New Zealand Aluminium Smelters Limited

Interdepartmental

Committee

Report

1997

Report to the Interdepartmental Committee on Environmental Effects of the Tiwai Aluminium Smelter for the Year Ending 31 December 1997

Meeting at Tiwai
22 May 1998

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Summary

The commissioning of the dry scrubbing system on the main stack was completed in January 1997. The discharges from the main stack were low throughout 1997. As a consequence, the fluoride concentrations in the surrounding environment have reduced in many instances to near background levels.

The operating instability in the reduction lines continued into early 1997. The roof louvre discharges were higher during this period.

Meteorological conditions were generally wetter and more windy during 1997 particularly during October, November and December when the El Nino weather pattern dominated.

Ambient air monitoring was changed to Australian Standard AS 3580 at most monitoring sites. The ambient air fluoride concentrations measured at most sites were generally below the detection limit of 0.1 $\mu g/m^3$ during 1997.

Grazing Monitor Farms and ungrazed grass monitoring sites effected by the main stack discharge indicated lower exposure to fluoride. The decrease reflected the decreased fluoride discharge from the main stack. This is most evident east and northeast of the smelter.

The fluoride concentration of pinus radiata needles was generally higher during 1997 than during 1996. The 1997 concentrations were lower than for 1995 when there was no scrubbing of the main stack discharges.

The smelter's discharges into water and their effects on the environment were similar to previous years.

Monitoring of the quality of the landfill groundwater did not indicate any significant trends during 1997.

Monitoring of the cathode pad area groundwater contamination plume indicated that the contamination was reducing as predicted. As a result the Southland Regional Council agreed that NZAS could reduce the monitoring program.

Monitoring of total petroleum hydrocarbon concentrations in groundwater surrounding the diesel spill plume at the smelter site indicated there is no movement of the plume downstream or off-site.

Chapter 1

Introduction

Operations at NZAS returned to normal during 1997 as the recent upgrade work was completed and commissioned, and issues arising from the upgrade were resolved.

This report outlines NZAS' commitment to maintaining and where possible improving the smelter's environmental performance.

There are some layout changes to this report compared to previous reports. The large chapter on dispersion and effects of discharges on the environment is separated into seven chapters. Each of the additional chapters is focussed on a single issue:

- dispersion conditions,
- ambient air,
- atmospheric deposition,
- ungrazed grass,
- pinus radiata,
- Grazing Monitor farms, and
- Tiwai Experimental farms.

The data is provided in summaries, maps and where appropriate as graphs. Analysis of trends and other comments are also included where appropriate.

Chapter 2

Discharges to Air

Introduction

Discharges into air from the smelter and wharf are covered by Air Discharge Permit Number 93566 issued by the Southland Regional Council which commenced on 26 April 1994.

This chapter covers:

- main stack discharges,
- Reduction Lines roof louvre discharges,
- fluoride discharges into air,
- baghouse discharges,
- Carbon Baking Furnace discharge to the main stack and,
- sulphur contents of raw materials and fuels used in the aluminium smelting process.

Main stack discharge permit standards

The standards applying to the main stack discharge transferred from Condition B1.1 to Condition C1.1 of the permit during 1997.

The standards for the period during the commissioning of the dry scrubbers were covered by Condition B1.1 of the air discharge permit. These standards were 12 month running averages and ceased to apply in February 1997. The permit standards applicable during January 1997 under Condition B1.1 were:

- Total particulate 12 month running average not to exceed 7.44 kg/min.
- Gaseous fluoride 12 month running average not to exceed 2.54 kg/min.
- Particulate fluoride 12 month running average not to exceed 2.71 kg/min .

From February 1997, the 34th month after the commencement of the permit referred to in Condition C1.1, the standards applying are for 12 month running averages with the first averaging period being the 12 months ending January 1998. The permit standards applying from January 1998 are:

- Total particulate 12 month running average not to exceed 3.25 kg/min.
- Gaseous fluoride 12 month running average not to exceed 0.65 kg/min.
- Particulate fluoride 12 month running average not to exceed 1.94 kg/min.

Main Stack Discharges

Monitoring results

The following table shows the average main stack monitoring results for 1997. The averages are equivalent to the 12 month running average for the period ending December 1997.

As is discussed in "Main stack discharge permit standards", page 2.1, the standards applying to the main stack discharge transferred from Condition B1.1 to Condition C1.1 at the beginning of February 1997. The first averaging period is the 12 months ending January 1998 so no permit standards are included in the table.

Parameter	Units	1997 average
Gas flow rate	Sm^3/min	71,400
Total particulate	kg/min	0.93
Gaseous fluoride	kg/min	0.16
Particulate fluoride	kg/min	0.02
Sulphur dioxide	kg/min	13.31
Total condensable hydrocarbons	kg/min	0.34

Main Stack Discharges

Monitoring results

The following table shows the average main stack monitoring results for 1997. The averages are equivalent to the 12 month running average for the period ending December 1997.

As is discussed in "Main stack discharge permit standards", page 2.1, the standards applying to the main stack discharge transferred from Condition B1.1 to Condition C1.1 at the beginning of February 1997. The first averaging period is the 12 months ending January 1998 so no permit standards are included in the table.

Parameter	Units	1997 average
Gas flow rate	Sm^3/ min	64,400
Total particulate	kg/min	0.97
Gaseous fluoride	kg/min	0.15
Particulate fluoride	kg/min	0.01
Sulphur dioxide	kg/min	13.16
Total condensable hydrocarbons	kg/min	0.34

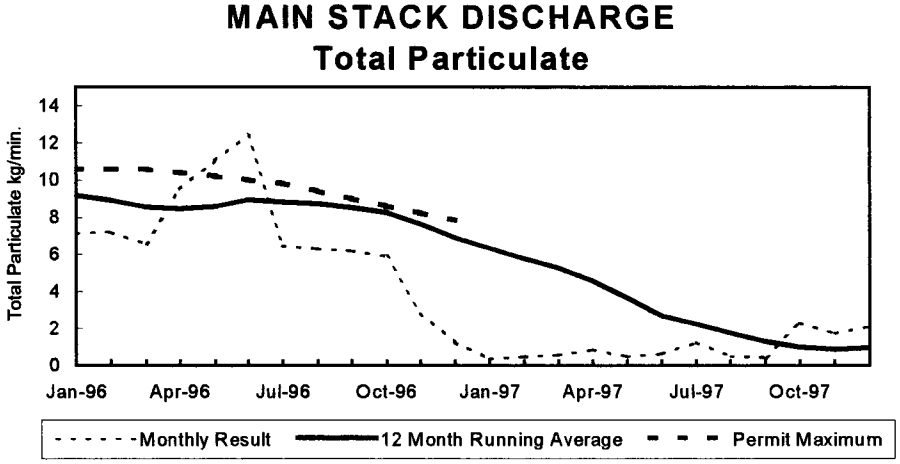
Main Stack Discharges, Continued

Total particulate

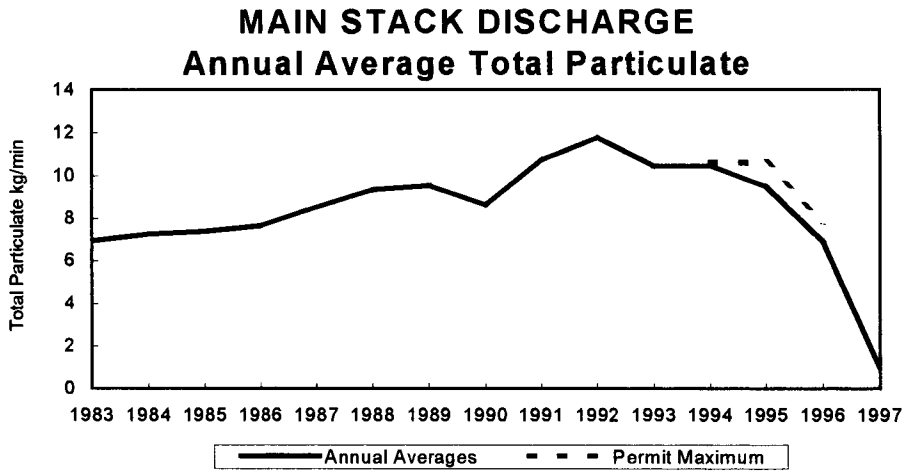
Standard: 12 month running average not to exceed 7.44 kg/min during January 1997.

As is discussed in "Main stack discharge permit standards", page 2.1, the standards applying to the main stack discharge transferred from Condition B1.1 to Condition C1.1 at the beginning of February 1997. The first averaging period for Condition C1.1 is the 12 months ending January 1998 and the standard for the main stack total particulate discharge at that time is 3.25 kg/min.

The following graph shows both the average monthly and twelve month running average main stack total particulate discharge during 1996 and 1997.



The following graph shows the annual average main stack total particulate discharge.



Main Stack Discharges, Continued

Total particulate

Standard: 12 month running average not to exceed 7.44 kg/min during January 1997.

