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WHOLE LAKE ADDITIONS IN THE EXPERIMENTAL LAKES AREA, 1986-1989

bу

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ABSTRACT

Cruikshank, D.R. 1991. Whole lake additions in the Experimental Lakes Area, 1986-1989. Can. Data Rep. Fish. Aguat. Sci. 816: iv + 18 p.

Acidification of three lake basins continued from 1986 to 1989. Sulfuric acid was added to Lakes 223 and 302S while nitric and hydrochloric acids were added to Lake 302N. Additions of sulfuric acid were halted to Lake 114. Nitrogen and phosphorus were added to Lake 227 in continuation of a 20-year eutrophication experiment. Cadmium chloride and cadmium were added to Lake 382 in 1987, 1988 and 1989. Radionuclides were added to the hypolimnetic waters of Lake 226. Two lake enclosure experiments were started; nutrient additions were made to enclosures in Lake 227 and organic chemicals were added to enclosures in Lake 375.

Key words: acidification; fertilization; trace metals; whole-lake manipulations.

RÉSUMÉ

Cruikshank, D.R. 1991. Whole Take additions in the Experimental Lakes Area, 1986-1989. Can. Data Rep. Fish. Aquat. Sci. 816: iv + 18 p.

On a poursuivi l'acidification de trois bassins entre 1986 et 1989. De l'acide sulfurique a été ajouté dans les lacs 223 et 302S. De l'acide nitrique et de l'acide chlorhydrique ont été ajoutés dans le lac 302N. On a interrompu l'addition d'acide sulfurique dans le lac 114. Dans le cadre d'un programme expérimental d'eutrophisation étalé sur vingt ans, on a ajouté de l'azote et du phosphore dans le lac 227. Du chlorure de cadmium et du cadmium ont été ajoutés dans le lac 382 en 1987, en 1988 et en 1989. Des radionucléides ont été ajoutés dans les eaux hypolimniques du lac 226. On a amorcé des expériences à l'intérieur des limites de deux lacs: des éléments nutritifs ont été ajoutés dans le cas du lac 227 et des produits chimiques organiques ont été ajoutés dans de cas du lac 375.

Mots-clés: acidification; fertilisation; métaux traces; expériences portant sur l'ensemble d'un lac.

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INTRODUCTION

This report is the third in a series of reports on whole lake additions at the Experimental Lakes Area (ELA). For data on additions from 1969-1983 inclusive see Cruikshank (1984). For data on additions made during 1984 and 1985 see Cruikshank (1986). Summary data on additions from past years are included in the tables with the new data from 1986-1989. Equipment and methodology remain unchanged and were described in the first report.

The addition ratios of carbon, nitrogen and phosphorus to L227 remain unchanged from past years (Table 1). In June 1988, six 5 m diameter polyethylene tubes (limnocorrals) were installed in L227. Various amounts and ratios of nutrients and micronutrients were added to the tubes to study the effect micronutrients had on algal production (Table 2).

In 1987, a whole lake addition of cadmium began on L382 (Table 3a). The experiment is designed to test the adequacy of the Canadian Water Quality Guideline of 0.2 ug Cd L⁻¹. Cadmium was added in two forms. The majority of the cadmium was in the form of cadmium chloride. A radiotracer, Cd was added to follow the fate, accumulation and pathways of uptake of the Cd added to the lake.

In 1989, a mixture of furans with a ³H radiotracer was added to each of four lake enclosures in L375 (Table 3b). The fate of the furans was followed in sediments and aquatic organisms placed in the tubes. This experiment was conducted on a trial basis as a precursor to a whole-lake experiment involving organic chemicals.

The acidification experiment on L114 was terminated after the monthly addition in October, 1986 (Table 4). This experiment involved a monthly addition of sulfuric acid to L114 which was equivalent to the amount of [H] received in rainfall, in the Muskoka region of Ontario, in one month.

