171.0	10/15/1990	6.04		07/05/1991	5.98		05/21/1992	6.33	
07/24/1990	5.84		10/16/1990		171.0	07/08/1991	6.15		05/26/1992	6.48	136.8
07/25/1990	5.79		10/17/1990	5.76		07/09/1991	6.16		06/01/1992	6.68	
07/31/1990	5.84	136.8	10/18/1990	5.74		07/11/1991		68.4	06/02/1992	6.73	205.2

Appendix 1 cont'd. L223 daily pH and sulfuric acid additions.

Date of addition	pH	kg H_2SO_4 added	Date of addition	ph	kg H_2SO_4 added	Date of addition	pH	kg H_2SO_4 added	Date of addition	ph	kg H_2SO_4 added
06/04/1992	6.65		09/04/1992	6.05		06/16/1993		256.5	10/04/1993	6.4	
06/07/1992		102.6	09/08/1992	6.18		06/21/1993	6.27		10/05/1993		136.8
06/08/1992	6.71		09/09/1992		85.5	06/22/1993		342.0	10/06/1993	6.38	
06/09/1992		205.2	09/14/1992	6.21		06/23/1993	5.99		10/14/1993	6.27	
06/11/1992	6.5		09/16/1992	6.21	102.6	07/05/1993	6.31		10/18/1993	6.22	
06/15/1992	6.4		09/23/1992	6.1		07/06/1993		171.0	10/22/1993		102.6
06/16/1992	6.38		09/29/1992	6.15		07/12/1993	6.02		10/25/1993	6.34	
06/17/1992		205.2	09/30/1992	6.08		07/13/1993	6.27				
06/18/1992	6.25		10/07/1992		51.3	07/14/1993	6.21				
06/19/1992		256.5	10/08/1992	6.08		07/15/1993		119.7			
06/22/1992	6.36		10/13/1992	6.14		07/19/1993	6.21				
06/23/1992	6.29		10/19/1992	6.02		07/22/1993		205.2			
06/29/1992	6.29		05/03/1993	6.22		08/03/1993	6.21				
07/01/1992	6.32		05/04/1993		51.3	08/04/1993	6.33				
07/06/1992		307.8	05/10/1993	6.48	68.4	08/05/1993		256.5			
07/07/1992	5.88		05/11/1993	6.43	136.8	08/09/1993	5.97				
07/13/1992	6.14		05/12/1993	6.42		08/10/1993	6.14				
07/14/1992	6.16		05/13/1993	6.35	171.0	08/13/1993		102.6			
07/16/1992		68.4	05/17/1993	6.44	171.0	08/16/1993	5.83				
07/21/1992	5.99		05/18/1993	6.38		08/23/1993	5.88				
07/23/1992	6.02		05/19/1993		273.6	08/30/1993	6.17				
08/05/1992	6.26		05/25/1993	6.47		09/07/1993		256.5			
08/06/1992		68.4	05/26/1993	6.38	119.7	09/13/1993	6.03				
08/10/1992	6.24		05/31/1993	6.38		09/20/1993	6.29				
08/11/1992	6.27		06/01/1993	6.49	136.8	09/21/1993	6.2	85.5			
08/13/1992	6.31	68.4	06/07/1993	6.45		09/22/1993	6.28				
08/19/1992	6.22		06/08/1993		239.4	09/27/1993	6.04				
08/20/1992		68.4	06/09/1993	6.27	171.0	09/28/1993	6.21				
09/03/1992	6.32	102.6	06/14/1993	6.3		09/30/1993	6.35				

Appendix 2. L302S daily pH and sulfuric acid additions.