As is discussed in "Main stack discharge permit standards", page 2.1, the standards applying to the main stack discharge transferred from Condition B1.1 to Condition C1.1 at the beginning of February 1997. The first averaging period for Condition C1.1 is the 12 months ending January 1998 and the standard for the main stack total particulate discharge at that time is 3.25 kg/min.

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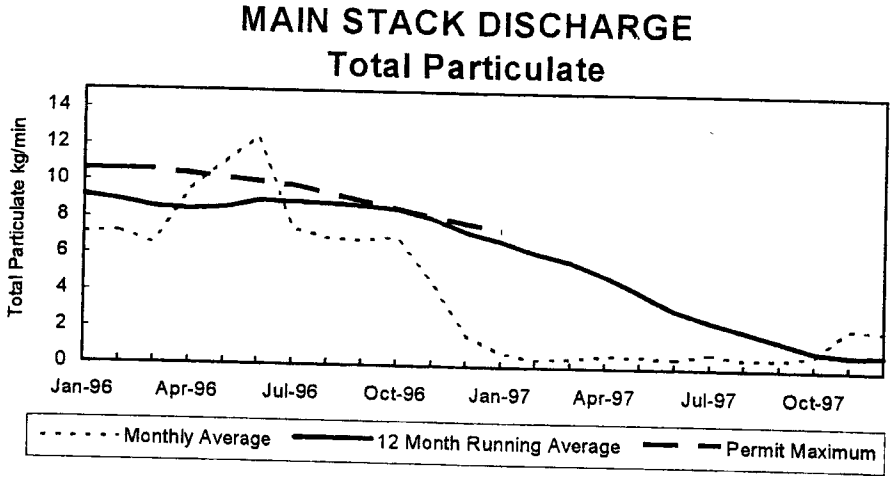
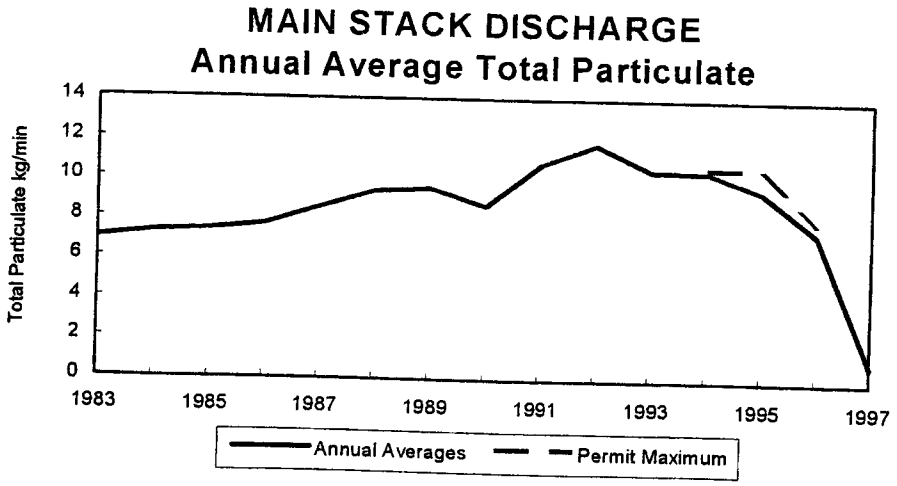


The following graph shows the annual average main stack total particulate discharge.



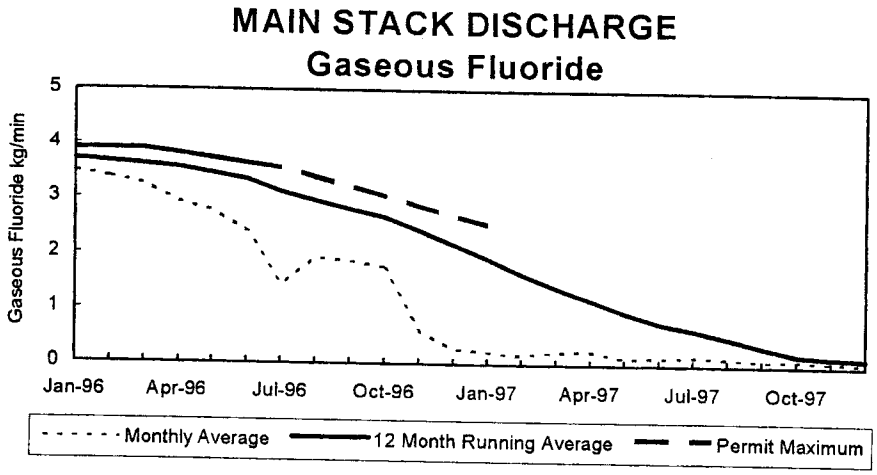
Main Stack Discharges, Continued

Gaseous fluoride

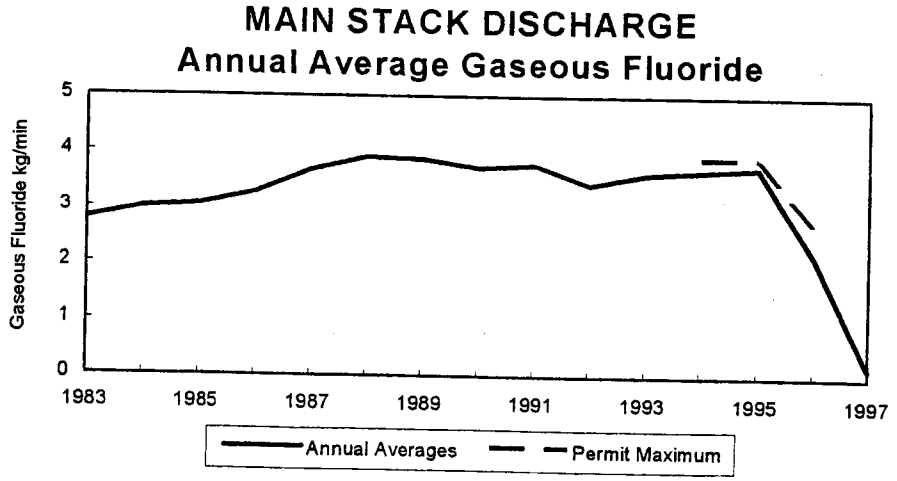
Standard: 12 month running average not to exceed 2.54 kg/min during January 1997.

As is discussed in "Main stack discharge permit standards", page 2.1, the standards applying to the main stack discharge transferred from Condition B1.1 to Condition C1.1 at the beginning of February 1997. The first averaging period for Condition C1.1 is the 12 months ending January 1998 and the standard for the main stack gaseous fluoride discharge at that time is 0.65 kg/min.

The following graph shows both the average monthly and twelve month running average main stack gaseous fluoride discharge during 1996 and 1997.



The following graph shows the annual average main stack gaseous fluoride discharge.



Main Stack Discharges, Continued

Gaseous fluoride

Standard: 12 month running average not to exceed 2.54 kg/min during January 1997.

As is discussed in "Main stack discharge permit standards", page 2.1, the standards applying to the main stack discharge transferred from Condition B1.1 to Condition C1.1 at the beginning of February 1997. The first averaging period for Condition C1.1 is the 12 months ending January 1998 and the standard for the main stack gaseous fluoride discharge at that time is 0.65 kg/min.

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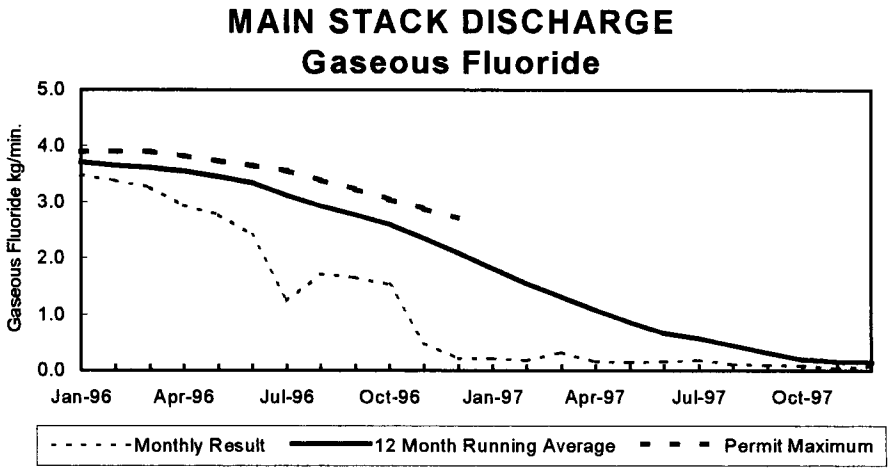
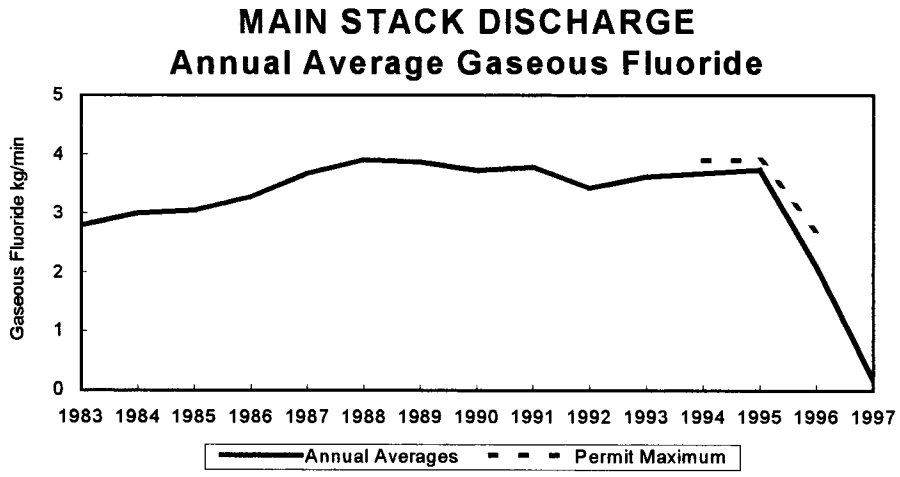


The following graph shows the annual average main stack gaseous fluoride discharge.