L225 is a small (3.99 ha) shallow (<1.75 m deep) humic lake (pH = 5.15). In July 1987, two additions of hydrochloric acid (total of 70 litres) were made. This experiment was to study the effects of further acidification of an already acidic system on light transparency and any changes in zooplankton genetics.

The recovery phase of the long-term acidification experiment of L223 continued. The target pH for 1986 and 1987 was 5.4. In 1988-1989 the lake was allowed to recover to a target pH of 5.8 (Table 5).

L302 is a double-basin lake divided by a polyethylene curtain wall into L302N and L302S. In 1986, the nitric acid additions to L302N ended on October 21. This concluded a five-year experiment comparing the effects of nitric vs sulfuric acids on lake chemistry and aquatic ecosystems. Beginning in June 1987, additions of hydrochloric acid to L302N were made. These additions were continued in 1988 and 1989 (Table 6). The plan was to keep L302N at a pH near but less than 5.4 in 1988. This target pH was selected for a future experiment on the nitrogen cycle. In 1989, the target pH for L302N was 5.0.

Sulfuric acid additions to L302S continued with a target pH of 5.0 and 4.75 for 1986 and 1987 respectively. The target pH in 1988 and 1989 was 4.5 (Table 7). Additions to reduce the pH to below pH 5.0 in 1987 and 1988 were continued to document the effects of low pH on aquatic organisms.

Atomic Energy of Canada added 3 radiotracers consisting $_{134}^{0}$ Co and 125 mCi $_{134}^{0}$ Cs to the waters of the hypolimnion of L226. AECL were following the movement of the tracers through the lake system.

METHODS

Acid additions to L114, L225, L223, and L302 were made using the "Prop-tube mix" method. Nutrient additions to L227 were made using the "barrel method" (Cruikshank 1984). Micronutrients were added to each tube (limnocorral) in L227 from a container that contained the previously mixed ratios of nutrients for each respective tube. Each nutrient solution was trickled into the tube by sliding the boat around the tube circumference and adding a little solution every metre. The entire tube was then mixed by stirring using a paddle.

In 1987, cadmium was added twice a week to the epilimnion of L382. A container with an outlet consisting of Tygon tubing with a syringe attached. The radiotracer cadmium was first added to the container followed by the cadmium chloride dissolved in water. The solution then slowly dripped into the lake over a period of two days. The delivery apparatus was attached to a buoy in the center of the lake. The delivery system was modified in 1988 using a small battery operated pump to provide a continuous flow during the ice-free season.

CHEMICAL SOURCES

The sulfuric, hydrochloric and phosphoric acids and the sodium nitrate were purchased from two local Winnipeg firms. The sulfuric acid came in 10 litre (18 kg) plastic carboys, the hydrochloric acid in 20 litre (22 kg) carboys and the phosphoric acid in 34 kg cubitainers. Costs vary from year-to-year but the unit prices for sulfuric and phosphoric acid in 1989 were 21 dollars and 74 dollars respectively. The hydrochloric acid was priced at 11 dollars per carboy in 1987. The sodium nitrate was purchased in 25 kg bags for 16 dollars a bag in 1989. The calcium chloride was purchased in 1989 for 339 dollars for 2.5 kg. The cadmium radiotracer was leftover from previous work.

New suppliers were found for the sulfuric acid in 1986. The sulfuric acid is 93.2% pure with a specific gravity of 1.835. The sulfuric acid used prior to 1986 was 93.29% pure with a specific gravity of 1.81. The phosphoric acid is 85% pure with a specific gravity of 1.686. The hydrochloric acid was 31.45% pure with a specific gravity of 1.10.

ACKNOWLEDGMENTS

I would like to thank Tim Cooper, Joel Miller, Steve Sandstrom, Jason Falk, Randy Boychuk, Scott Herron and Gord Taylor who made many of the additions over the four years. I also appreciate information on L227 enclosure additions from Stephanie Guildford, L382 Cd additions from Ray Hesslein and Chris Baron, L375 furan additions from Wayne Fairchild and L226 radiotracer additions from Malcolm Stephenson. Ticia Lyng and Allison Broughton provided the pH data. I would also like to thank Donna Laroque who typed this report.