Date of addition	pH	kg H_2SO_4 added	Date of addition	ph	kg H_2SO_4 added	Date of addition	pH	kg H_2SO_4 added	Date of addition	ph	kg H_2SO_4 added
05/07/1990	4.84		08/07/1990	4.52		10/16/1990		128.3	06/11/1991	4.56	
05/08/1990	4.83		08/09/1990	4.5		10/17/1990	4.47		06/12/1991	4.56	
05/09/1990	4.87	256.5	08/13/1990	4.51		10/18/1990	4.45		06/13/1991	4.56	
05/15/1990	4.61		08/15/1990	4.49		10/22/1990	4.32		06/17/1991	4.57	51.3
05/16/1990	4.45	102.6	08/16/1990	4.58		10/23/1990	4.51		06/19/1991	4.54	
05/22/1990	4.52		08/22/1990	4.54	51.3	10/24/1990	4.52		06/25/1991	4.57	
05/23/1990	4.5		08/23/1990	4.55		10/25/1990	4.53		06/26/1991		51.3
05/24/1990	4.51		08/27/1990	4.57		10/26/1990		68.4	07/03/1991	4.58	
05/30/1990	4.51		08/28/1990	4.54	85.5	10/29/1990	4.45		07/04/1991	4.6	
06/04/1990	4.47		08/30/1990	4.47		11/01/1990	4.43		07/08/1991	4.59	
06/05/1990	4.47		09/04/1990	4.52					07/09/1991	4.58	
06/06/1990	4.45		09/06/1990	4.62		05/01/1991	4.89		07/10/1991	4.64	
06/07/1990	4.47		09/10/1990	4.55		05/02/1991	4.86		07/11/1991	4.59	51.3
06/12/1990	4.5		09/11/1990	4.54		05/06/1991	4.89		07/15/1991	4.57	
06/13/1990	4.48		09/12/1990		68.4	05/08/1991		102.6	07/18/1991		51.3
06/18/1990	4.46		09/17/1990	4.63		05/09/1991	4.93		07/23/1991	4.58	
06/20/1990	4.47		09/19/1990	4.68	136.8	05/11/1991	4.83		08/01/1991	4.59	
06/26/1990	4.49		09/21/1990	4.66		05/13/1991	4.66	136.8	08/06/1991	4.64	
07/03/1990	4.45		09/24/1990		171.0	05/15/1991	4.46		08/07/1991	4.45	51.3
07/04/1990	4.52		09/25/1990	4.57		05/16/1991	4.64		08/08/1991	4.54	
07/05/1990	4.54		09/26/1990	4.54	102.6	05/21/1991	4.51		08/09/1991	4.57	
07/10/1990	4.51		09/27/1990	4.55		05/22/1991	4.63		08/12/1991	4.58	
07/12/1990	4.48		09/28/1990		136.8	05/24/1991		51.3	08/15/1991		51.3
07/16/1990	4.54	34.2	10/01/1990	4.52		05/28/1991	4.49		08/20/1991	4.61	
07/18/1990	4.57		10/02/1990	4.53		05/29/1991	4.54		08/21/1991		68.4
07/19/1990	4.46		10/09/1990	4.61		05/30/1991	4.55		08/26/1991	4.58	
07/24/1990	4.52		10/10/1990		102.6	06/03/1991	4.54		08/27/1991	4.58	51.3
07/26/1990	4.51		10/11/1990	4.55		06/06/1991	4.54		08/29/1991	4.54	
07/30/1990	4.54		10/12/1990		51.3	06/08/1991	4.53		09/04/1991		34.2
08/02/1990	4.48		10/15/1990	4.67		06/10/1991	4.54		09/09/1991	4.62	

Appendix 2 cont'd. L302S daily pH and sulfuric acid additions.