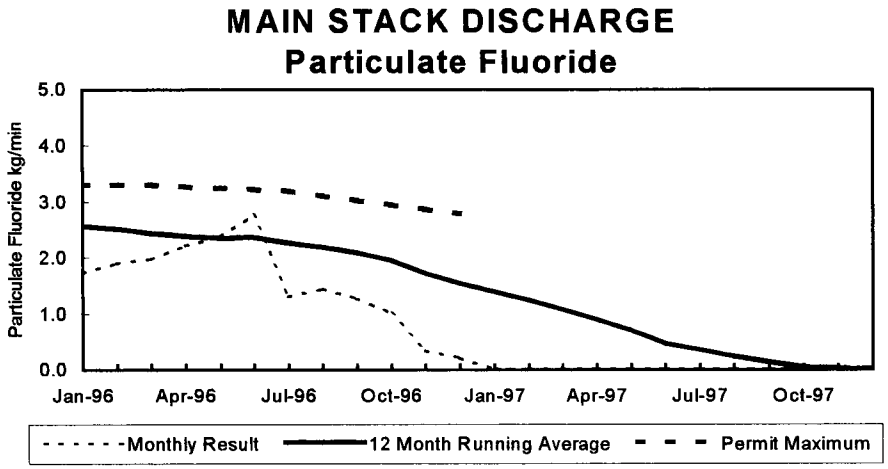
Main Stack Discharges, Continued

Particulate fluoride

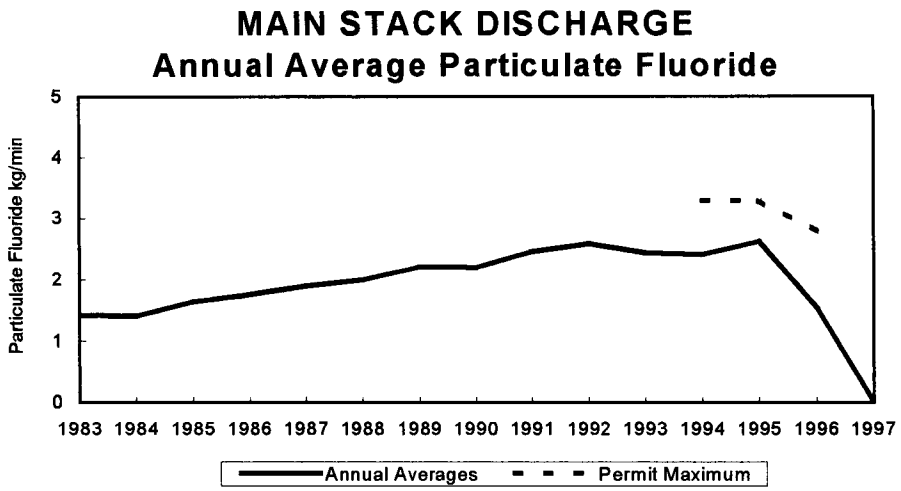
Standard: 12 month running average not to exceed 2.71 kg/min during January 1997.

As is discussed in "Main stack discharge permit standards", page 2.1, the standards applying to the main stack discharge transferred from Condition B1.1 to Condition C1.1 at the beginning of February 1997. The first averaging period for Condition C1.1 is the 12 months ending January 1998 and the standard for the main stack particulate fluoride discharge at that time is 1.94 kg/min.

The following graph shows both the average monthly and twelve month running average main stack particulate fluoride discharge during 1996 and 1997.



The following graph shows the annual average main stack particulate fluoride discharge.



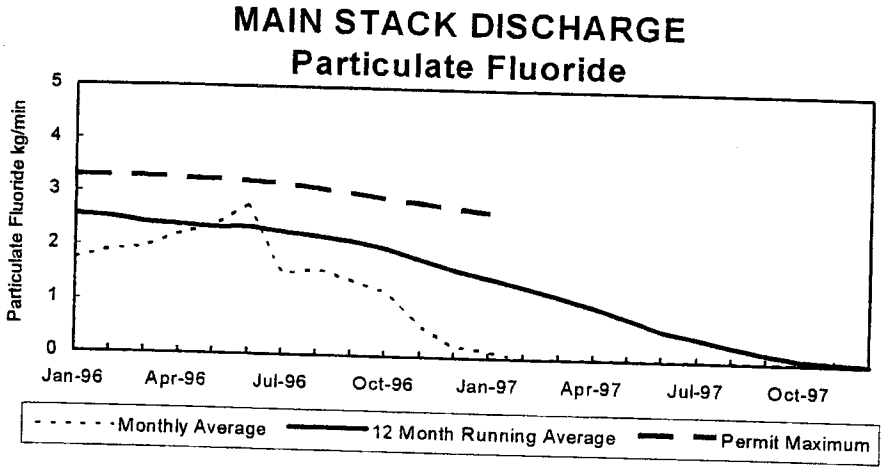
Main Stack Discharges, Continued

Particulate fluoride

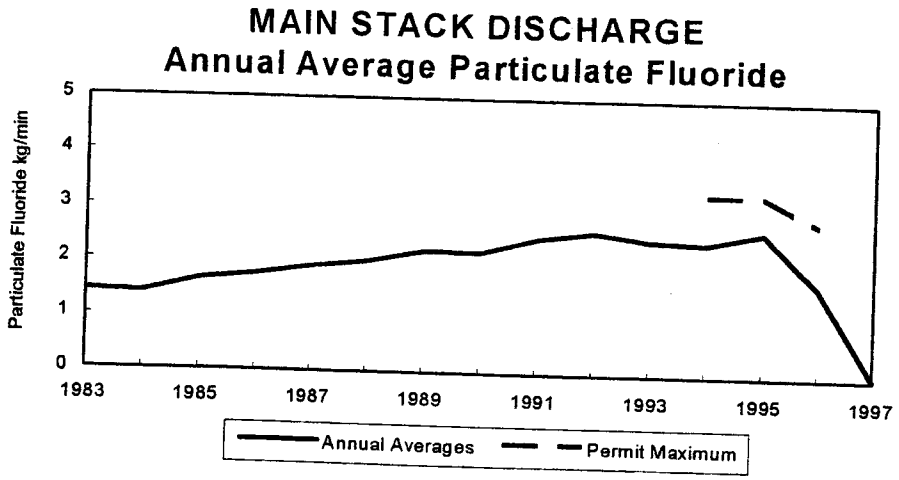
Standard: 12 month running average not to exceed 2.71 kg/min during January 1997.

As is discussed in "Main stack discharge permit standards", page 2.1, the standards applying to the main stack discharge transferred from Condition B1.1 to Condition C1.1 at the beginning of February 1997. The first averaging period for Condition C1.1 is the 12 months ending January 1998 and the standard for the main stack particulate fluoride discharge at that time is 1.94 kg/min.

The following graph shows both the average monthly and twelve month running average main stack particulate fluoride discharge during 1996 and 1997.



The following graph shows the annual average main stack particulate fluoride discharge.



Comments

Dry scrubbing
The main stack total particulate, gaseous fluoride and particulate fluoride discharges were significantly lower than previous years due to the commissioning of the dry scrubbing equipment. The commissioning of this equipment was completed in January 1997.

Total particulate
The average main stack total particulate discharge for 1997 was 0.93 kg/min. This average and all the monthly results were within the permit standard of 3.25 kg/min which applies from January 1998.

The increased total particulate discharge during November and December was most likely due to increased alumina discharge from the dry scrubbing system which resulted from:

- broken bags in the dry scrubber baghouses and
- leaks around the clean air plenum hatches.

All of the baghouses were inspected and a small number of broken bags were replaced. Some of the clean air hatches have been resealed and additional resealing work was completed during the first quarter of 1998. Maintenance systems are in place to ensure low risk continuous operation of the scrubbers.

Particulate material analysed during November also showed the presence of firebrick material. Firebrick material was absent from a second sample collected during December. Upgrading of Carbon Baking Furnace No.1 was in progress at the time. Although particular attention is made to minimise the amount of dust able to escape into the ducts during the upgrade work, this may have been the source. The Carbon Baking Furnace No.1 upgrade is scheduled for completion in August 1998.