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Table 1. L227 nutrient additions.

			Sodium A	ım Nitrate			Phos	Phosphoric acid		
Year	Year Date	kg/wk	Total kg	kg N per wk	Total kg N	Litres per wk	Total litres	Total kg	kg P per wk	Total kg P
1986	May 06 - Sep 16 (20 additions)	34.0	680.4	5.61	112.2	2.5	50.0	85.0	1.14	22.83
1987	May O5 - Sep 15 (20 additions)	34.0	680.4	5.61	112.2	2.5	50.0	85.0	1.14	22.83
1988	May 10 - Sep 20 (20 additions)	34.0	680.4	5.61	112.2	. 2.5	50.0	85.0	1.14	22.83
1989	May 16 – Sep 26 (20 additions)	34.0	680.4	5.61	112.2	2.5	50.0	85.0	1.14	22.83

All additions to L227 from 1975-1988 inclusive were made in the N:P ratio of approximately 5:1. Additions from 1969-1974 were made in a 13:1 ratio of N:P. The phosphoric acid has a S.G.= 1.686. N B

Table 2. L227 limnocorral additions 1988.

Limnocorral #	Treatment 1988 (June 3 – Aug 23)	Treatment 1989 (May 31 - Aug 29)
1 2 3 4 5 6	N, P, trace metals N, P EDTA, N, P N, P high P N, P, trace metals	NO TREATMENT N, P NO TREATMENT P N, P P
Treatment sour	ces as follows:	
Treatmen	t	Quantity (wt. chemical per week to each corral)
- - - - -	FeCl3•6H ₂ O H ₃ BO ₃ MnCl2•4H ₂ O Na ₂ MoO ₄ •2H ₂ O ZNSO ₄ •7H ₂ O CaCl ₂ •6H ₂ O CuSO ₄ •5H ₂ O	13.53 g NaNO ₃ 1.0 mL H ₃ PO ₄ 8.74 g 8.74 g 6.30 g 2.00 g 0.36 g 0.012 g 0.044 g 0.02 g 0.02 g 0.02 g

Table 3a. L382 cadmium additions.

Year	Grams Cd added	109 _{Cd} mCi added	Target Epi [Conc] ng Cd/L	Mean Epi [Conc] ng Cd/L
1987	900	89	100	83
1988	640	62	100	51
1989	686	68	120	110

Table 3b. L375 furan additions to enclosures.

CHEMICAL	QUANTITY	
3 _{H-2,3,7,8} TCBF	10 ug	
1,2,3,7 TCBF	250 ug	
1,2,3,4,8 TCBF	250 ug	
2,8 DCDF	250 ug	
OCDF	250 ug	
1,2,3,6,8,9 HCDF	40 ug	

Above mixture added to each of 4 lake enclosures.

Table 4. L114 sulfuric acid addition.

/ear	Date	Litres added	Kg H ₂ SO ₄ added	Kg H ⁺ added	Time-weighted mean epilimnion pH
1979	Jul 23 - Oct 15 (4 additions)	134.4	226.94	4.67	5.82
1980	Jul 13 - Sep 29 (7 additions)	235.2	397.15	8.18	6.11
1981	May 11 - Sep 28 (6 additions)	201.6	340.41	7.01	6.05
1982	May 17 - Oct O4 (6 additions)	201.6	340.41	7.01	5.90
1983	May 17 - Oct 04 (6 additions)	201.6	340.41	7.01	5.94
1984	May 31 - Sep 27 (5 additions)	168.0	283.68	5.84	5.65
1985	Máy 24 – Oct 10 (6 additions)	201.6	340.41	7.01	5.88
1986	May 28 - Oct 02 (6 additions)	201.6*	344.78	7.10	6.26
1987	Apr - Sep 06 (Leakage)	90.0*	153.92	3.17	
Total A	dditions	1635.6	2768.11	57.00	-

 $[\]star$ Denotes change to a different type of sulfuric acid. Sulfuric acid used prior to 1986 had a S.G.= 1.81 while sulfuric acid used from 1986 on had a S.G.= 1.835.