Date of addition	pH	kg H_2SO_4 added	Date of addition	ph	kg H_2SO_4 added	Date of addition	pH	kg H_2SO_4 added	Date of addition	ph	kg H_2SO_4 added
09/10/1991		168.4	05/12/1992	5.22		08/26/1992	4.79		05/31/1993	5.09	
09/12/1991	4.63		05/13/1992	5.18	171.0	09/03/1992	4.9		06/01/1993	5.07	3.1
09/16/1991	4.54		05/14/1992	4.8		09/15/1992	5.03		06/02/1993	5.02	
09/17/1991	4.54		05/19/1992	4.9		09/21/1992	4.94		06/03/1993	5.05	
09/18/1991		51.3	05/20/1992	4.9		09/23/1992	5.21		06/07/1993	4.97	
09/19/1991	4.64		05/25/1992	4.86		09/24/1992	5.25		06/09/1993	4.92	
09/20/1991		85.5	05/26/1992	4.86		09/29/1992		68.4	06/10/1993	4.83	
09/23/1991	4.73		05/28/1992	4.65		09/30/1992	5.2		06/14/1993	4.99	
09/24/1991		136.8	06/01/1992	4.86		10/01/1992	5.2		06/15/1993	4.99	
09/25/1991	4.66		06/02/1992	4.84		10/02/1992		136.8	06/17/1993	4.88	
09/26/1991	4.69	51.3	06/03/1992	4.82		10/05/1992	5.01		06/22/1993	4.95	
09/30/1991	4.64		06/08/1992	4.83		10/06/1992	5.04		06/23/1993	4.86	
10/01/1991		51.3	06/09/1992	4.82		10/20/1992	5.01		06/24/1993	4.81	
10/02/1991	4.61		06/11/1992	4.74		10/21/1992	5.08		06/28/1993	4.89	
10/03/1991		68.4	06/15/1992	4.7		10/22/1992	5.02		06/30/1993	4.97	
10/04/1991	4.64		06/17/1992	4.67					07/05/1993	4.76	
10/07/1991	4.64		06/23/1992	4.7		05/03/1993	5.61		07/06/1993	4.92	
10/08/1991		85.5	06/29/1992	4.74		05/04/1993	5.6	34.2	07/08/1993	4.87	
10/09/1991	4.59		07/06/1992	4.8		05/06/1993	5.73		07/12/1993	4.93	
10/11/1991		102.6	07/07/1992	4.83		05/10/1993	5.72	102.6	07/13/1993	4.89	
10/15/1991	4.6		07/09/1992	4.73		05/11/1993	5.58	136.8	07/15/1993	4.96	
10/16/1991		102.6	07/13/1992	4.79		05/12/1993	5.14		07/20/1993	5.13	
10/17/1991	4.54		08/05/1992	4.8		05/13/1993	5.2		07/21/1993	4.94	
10/21/1991	4.62		08/06/1992	4.76		05/17/1993	5.22	51.3	07/22/1993	4.94	
10/22/1991		136.8	08/10/1992	4.84		05/18/1993	5.2		07/26/1993	5.04	
10/23/1991	4.54	102.6	08/12/1992	4.83		05/19/1993	5.23	68.4	07/28/1993	4.92	
10/24/1991	4.49		08/18/1992	4.83		05/20/1993	5.02		07/29/1993	4.93	
10/28/1991	4.54	68.4	08/19/1992	4.77		05/25/1993	5.05		08/03/1993	4.91	
10/29/1991	4.5		08/20/1992	4.8		05/27/1993	5.1		08/05/1993	4.97	

Appendix 2 cont'd. L302S daily pH and sulfuric acid additions.

Date of addition	pH	kg H_2SO_4 added
08/09/1993	4.81	
08/10/1993	4.88	
08/12/1993	4.84	
08/16/1993	4.8	
08/17/1993	4.9	
08/18/1993	4.98	
08/19/1993	4.98	
08/23/1993	4.92	
08/24/1993	4.87	
08/26/1993	4.95	
08/31/1993	4.93	
09/01/1993	5.01	
09/02/1993	5.06	
09/07/1993	5.07	
09/15/1993	4.75	51.3
09/20/1993	5.34	
09/22/1993	5.2	
09/23/1993	5.18	
09/28/1993	5.21	
09/29/1993	5.06	85.5
10/01/1993	5.06	
10/04/1993	5.13	
10/05/1993	5.00	
10/12/1993	4.68	
10/14/1993	4.86	
10/26/1993	5.01	

Appendix 3. L302N acid and fertilizer additions 1990-1993.