Gaseous fluoride
The average main stack gaseous fluoride discharge for 1997 was 0.16 kg/min. This average and all the monthly results were within the permit standard of 0.65 kg/min which applies from January 1998.

Particulate fluoride
The average main stack particulate fluoride discharge for 1997 was 0.02 kg/min. This average and all the monthly results were within the permit standard of 1.94 kg/min which applies from January 1998.

Main Stack Discharges, Continued

Comments

Dry scrubbing
The main stack total particulate, gaseous fluoride and particulate fluoride discharges were significantly lower than previous years due to the commissioning of the dry scrubbing equipment. The commissioning of this equipment was completed in January 1997.

Total particulate
The average main stack total particulate discharge for 1997 was 0.97 kg/min. This average and all the monthly results were within the permit standard of 3.25 kg/min which applies from January 1998.

The increased total particulate discharge during the fourth quarter was most likely due to increased alumina discharge from the dry scrubbing system which resulted from:

- broken bags in the dry scrubber baghouses and
- leaks around the clean air plenum hatches.

All of the baghouses were inspected and a small number of broken bags were replaced. Some of the clean air hatches have been resealed and additional resealing work was completed during the first quarter of 1998.

Particulate material analysed during November also showed the presence of firebrick material. Firebrick material was absent from a second sample collected during December. Upgrading of Carbon Baking Furnace No.1 was in progress at the time. Although particular attention is made to minimise the amount of dust able to escape into the ducts during the upgrade work, this may have been the source. The upgrade is scheduled for completion in August 1998

Gaseous fluoride
The average main stack gaseous fluoride discharge for 1997 was 0.15 kg/min. This average and all the monthly results were within the permit standard of 0.65 kg/min which applies from January 1998.

Particulate fluoride
The average main stack particulate fluoride discharge for 1997 was 0.01 kg/min. This average and all the monthly results were within the permit standard of 1.94 kg/min which applies from January 1998.

Main Stack Discharges, Continued

Comments, continued

Sulphur dioxide

The average main stack sulphur dioxide discharge for 1997 was 13.16 kg/min. This average is about 15% higher than for 1996. The sulphur dioxide measured during 1997 matches the sulphur content of the raw materials. Indications are that the sulphur dioxide discharge measured in previous years was lower than that predicted from raw materials but no reason for this can be found.

Main Stack Discharges, Continued

Comments, continued

Sulphur dioxide

The average main stack sulphur dioxide discharge for 1997 was 13.31 kg/min. This average is about 16% higher than for 1996. The sulphur dioxide measured during 1997 is consistent with the sulphur content of the raw materials. The results now correlate well on a mass balance basis. In the past correlation on mass balance has not been as conclusive.

Reduction Line Roof Louvre Discharges

Monitoring results

The following table shows the Reduction Line roof louvre monitoring results for 1997. The permit standards are for 12 month running averages.

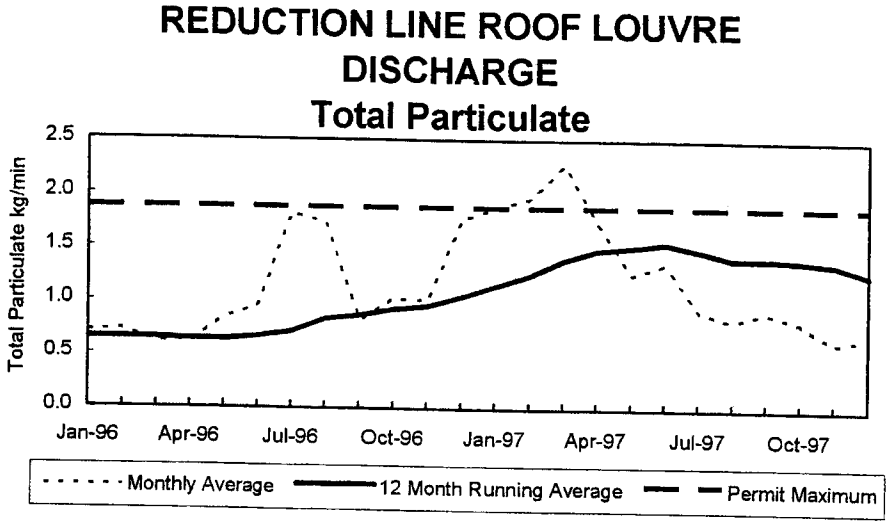
Parameter	Units	Running 12 month average		
		Standard	1997 result	Maximum for any month
Total particulate	kg/min	1.87	1.27	1.55
Gaseous fluoride	kg/min	0.233	0.11	0.16
Particulate fluoride	kg/min	0.233	0.19	0.26
Sulphur dioxide	kg/min	-	0.35	0.41

Reduction Line Roof Louvre Discharges, Continued

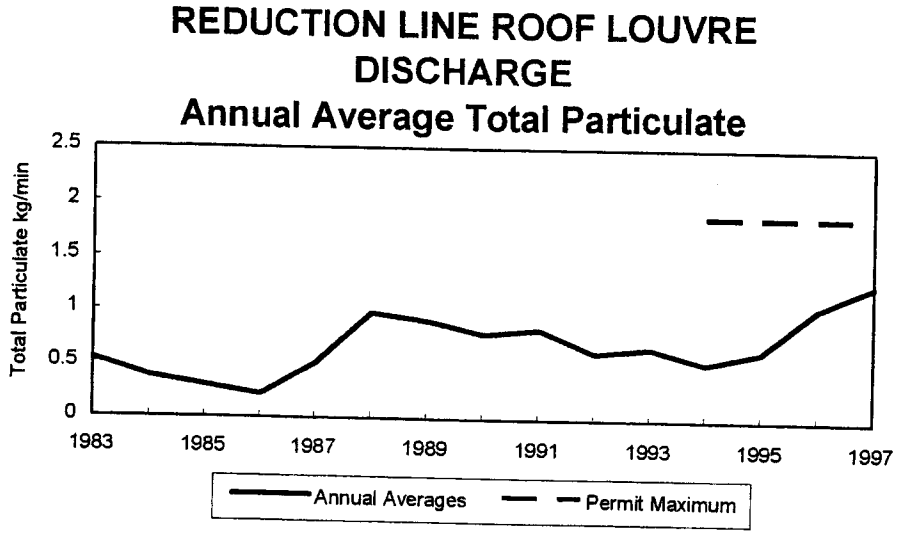
Total particulate

Standard: 12 month running average not to exceed 1.87 kg/min.

The following graph shows both the average monthly and 12 month running average Reduction Line roof louvre total particulate discharge during 1996 and 1997.



The following graph shows the annual average Reduction Line roof louvre total particulate discharge.

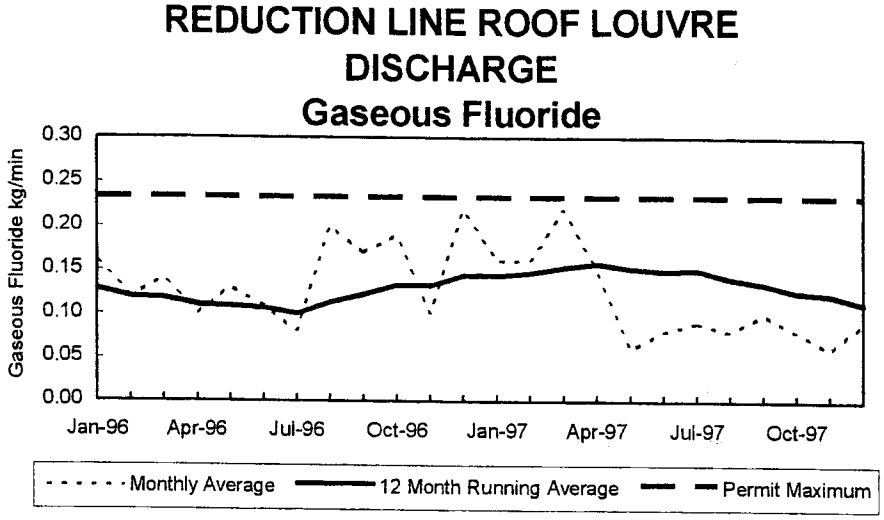


Reduction Line Roof Louvre Discharges, Continued

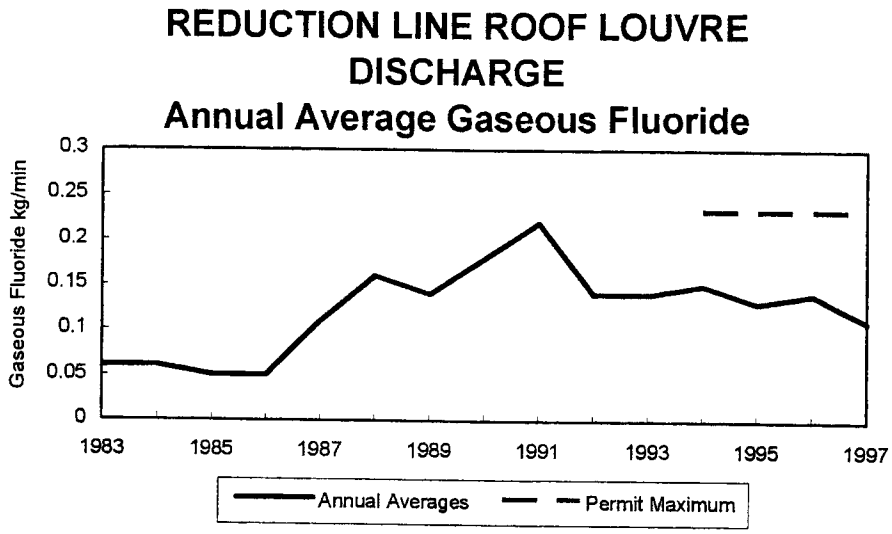
Gaseous fluoride

Standard: 12 month running average not to exceed 0.233 kg/min.