Table 5. L223 sulfuric acid additions.

Year	Date	Litres added	Kg H ₂ SO4 added	Kg H ⁺ added	Target pH	Time-weighted Mean Epi pH
1976		5537.8	9350.85	192.63		6.49
1977	May 04 - Oct 17 (17 additions)	2910.6	4914.59	101.24	6.00	6.13
1978	May 08 - Oct 23 (31 additions)	3377.4	5702.96	117.48	5.75	5.93
1979	May 21 - Oct 29 (45 additions)	2816.1	4755.12	97.97	5.50	5.64
1980	May 05 - Oct 22 (35 additions)	3099.6	5233.83	107.82	5.25	5.59
1981	May 06 - Oct 22 (35 additions)	3553.2	5999.75	123.59	5.00	5.02
1982	May 05 - Oct 26 (38 additions)	3458.7	5840.18	120.31	5.00	5.09
1983	May 10 - Oct 28 (30 additions)	2230.2	3765.80	·77 . 58	5.00	5.13
1984	May 21 - Oct 08 (14 additions)	680.4	1148.89	23.67	5.40	5.44
1985	May 13 - Nov 06 (34 additions)	3761.1	6350.80	130.83	5.40	5.53
1986	May 05 - Oct 22 (19 additions)	2360.0*	4036.12	83.14	5.40	5.45
1987	May 06 - Oct 12 (18 additions)	1860.0*	3181.01	65.53	5.40	5.42
1988	May 24 - Oct 13 (15 additions)	1160.0*	1983.86	40.87	5.80	5.81
1989	May 23 - Oct 24 (22 additions)	1795.0*	3069.85	63.24	5.80	5.81
Total .	Additions	38600.1	65333.71	1345.90		

^{*} Change in suppliers of sulfuric acid. Acid used from 1986 has a S.G. = 1.835 while acid used prior to 1986 has a S.G. = 1.81.

Table 6. L302N nitric and hydrochloric acid additions.

Year	Date	Litres HNO3 added	Kg HNO3 added	Litres HCT added	Kg HC1 added	Kg H ⁺ added	Time-weighted Mean Epi pH
1982	Jun 29 - Oct 05 (14 Additions)	2282.9	1981.15			31.70	6.71
1983	May 23 - Oct 24 (26 Additions)	2463.3	2137.70			34.20	6.34
1984	May 09 - Sep 25 (25 Additions)	2804.4	2433.72	,		38.94	6.24
1985	May 15 - Oct 09 (21 additions)	3050.4	2647.20			42.36	6.02
1986	May 06 - Oct 21 (17 additions)	3247.2	2817.99			45.09	5.98
1987	Jun 04 - 0ct 27 (24 additions)			7320.0	2532.35	69.89	5.48
1988	May 23 - Oct 19 (15 additions)			2660.0	920.23	25.40	5.32
1989	MAY 15 - OCT 30 (26 additions)			3510.0	1214.28	33.04	5.04
Total	Additions	13848.2	12017.79	13490.0	4666.86	321.09	

The nitric acid has a S.G.= 1.381 and the hydrochloric acid as a S.G.= 1.10.

Table 7. L302S sulfuric acid additions.