Date of addition	pH	kg HCl added	kg $NaNO_3$ added	kg Na_2SO_4 added	kg H_3PO_4 added	Date of addition	pH	kg HCl added	kg $NaNO_3$ added	kg Na_2SO_4 added	kg H_3PO_4 added
02/16/1990				90.3		08/23/1990			196.3	90.3	
05/07/1990	5.43					08/26/1990	5.25				
05/09/1990	5.43	138.4				08/29/1990	5.21				
05/15/1990	5.12		122.7	90.3		09/04/1990	5.28				
05/16/1990	4.86					09/06/1990			147.2	90.3	
05/17/1990		173.0	245.4	45.2		09/10/1990	5.32				
05/21/1990			245.4			09/11/1990	5.25				
05/22/1990	4.97					09/14/1990	5.41				
05/23/1990	5.00					09/17/1990	5.47				
05/24/1990	5.05					09/19/1990	5.48		147.2	90.3	
05/29/1990				361.4		09/20/1990		41.5			
05/30/1990	5.05			271.0		09/21/1990	5.81				
06/04/1990	5.02					09/24/1990		69.2			
06/06/1990	5.06		245.4			09/25/1990	5.31				
06/07/1990	5.08					09/26/1990	5.27	41.5			
06/12/1990	5.08					09/27/1990	5.25				
06/13/1990	5.09					09/28/1990		27.7			
06/18/1990	5.02					10/01/1990	5.25				
06/20/1990	5.02					10/02/1990	5.33				
06/21/1990				271.0		10/09/1990	5.56				
06/22/1990				271.0		10/10/1990		69.2	147.2	135.5	
06/27/1990	5.06					10/11/1990	5.46				
07/02/1990				45.2		10/12/1990		69.2			
07/03/1990	5.13					10/15/1990	5.66				
07/05/1990	5.15					10/16/1990		110.7			
07/10/1990	5.07					10/17/1990	5.29		196.3	225.9	
07/11/1990			245.4	135.5		10/18/1990	5.36				
07/12/1990	5.01					10/22/1990	5.13				
07/16/1990	5.04					10/25/1990	5.41				
07/18/1990	5.01					10/26/1990		41.5			
07/19/1990	4.94					10/29/1990	5.37				
07/24/1990	5.21					10/30/1990		27.7	98.2	90.3	
07/26/1990	5.26					11/01/1990	5.27				
07/30/1990	5.28										
08/01/1990	5.29					05/06/1991	5.54				
08/06/1990	5.33					05/08/1991		55.4			
08/07/1990		20.7				05/13/1991	5.54	83.0			
08/08/1990	5.17					05/15/1991	5.46				
08/09/1990			122.7			05/16/1991		55.4			
08/12/1990	5.21					05/21/1991	5.27				
08/14/1990	5.14		122.7			05/22/1991	5.04				
08/15/1990	5.21					05/25/1991	6.67				
08/21/1990	5.25					05/28/1991	4.99				
08/22/1990	5.24					06/10/1991	5.13				

N.B. On May 15, 1990 9.0 kg of nitric acid leaked from a drum into L302N.

Appendix 3 cont'd. L302N acid and fertilizer additions 1990-1993.

Date of addition	pH	kg HCl added	kg $NaNO_3$ added	kg Na_2SO_4 added	kg H_3PO_4 added
06/11/1991	5.13				
06/12/1991			245.4		
06/13/1991	5.13				
06/17/1991	5.13				
06/25/1991	5.17				
07/03/1991	5.20				
07/05/1991			73.6		
07/15/1991	5.20				
07/23/1991	5.23				
08/06/1991	5.36				
08/12/1991	5.34				
08/15/1991		13.8			
08/20/1991	5.41				
08/21/1991		20.8			
08/26/1991	5.44				
08/27/1991	5.41	27.7			
09/03/1991	5.55				
09/04/1991		27.7	73.6		
09/09/1991	5.57				
09/10/1991		69.2			
09/12/1991	5.46				
09/16/1991	5.36				
09/17/1991	5.38				
09/18/1991		41.5			
09/19/1991	5.46				
09/20/1991		69.2			
09/23/1991	5.49				
09/24/1991		69.2	73.6		
09/25/1991	5.49				
09/26/1991		41.5			
09/30/1991	5.54				
10/01/1991		55.4			
10/02/1991	5.40				
10/03/1991		48.4			
10/07/1991	5.53				
10/08/1991		69.2	147.2		
10/09/1991	5.41				
10/11/1991		69.2			
10/15/1991	5.36				
10/16/1991		69.2			
10/17/1991	5.26				
10/21/1991	5.32				
10/24/1991	5.36				
10/26/1991			245.4		
10/28/1991	5.41			90.3	
10/29/1991	5.32				
05/12/1992	5.32				
05/19/1992	5.38				
05/20/1992	5.40				
05/21/1992		69.2			
05/25/1992	5.16				
05/26/1992	5.13				
05/28/1992	5.14				
05/29/1992			147.2		
06/01/1992	5.25				
06/02/1992	5.18				
06/03/1992	5.15				
06/08/1992	5.23				
06/09/1992	5.25				
06/11/1992	5.22				
06/15/1992	5.22				
06/17/1992	5.18				
06/23/1992	5.28				
06/29/1992	5.28				
07/02/1992		76.1	73.61	6.77	7.88
07/06/1992	5.34				
07/07/1992	5.49	76.1	76.61	6.77	7.88
07/13/1992	5.17	76.1	76.61	6.77	7.88
07/20/1992		76.1	76.61	6.77	7.88
07/27/1992	5.03	76.1	76.61	6.77	7.88
08/04/1992		76.1	76.61	6.77	7.88
08/05/1992	4.81				
08/10/1992	4.97	76.1	76.61	6.77	7.88
08/12/1992	4.88				
08/17/1992		76.1	76.61	6.77	7.88
08/18/1992	4.85				
08/19/1992	4.85				
08/25/1992		76.1	76.61	6.77	7.88
08/26/1992	4.87				
09/01/1992		76.1	76.61	6.77	7.88
09/03/1992	4.89				
09/08/1992		76.1	76.61	6.77	7.88
09/15/1992	5.03	76.1	76.61	6.77	7.88
09/22/1992		76.1	76.61	6.77	7.88
09/23/1992	5.04				
09/24/1992	5.06				
09/29/1992		76.1	76.61	6.77	7.88
09/30/1992	4.99				
10/01/1992	5.03				
10/05/1992	5.09				
10/22/1992	5.40				