The following graph shows both the average monthly and 12 month running average Reduction Line roof louvre gaseous fluoride discharge during 1996 and 1997.



The following graph shows the annual average Reduction Line roof louvre gaseous fluoride discharge.

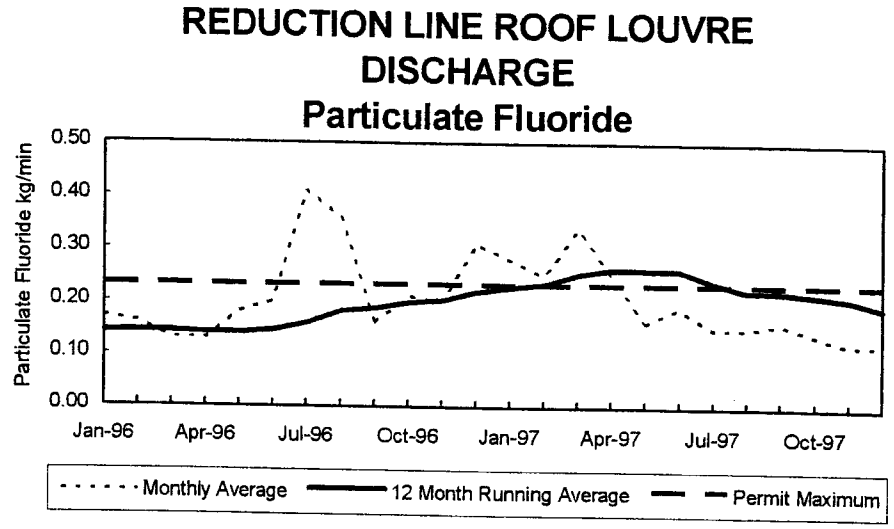


Reduction Line Roof Louvre Discharges, Continued

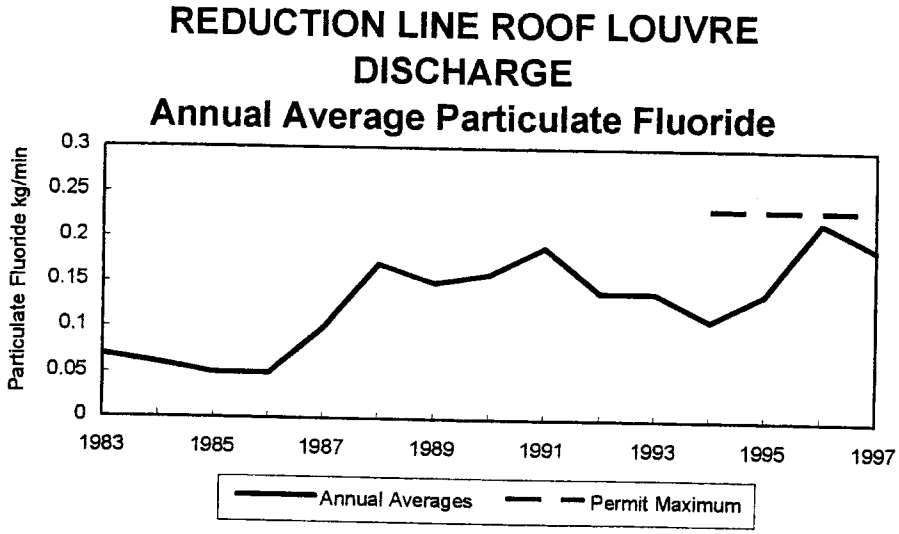
Particulate fluoride

Standard: 12 month running average not to exceed 0.233 kg/min.

The following graph shows both the average monthly and 12 month running average Reduction Line roof louvre particulate fluoride discharge during 1996 and 1997.



The following graph shows the annual average Reduction Line roof louvre particulate fluoride discharge.



Reduction Line Roof Louvre Discharges, Continued

Comments

The Reduction Line roof louvre particulate fluoride discharge exceeded the permit (rolling average) standard from February to July 1997 as a result of high discharges during the period July 1996 to April 1997.

All other Reduction Line roof louvre discharges were within permit standards throughout 1997.

The particulate fluoride permit standard was exceeded due to a continuation of the process instability in the reduction lines, as discussed in the 1996 report. This process instability was the result of the cumulative effects of upgrade changes including:

- introduction of reacted alumina from the dry scrubbing system,
- anodes size changes, and
- increased current.

The total particulate, gaseous fluoride and particulate fluoride discharges decreased from April as the process instability was resolved. Work to reduce the generation of fines during the conveyance of materials from the dry scrubbing system continued throughout the year.

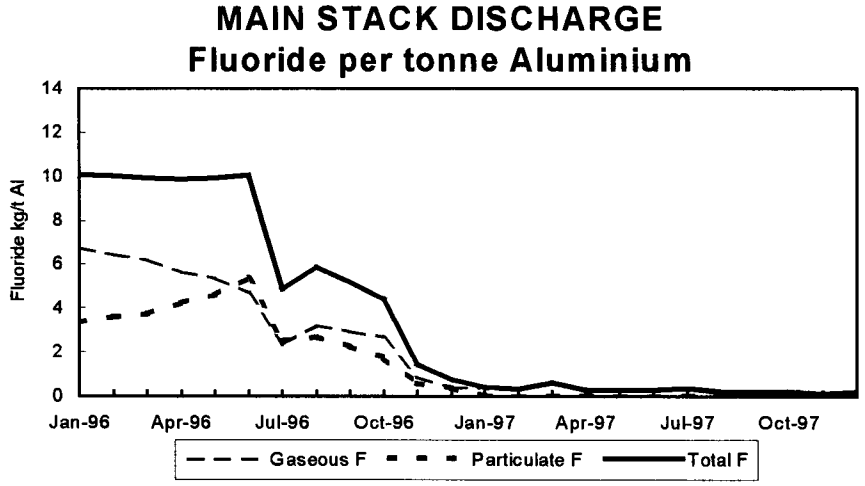
Fluoride Discharges

Performance data

The following table shows the fluoride discharges expressed as a ratio of hot aluminium metal production during 1997.

Parameter	Units	1997 result	Maximum for any month
Main Stack			
• Gaseous fluoride	kg/t Al	0.26	0.58
• Particulate fluoride	kg/t Al	0.02	0.06
• Total fluoride	kg/t Al	0.28	0.60
Reduction Line Roof Louvres			
• Gaseous fluoride	kg/t Al	0.19	0.39
• Particulate fluoride	kg/t Al	0.33	0.60
• Total fluoride	kg/t Al	0.52	0.98
Plant			
• Gaseous fluoride	kg/t Al	0.45	0.97
• Particulate fluoride	kg/t Al	0.35	0.62
• Total fluoride	kg/t Al	0.80	1.59

The following graph shows the average monthly main stack fluoride discharge during 1996 and 1997.



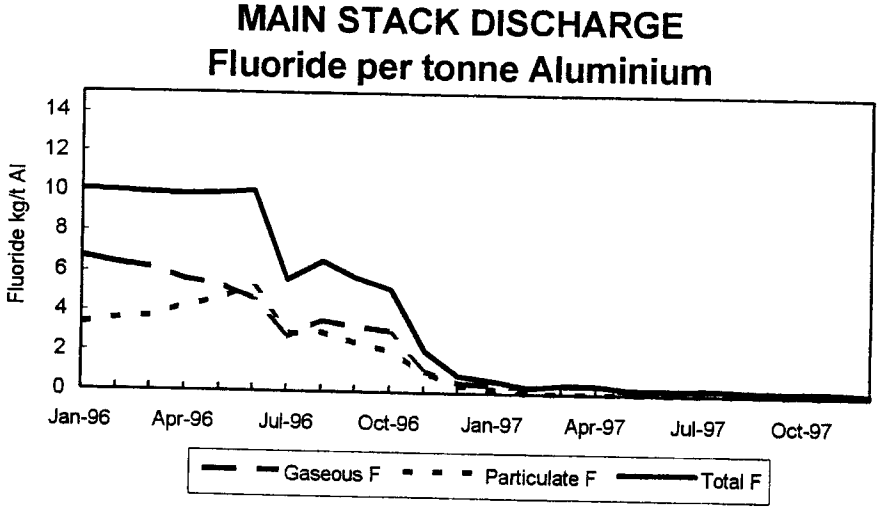
Fluoride Discharges

Performance data

The following table shows the fluoride discharges expressed as a ratio of hot aluminium metal production during 1997.