Year	Date	Litres added	Kg H ₂ SO ₄ added	Kg H ⁺ added	Target pH	Time-weighted Mean Epi pH
1981						6.75
1982	Jun 29 - Oct 05 (14 additions)	1228.5	2074.38	42.73		6.25
1983	May 23 - Oct 24 (26 additions)	1107.7	1870.41	38.53	5.80	5.86
1984	May 09 - Oct 08 (24 additions)	1152.9	1946.73	40.10	5.50	5.60
1985	May 14 - Oct 08 (21 additions)	1247.4	2106.30	43.39	5.30	5.31
1986	May 06 - Oct 21 (18 additions)	1272.3*	2175.91	44.82	5.00	5.02
1987	May 05 - Oct 28 (19 additions)	1450.0*	2479.82	51.08	4.75	4.80
1988	May 09 - Oct 19 (29 additions)	2020.0*	3454.64	71.17	4.50	4.58
1989	MAY 15 - OCT 30 (23 additions)	1220.0*	2088.48	43.02	4.50	4.53
Total	Additions	10698.8	16108.19	331.82		

^{*} Change in suppliers of sulfuric acid. Acid used from 1986 had a S.G. = 1.835. Acid used prior to 1986 had a S.G. = 1.81.

Appendix la. Daily L223 pH measurements and sulfuric acid additions.

	1988 1989	рН H2SO4 рН H2SO4 kg kg	5.72	5.87 5.86 136.8	68.4 5.65 5.97	5.84	5.86 5.80 85.5	5.82 68.4 5.72	5.90	5.87 5.85	5.81	5.97 136.8 5.88 5.74	4.00 60
JUNE	1987	pH H ₂ S0 ₄ kg	5.33	r.	5.46 5.46		ເດັ	5.67	L.	5.46		85.5	
	1986	pH H2S04 kg	5.62 5.50 102.6	5,59 102,6	5.51	5,52 5,53 5,58		5.59 5.67 119.7	5.26	5 53 102 E	5.52 5.46		
	1989	pH H ₂ S0 ₄ kg						5.71 5.83		6.04 171.0	5.92	171.0	
MAY	1988	pH H ₂ SO ₄ kg	5.69	5.50		5.80		5.80		5.90		5,79	
	1987	рН H2S04 kg		5.93 5.94 34.2	34.2	5.81 5.79 68 /	5.03		5.16		5.35		
	1986	pH H ₂ S04 kg		5.96 478.9 5.76 513 1	5.61 376.3	5.60	427.6		5.19 5.26	5,30	9	5.41	

Appendix 1b. Daily L223 pH measurements and sulfuric acid additions.

	1989	H2504 kg	5.64		5.89 68.4	7,	9	o''c	5.77	5.73 5.77	5.75	5.78	5.69
		五	2		ທີ່ແ	•	L	ភ	Ŋ	ດນ ດນ	ις	ນ	2
	1988	H2S04 kg	35 34 51.3		84			5.91		5.75		ï	5.80
		둅	5.85 5.84		5.84	5.73		'n		ກໍ		ŧ	വ്വ
AUGUST	1987	H2S04 kg	i _	85.5		85.5		·	m m		8 171.0	S.	
		표	5,46	5.41		5.42			5.38		5.68	5.55	
	1986	pH H2S04		5.36		5.71	85.5 5.44		5.43		5.52	5.03 171.0 5.42	
	•						۵,						0
	1989	pH H ₂ S04		5.93 136.8 5.72		5.84 5.74	5.83		5.99	5.52	5.79 5.77	5.84	6.01 171.0
	1988	pH H2S04		5.76 5.74	5.78	75	5.96	5.94 102.6	5.99	5.75 5.93 205.2	5.71	5.74 5.72	
JULY	1987	pH H2S04		c C	4.96	5.22		5.35 5.40		5.39 5.39	5.42	5.44	5.42 5.41
	1986	pH H2S04	5.41		5.55	5.77 5.85 171.0 5.85	2 .	5.34		5.42	5.32	70.27	5.35
		Date	1 2	w 4 ro	9 / 0	0 6 0 E	15	1 4 5 5 4 5	16 17 18	19 20 21	23 24 25	52 52 33	ខ្លួនក

Appendix 1c. Daily L223 pH measurements and sulfuric acid additions.