Appendix 3 cont'd. L302N acid and fertilizer additions 1990-1993.

Date of addition	pH	kg HCl added	kg $NaNO_3$ added	kg Na_2SO_4 added	kg H_3PO_4 added	Date of addition	pH	kg HCl added	kg $NaNO_3$ added	kg Na_2SO_4 added	kg H_3PO_4 added
05/03/1993	5.21	76.1	76.61	6.8	7.88	08/16/1993	4.66				
05/06/1993	4.97					08/17/1993	4.99	78.5	76.61	6.8	7.88
05/10/1993	5.07	76.1	76.61	6.8	7.88	08/18/1993	4.91				
05/11/1993	4.86					08/19/1993	4.86				
05/13/1993	5.08					08/23/1993	4.85				
05/17/1993	5.12	78.5	76.61	6.8	7.88	08/24/1993	4.82	78.5	76.61	6.8	7.88
05/18/1993	4.84					08/26/1993	4.77				
05/19/1993	4.96					08/31/1993	4.80				
05/20/1993	5.00					09/02/1993	4.88				
05/25/1993	5.07	78.5	76.61	6.8	7.88	09/07/1993	4.94				
05/27/1993	5.02					09/15/1993	4.69				
05/31/1993	5.12					09/20/1993	5.20				
06/01/1993	5.11	78.5	76.61	6.8	7.88	09/22/1993	5.33				
06/02/1993	4.98					09/28/1993	5.29				
06/03/1993	4.93					09/29/1993	5.31				
06/07/1993	5.04					10/01/1993	5.50				
06/08/1993		78.5	76.61	6.8	7.88	10/04/1993	5.53				
06/09/1993	4.82					10/05/1993	5.57				
06/10/1993	4.92					10/12/1993	5.54				
06/14/1993	4.99					10/14/1993	5.54				
06/15/1993	4.92	78.5	76.61	6.8	7.88	10/26/1993	6.01				
06/17/1993	4.85										
06/22/1993	4.98	78.5	76.61	6.8	7.88						
06/23/1993	4.64										
06/24/1993	4.68										
06/28/1993	4.88										
06/29/1993		78.5	76.61	6.8	7.88						
06/30/1993	4.84										
07/05/1993	4.81										
07/06/1993	5.10										
07/07/1993		78.5	76.61	6.8	7.88						
07/09/1993	4.90										
07/12/1993	5.06										
07/14/1993		78.5	76.61	6.8	7.88						
07/15/1993	4.99										
07/19/1993		78.5	76.61	6.8	7.88						
07/20/1993	4.96										
07/21/1993	4.90										
07/22/1993	5.01										
07/26/1993	4.95										
07/28/1993	5.05	78.5	76.61	6.8	7.88						
07/30/1993	4.94										
08/04/1993	5.10	78.5	76.61	6.8	7.88						
08/05/1993	5.04										
08/09/1993	4.91	78.5	76.61	6.8	7.88						
08/12/1993	4.97										