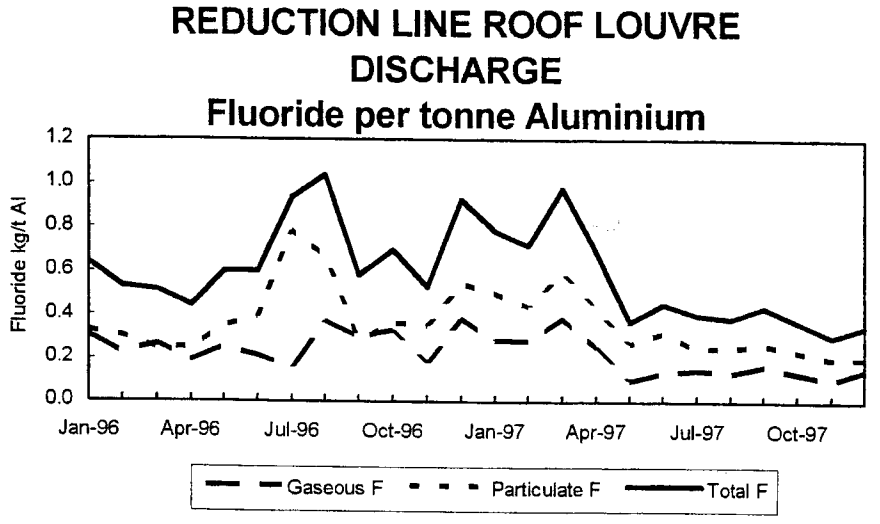
Parameter	Units	1997 average	Maximum for any month
Main Stack			
• Gaseous fluoride	kg/t Al	0.27	0.43
• Particulate fluoride	kg/t Al	0.04	0.23
• Total fluoride	kg/t Al	0.31	0.64
Reduction Line Roof Louvres			
• Gaseous fluoride	kg/t Al	0.19	0.39
• Particulate fluoride	kg/t Al	0.33	0.60
• Total fluoride	kg/t Al	0.52	0.98
Plant			
• Gaseous fluoride	kg/t Al	0.46	0.81
• Particulate fluoride	kg/t Al	0.37	0.73
• Total fluoride	kg/t Al	0.83	1.43

The following graph shows the average monthly main stack fluoride discharge during 1996 and 1997.

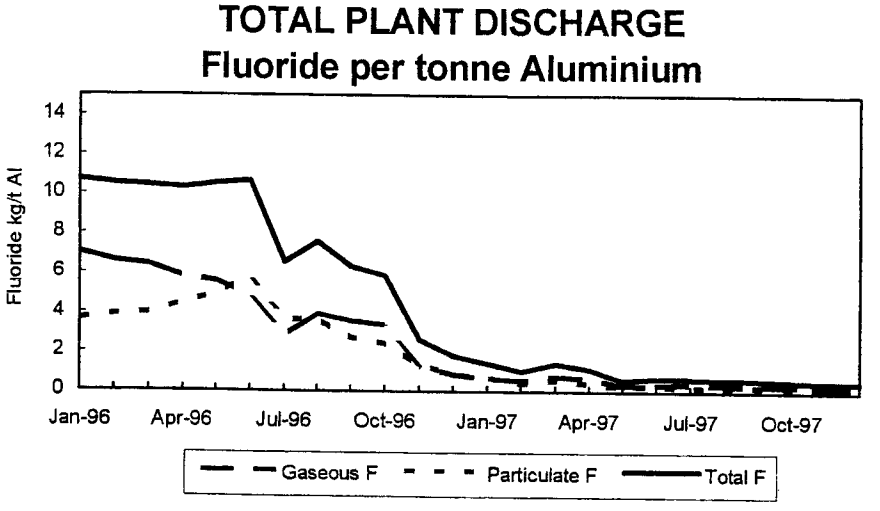


Performance data, continued

The following graph shows the average monthly Reduction Lines roof louvre fluoride discharge during 1996 and 1997.



The following graph shows the average monthly total plant fluoride discharge during 1996 and 1997.



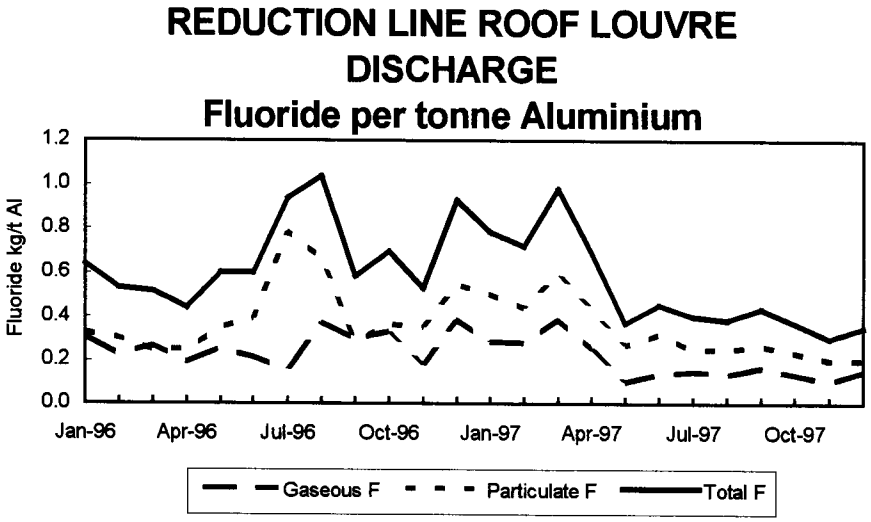
Comments

The fluoride discharge rate from the plant was significantly lower due to the commissioning of the main stack dry scrubbing equipment. The discharge rate from the Reduction Line's roof louvres decreased during 1997 as a result of the improved operating stability of the cells.

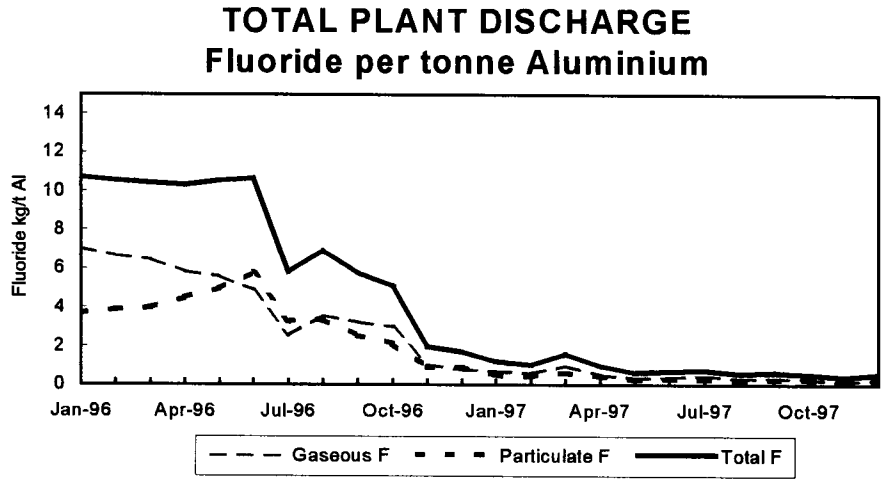
Fluoride Discharges, Continued

Performance data, continued

The following graph shows the average monthly Reduction Lines roof louvre fluoride discharge during 1996 and 1997.



The following graph shows the average monthly total plant fluoride discharge during 1996 and 1997.



Comments

The fluoride discharge rate from the plant was significantly lower due to the commissioning of the main stack dry scrubbing equipment. The discharge rate from the Reduction Line's roof louvres decreased during 1997 as a result of the improved operating stability of the cells.

Baghouse Discharges

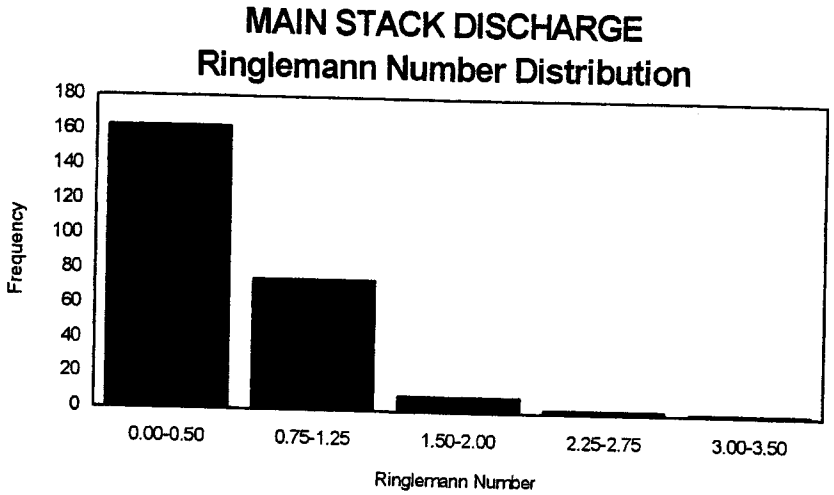
The regular inspection of the baghouse discharges continued during 1997. These inspections were in addition to the on-going operational surveillance of this equipment.