	6	H2S04 kg		102.6	171.0		179.6	171.0			171.0			102.6		
	1989	书		5.85 10	5.96 6.00 17		5.86 17	5.80 17		5.89	5.72 17		5.83	102		5.81
BER	1988			13	13 102.6 8		171.0	171.0				10				LC.
OCTOBER		古		5.87	6.03 5.78		6.01	6.02			5.76	5.75	•	6.01	5	
	1987	H2S04 kg			102.6 68.4			136.8								
	1	표	5.47		5.63			5.49	i	5.59	5.51				5.55	
	1986	H2S04 kg			5.66 205.2			136.8				273.6	51.3			
		표			5.66	5.59		5.67 136.8	5,58			5.64 2 5.43	5.48		5.48	5.50
	1989	H2S04 kg			68.4		·	102.6			171.0					
		둅			5.91 5.80 5.80						5.90 1	5.65		5.79	5.80	
	1988	H2S04 kg						. 526.5	102 6	0.301					102.6	
SEPTEMBER		됩			5.86		r (5.04 5.73			5.73	5.73			5.87 1 5.84	
	1987	H ₂ S0 ₄ kg	5.60 136.8		119.7	30	00°0		•	102.6			171.0			
		된	5.60	5.37	5.56 119.7			5.46	5.47	•		5.53 5.53	5.48 1		5.50	<u>!</u>
	1986	H2504 kg											205.2			273.6
]	Hd	5.48			5.48			2.60			5.64	71	5.69	5,53	
	Date		7 7	m 4	8 7 6 5	9 0	111	13	15 16	17	019 019			25 26 27	 28.62 28.62	

Appendix 2a. Daily L302S pH measurements and sulfuric acid additions.

	~	MAY	!		JUNE	F	
1986	1987	1988	1989	1986	1987	1988	1989
H2S04 kg	pH H ₂ S0 ₄ kg	pH H ₂ S04 kg	pH H2S04 kg	pH H2S04 kg	pH H ₂ S04 kg	pH H2SO4 kg	рН H2S04 kg
							4.50
		F //		5.00	4.67		
		· ·		90.5			
ç	5.85 342.0	2.67		5.04	4.78	85 7	4 55 68 4
330.8	5 37					4.59 102.6	4.54
342.0	342.0						4.58 171.0
	256.5	5.24	5.01	5.06	4.// 102.b 4.75		
	4.91 171.0	324.9) -		4.50	4.50
100.7	4.80	r 5			4.50		4.51
			5.01 171.0	л 10	4.73	4.48 34.2	4.54
		4.b3 171.0	4.3/	5.14 68.4	00.	4.49	
	4.81	4.48					4.55 68.4
	4./5			102.b			4.54
	4.83					4.53	4.52
					4.80	4.50	4.04
		4.45	4.79 171.0	4.93	4.76	4.52	
				,			4.55 85.5
	4.82			4.98		34.2	4.52
	85.5		i v		č	,)	:
			4.69	5.07	4.91	4.54	
		4.52	4.54				

Appendix 2b. Daily L302S pH measurements and sulfuric acid additions.

	1989	H2S04 kg			68.4									51.3
		盂	4.47		4.57	4.47		4.44	4 44	4.46	4.48 4.46	4.44		4.50
	1988	H2S04 kg	51.3			96.4	0 • 0 0		102.6			85.5		102.6 102.6
Augusi		퓹	4.59	4.50		4.38 8.38		4.55	4.59		4.74	4.58 4.59		4.64 1 4.61 4.58 1
AUG	1987	H2S04 kg		136.8			171.0			-		85.5		
	1	抵		4.82 4.83		4.89			4.83	4.80		4. 76	4.75	
	1986	H2S04 kg		68.4			102.6						136.8	
		Н		5.09 5.13 4.88	4.92	7. 10	200	4.92		4.95	5.02	5.23		
·	1989	H2504 kg										51.3		
		됩		4.48 4.48		4.44	4.46	• •	4.44	4.44	4.53	4.55	4.40	
	1987 1988	H2S04 kg		51.3		7.	•	171.0		171.0				
		Ħ		4.60 4.61 4.57	4.58	4 63	4.64			.52	4.52	Ĺ	4.53	
i		H2504 kg			136.8						136.8		68.4	
·		듑	4.70	4.96	4.68	7	4.87	4.88	4.81 4.83		4.89 5.05 1 4.76	4.81	4.86	4.77
	1986	H2S04 kg	102.6		102.6			•	102.6					102.6
:		표	4.99 5.06		5.03	4.98		5.04 5.10	4.92		5.01	4.99		5.09 1 4.96 4.93
	Da+e		1 2 7	w 4 rv ro	∼ 80	10,	12	14 15	16 17	18 19	20 22 23 22	25 25 25	27 28 28	330 31 31

Appendix 2c. Daily L302S pH measurements and sulfuric acid additions.

	1989	H2S04 kg	102.6		Ċ	82°2	85.6			34.2		51.3
	19	됩	4.53 4.53		4.50	4.51	4.57	4.50		4.50		4.52
	88	H2S04 kg	85.5		85.5 136.8	85.5		168.9				
BER	1988	描	4.63	4.59	4.65	4.55	2	4.58	4.03	4.50	4.60	
OCTOBER	22	H2S04 kg		102.6		102.6		ï	51.3			
	1987	됩	4.83	4.93		4.85	4.77	•	4.80 4.74 4.76	,	4.81	
	36	H2S04 kg		68.4		5	4.80		136.8		51.3	
<u>.</u>	1986	표	4.99	5.10 4.99		5.09	4.96	1	5.19		4.97	5.04
	 &	H2S04 kg		51.3		102.6	102.6	102.6		171.0		
	1989	품		4.58	4.56	4.57		4.55		4.64	4.50	
	 œ	H2504 kg	i.	171.0 102.6	•	171.0						102.6
SEPTEMBER	1988	퓹		4.61 4.62 4.55		4.56		•	4.50		4.60	
SEPTEMBE	23	H2S04 kg	85.5	102.6						102.6		
	1987	五	4.84	4.81			4.77		4.87	4.76		4.86
	9.9	H2S04 kg	34.2				5.10 102.6			102.6		
	1986	퓹	4.83	4.87	5.05	5.04	5.10	5.00	5.04	4.78		4.96
		Date	321	450/a	9601	12	14 15 16	18 17 2	20 21 22 23	23 24 25	24 27 28 28 28	330

Daily L302N pH measurements and nitric/hydrochloric additions. Appendix 3a.

	68	HC1 kg			34.6	69.2								,	
	1989	Ħ	4.89		5.00	5.06		4.95	4.96	6 6	5.00 5.01	5.03	5.06	5.00	
	1988	HCJ kg						55 A	r ?				83.0		
JUNE	19	둞			5,34 5,34	5.29		5.44	5.30	5.20	д	5.34 5.34 5.30	_	5.44	,
	1987	HC1 kg	<u>_</u>	200.7		207.0	69.2		69.2	69.2			103.8	138.4	
	151	捳	6.72	•	9. 08	6.46	5.57		5.72			5.43 5.54		5.51 4.95	
	1986	HNO3 kg	ou m							85.7 85.7					
		揯	6.1	6.20		7	6.04		6.14	6.16 5.92	5.77	6.14	6.14	6.35	
	1989	HC1 kg				•			103.8			69.2		69.2	
	15	五				7 23	•		5.40			5.20		5.14	
	1988	HC1 kg	_									207.6			
MAY) ši	Hd	5.23	5.23		5,29	• • • •	5.30	5.37	5.43		5.80 4.86	•	5.03 5.11	
MAY	1987	HC1 kg													
	15	퓹		6.34	6.42		6,69	6.63		6.57	6.45		6.45 6.65		
	1986	HN03 kg		427.0				128.1							
	1	Hg		6.18	5.59		, ,	0°.50	2.20	5.44	t 1	5./6	6.15		
	Date		~ ~ ~ ·	4 ი ი	~ 8	90	11 12	14	15 16 17	18 19	23 23 23	23 24 25	26 27 28	38.35 38.35 38.35	

Appendix 3b. Daily L302N pH measurements and nitric/hydrochloric additions.