Carbon Baking Furnace Discharges

Carbon Baking Furnace discharges to air during 1997 were similar to those during 1996.

Main Stack Opacity

Main stack opacity is determined by visual observations using the standard Ringlemann chart. The following graph summarises the observations recorded during 1997.



Sulphur Content of Raw Materials and Fuels

The following table shows the maximum, minimum, and average sulphur content of raw materials and fuels delivered to the smelter during 1997.

Material	Units	Permit Maximum	1997 Annual Average	1997 maximum	1997 minimum
Petroleum coke	%	3.0	2.86	2.95	2.74
Pitch	%	1.0	0.46	0.48	0.44
Heavy fuel oil	%	3.5	2.47	2.56	2.34

Comments

All shipments of raw materials and fuels during 1997 met permit standards for sulphur content.

The 1997 average sulphur contents were higher than those reported for 1996. The reported increase in petroleum coke was due to a change in the analysis method rather than an actual increase in the sulphur content. The increases reported for heavy fuel oil and pitch were actual increases in sulphur content but the effect of these increases on the smelter's discharge of sulphur dioxide is minor.

Chapter 3

Dispersion Conditions

Introduction

This chapter covers the monitoring of meteorological conditions at the Tiwai Point meteorological station. These conditions effect the dispersion of discharges into air from the smelter. The data includes

- the distribution of wind strength,
- the distribution of wind direction, and
- rainfall.

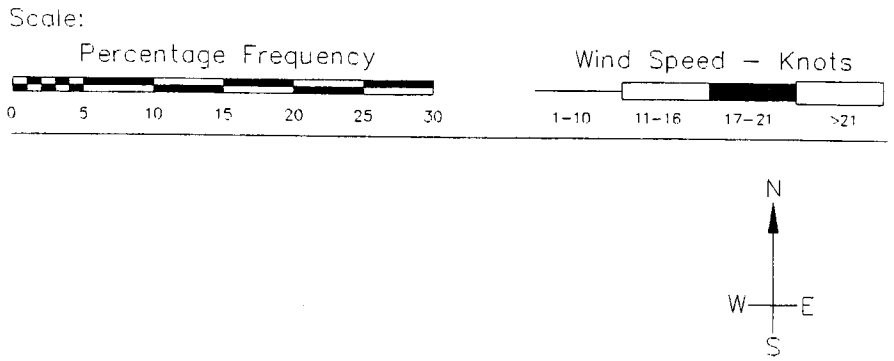
Meteorological Conditions

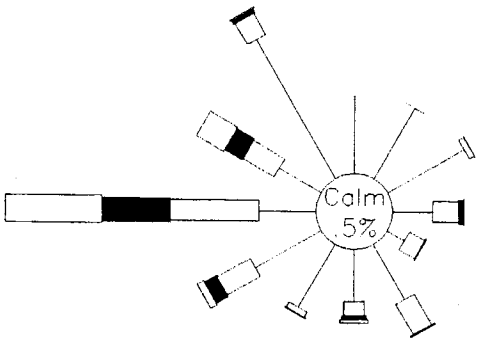
The mean wind frequency diagram on the following page shows that the 1997 wind pattern was dominated by westerly and north westerly winds.

The following table shows the predominant winds and total rainfall recorded for each month during 1997.

Month	Predominant Wind Direction	Rainfall (mm)
January	West and south	61
February	West, southeast and east	118
March	West	84
April	West and northwest	169
May	West, northwest and northeast	102
June	West, southwest and northwest	45
July	West, northwest and north	112
August	West, northwest and northeast	101
September	West, southwest and southeast	39
October	West and northwest	111
November	West and northwest	145
December	West and northwest	171

NEW ZEALAND ALUMINIUM SMELTERS LIMITED – TIWAI POINT
WORKPLACE AND ENVIRONMENTAL MONITORING OUTPUT TEAM
MEAN WIND FREQUENCY (%) OF SURFACE WIND DIRECTIONS
MONTH: SUMMARY 1997





% Time at	
1–10 Knots	59.9
11–16 Knots	20.9
17–21 Knots	8.6
>21 Knots	10.1
Calm	.5

Chapter 4

Ambient Air

Introduction

This chapter covers the monitoring for gaseous and particulate fluorides in ambient air at six monitoring sites

Permit standards

The standards for ambient air gaseous fluoride covered by the air discharge permit are:

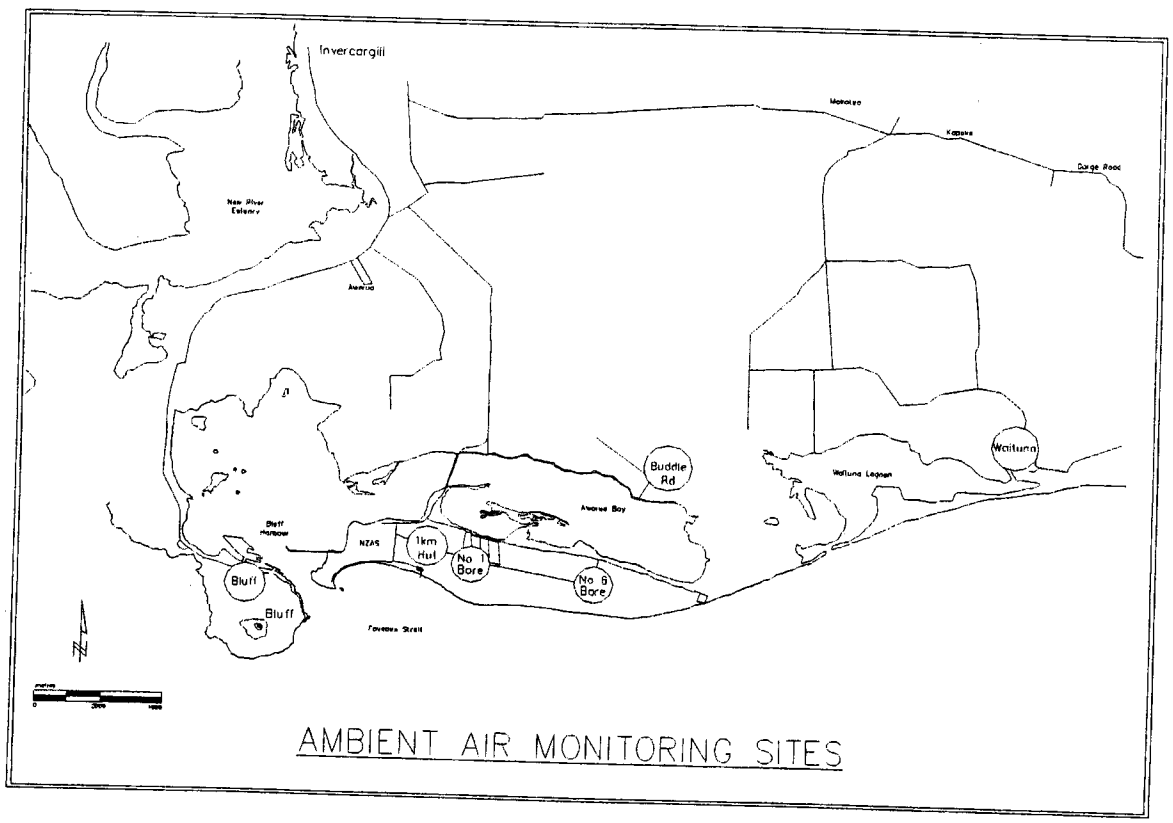
- 24 hour average 2.0 $\mu g/m^3$
- 7 day average 1.0 $\mu g/m^3$
- One month average 0.5 $\mu g/m^3$

The 24-hour average is not to be exceeded on more than eight days in any twelve consecutive months.

The standards apply to measurements on land off Tiwai Peninsula and on Tiwai Peninsula east of Comalco New Zealand Limited's freehold land.

Site locations

The locations of the monitoring sites are shown in following map.



Australian Standard Methods

The Southland Regional Council has approved the use of the current version of Australian Standard AS 3580, 13.2 (AS 3580) at the following sites:

- No.1 Bore,
- No.6 Bore,
- Bluff, and
- Waituna.

Beginning with No.6 Bore, AS 3580 was adopted progressively at the four sites during March, April, and May 1997.

Following liaison with the Southland Regional Council a modified version of the Australian Standard method was adopted at Buddle Road during July. The variation from the standard method is to use a scaled down sampling head. The modified version is required at this site to allow a battery powered sampling pump to be used as the site is not supplied with mains electricity.

AS 3580 quotes a detection limit of 0.1μg F/m^3 which is higher than the previous method used by NZAS. Most results reported during the twelve months prior to changing the methods were lower than 0.1 μg F/m^3. Since the change most results have remained below the detection limit of AS3580. The results are presented in tables but have not been presented graphically where AS 3580 is used due to the change in the monitoring method and the level of detection.