ļ	ļ	HC1 kg				55.4							41.5			7 TC	
	1989	Hq H x	5.06		r L	0. I	9.c		4.99	5.03	00.0	5.20	4.96		5.01		
IST	1988	pH HC1 kg		5.36 41.5	5.32	•	5.30	5,35		2	5.28		5,58	41.5		5.40 20.8 5.21	
AUGUST	1987	pH HC1 kg		5.31	5.36 5.48 69.2 5.30		5,43	5.57	5.32		5,54	5.53		5.37 5.68 69.2	т <u>т</u>	T	
	1986	pH HNO3 kg			5.89 6.40 85.4 6.17	6.19 6.40			6.36 128.1 6.08			6.23 6.38	6.32	6.35	6.32	20.0	
	1989	pH HC1			5.06 34.6 5.00 4.96		0	5.00	5.02 5.03		. 71	5.06 41.5 4.97	5.07	27.7	5.04 5.08 27.7		5.04
-	1088	pH HC1			5.44 41.5 5.37 5.16	5.15			5.18 5.16			5.32 5.31	5.35 5.34		5.38		
Y HILL.		PH HC1		5.28		ນ ທີ່ ພູນ ຊີ່	5.49		5 7d	5.82 138.4	5.21	5.28	5.40 5.74 34.6	5.34		5.56 . 5.49 69.2 5.14	
		1986 ph HN03	อิง -	6.21 6.21 128.1		6.36 128.1	6.10 6.26	96	0.30	6.23	6.45 128.1	5.97		6.57 6.92 6.34		6.38 85.4	6.50
		Date	ļ		w 4 ro	9	യ ഗ	10;	123	13 14	15 16	17 18	185	22 23 24 24	25 26 77	3888	30 31

Appendix 3c. Daily L302N pH measurements and nitric/hydrochloric additions.

	1000	E 12	2	41.5	6.9		((83.0		103.8	86.5				20.8
	-	Hd Hd		5.08 5.07 5.02			5.18	5.05		5.23	ò.		5.01	5.02	5.01 4.96
	1988	일		41.5		;	41.5 83.0	62.3			138.4				
3F.R	- 1	五		5.49	5.50		5.60	5.48		5,44		i :	5.30	5.40	
OCTORFR	1987	HC1 kg			103.8			138.4		138.4	69.2	ļ •		138.4	
	19	Ha	5.43		5.82		5,82	5.77	5.69		5,53	5.49		5.42 5.38 1 5.12	
	9	HN03 kg			85.4			נו	85.4			170.8			
	1986	Ha	5.98		5.98 5.92			6.08	6.01	6.17		6.04		6.10	6.15
	1989	HC1 kg		27.7				71 5	7	;	41.5		41.5	41.5	
	19	甚		5.06	5.04		4.99 5.01	5.06	4.97	5.04	5.09		5.05	5.04	
	1988	HC1 kg			20.8									7.73	•
SEPTEMBER	1	插		5.41	5,35 5,31		5.32	5.48	5,35	7.0	5.32			5.50 5.38	'
SEPT	1987	HC1 kg	83.0		103.8					103.8		103.8			
	19	Н	5.64	5.57	5.85 6.01	5.49			5.74			5.50	07.0	5.47	
	1986	HN03 kg	213.5	·					128.1			128.1			
	ļ	돐	5.73	5.71	5.87		6.24	ı	6.08 6.00			6.12			5.91
	Date		1 2	ოძნა	o ∨ ∞ 6	10	112 132	14	15 16	17 18 19	23	22.52	52	23 23 23 23 23	9 = 1