Ambient Air At 1 Kilometre Hut

Monitoring results

As was discussed in the 1996 report, reviews of the ambient air gaseous fluoride concentrations at the 1 Km Hut site and of the Kyoto HF-18 analyser operations identified faults with the analyser. All data from March 1995 to August 1996 was probably affected by the faults and NZAS withdrew the data from the air discharge permit reports.

Due to continuing problems with maintaining the Kyoto analyser it was decided in July 1997 that the analyser be withdrawn from service. A Merry-Go-Round (MGR) sampler using impregnated filters is now used at this site.

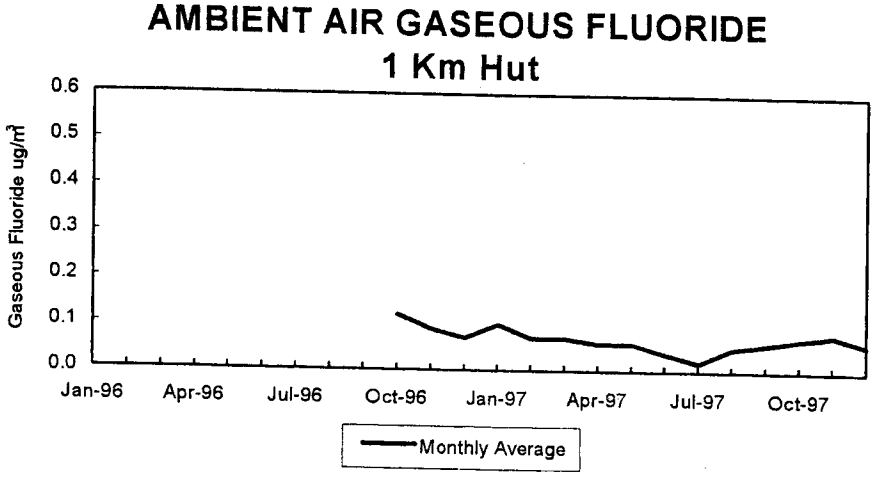
The following table summarises the monitoring results for 1997. The sampling frequency for ambient air gaseous fluoride at this site is 12 hours. Particulate fluoride is not sampled at this site.

Parameter	Units	Standard	1997
Gaseous fluoride concentration			
• Max 12 hour average	$\mu g/m^3$	-	0.37
• Max 24 hour average	$\mu g/m^3$	-	0.29
• Max 7 day average	$\mu g/m^3$	-	0.18
• Max monthly average	$\mu g/m^3$	-	0.10
• Annual Average	$\mu g/m^3$	-	0.06
• No. of days 24 hour average concentration exceeded 2.0 $\mu g/m^3$ during past 12 consecutive months	-	-	0

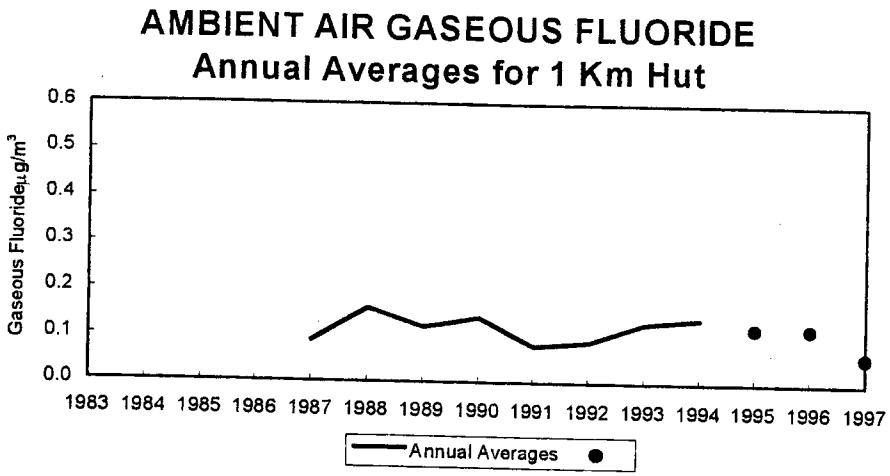
Ambient Air At 1 Kilometre Hut, Continued

Monitoring results, continued

The following graph shows the results of monthly average gaseous fluoride concentrations measured at the 1 Km Hut site during 1996 and 1997.



The following graph shows the annual average ambient air gaseous fluoride concentration measured at the 1 Km Hut site. The annual averages since 1994 are shown as points because data from March 1995 to August 1996 was corrected. The reason for the correction was discussed in the 1996 report.



Ambient Air At 1 Kilometre Hut, Continued

Comments

The annual average gaseous fluoride concentration measured at this site is the lowest measured since monitoring began in 1987. The decrease is consistent with:

- decreased fluoride discharges from the smelter's main stack due to the commissioning of the dry scrubbing equipment which was completed in January 1997 and
- lower fluoride discharges from the Reduction Line's roof louvres since April 1997.

Ambient Air At Other Sites On Tiwai Peninsula

Monitoring results

The following table summarises the monitoring results during 1996 and 1997 for the two other sites located on Tiwai Peninsula. The sampling frequency for ambient air fluoride at these sites is seven days.

Site	Parameter	Units	Standard	1996	1997
No.1 Bore	Gaseous fluoride concentration				
	• Max 7 day average	$\mu g/m^3$	1.0	0.48	0.20
	• Max monthly average	$\mu g/m^3$	0.5	0.16	0.10
	• Annual average	$\mu g/m^3$	-	0.09	<0.1
	Particulate fluoride concentration				
	• Max 7 day average	$\mu g/m^3$	-	0.12	0.20
	• Max monthly average	$\mu g/m^3$	-	0.04	<0.1
	• Annual average	$\mu g/m^3$	-	0.02	<0.1
No.6 Bore	Gaseous fluoride concentration				
	• Max 7 day average	$\mu g/m^3$	1.0	0.13	<0.1
	• Max monthly average	$\mu g/m^3$	0.5	0.10	<0.1
	• Annual average	$\mu g/m^3$	-	0.07	<0.1
	Particulate fluoride concentration				
	• Max 7 day average	$\mu g/m^3$	-	0.06	<0.1
	• Max monthly average	$\mu g/m^3$	-	0.02	<0.1
	• Annual average	$\mu g/m^3$	-	0.02	<0.1

Comments

All permit standards were met at these sites on Tiwai Peninsula.

The sampling method was changed to the current Australian standard method, AS 3580, at:

- No.1 Bore during April, and
- No.6 Bore during March.

The fluoride concentrations were close to or below the detection limit of the Australian standard method at these sites.

Ambient Air At Sites Off Tiwai Peninsula

Monitoring results

The following table summarises the monitoring results during 1996 and 1997 for the three ambient air monitoring sites located off Tiwai Peninsula. The sampling frequency for ambient air fluoride at these sites is seven days.

Site	Parameter	Units	Standard	1996	1997
Buddle Road	Gaseous fluoride concentration				
	• Max 7 day average	$\mu g/m^3$	1.0	0.08	<0.1
	• Max monthly average	$\mu g/m^3$	0.5	0.05	<0.1
	• Annual average	$\mu g/m^3$	-	0.03	<0.1
	Particulate fluoride concentration				
	• Max 7 day average	$\mu g/m^3$	-	0.12	<0.1
	• Max monthly average	$\mu g/m^3$	-	0.03	<0.1
	• Annual average	$\mu g/m^3$	-	0.01	<0.1
Waituna	Gaseous fluoride concentration				
	• Max 7 day average	$\mu g/m^3$	1.0	0.06	<0.1
	• Max monthly average	$\mu g/m^3$	0.5	0.05	<0.1
	• Annual average	$\mu g/m^3$	-	0.02	<0.1
	Particulate fluoride concentration				
	• Max 7 day average	$\mu g/m^3$	-	0.07	<0.1
	• Max monthly average	$\mu g/m^3$	-	0.04	<0.1
	• Annual average	$\mu g/m^3$	-	0.02	<0.1
Bluff	Gaseous fluoride concentration				
	• Max 7 day average	$\mu g/m^3$	1.0	0.12	<0.1
	• Max monthly average	$\mu g/m^3$	0.5	0.03	<0.1
	• Annual average	$\mu g/m^3$	-	0.02	<0.1
	Particulate fluoride concentration				
	• Max 7 day average	$\mu g/m^3$	-	0.11	<0.1
	• Max monthly average	$\mu g/m^3$	-	0.04	<0.1
	• Annual average	$\mu g/m^3$	-	0.02	<0.1

Ambient Air At Sites Off Tiwai Peninsula, Continued

Comments

All permit standards were met at the three sites off Tiwai Peninsula.

The sampling method was changed to the current Australian standard method, AS 3580, at:

- Waituna during April and
- Bluff during May.

The sampling method at Buddle Road was changed to a modified version of the Australian standard method during July.

The gaseous and particulate fluoride concentrations were below the detection limit of the Australian standard method at these sites during 1997.

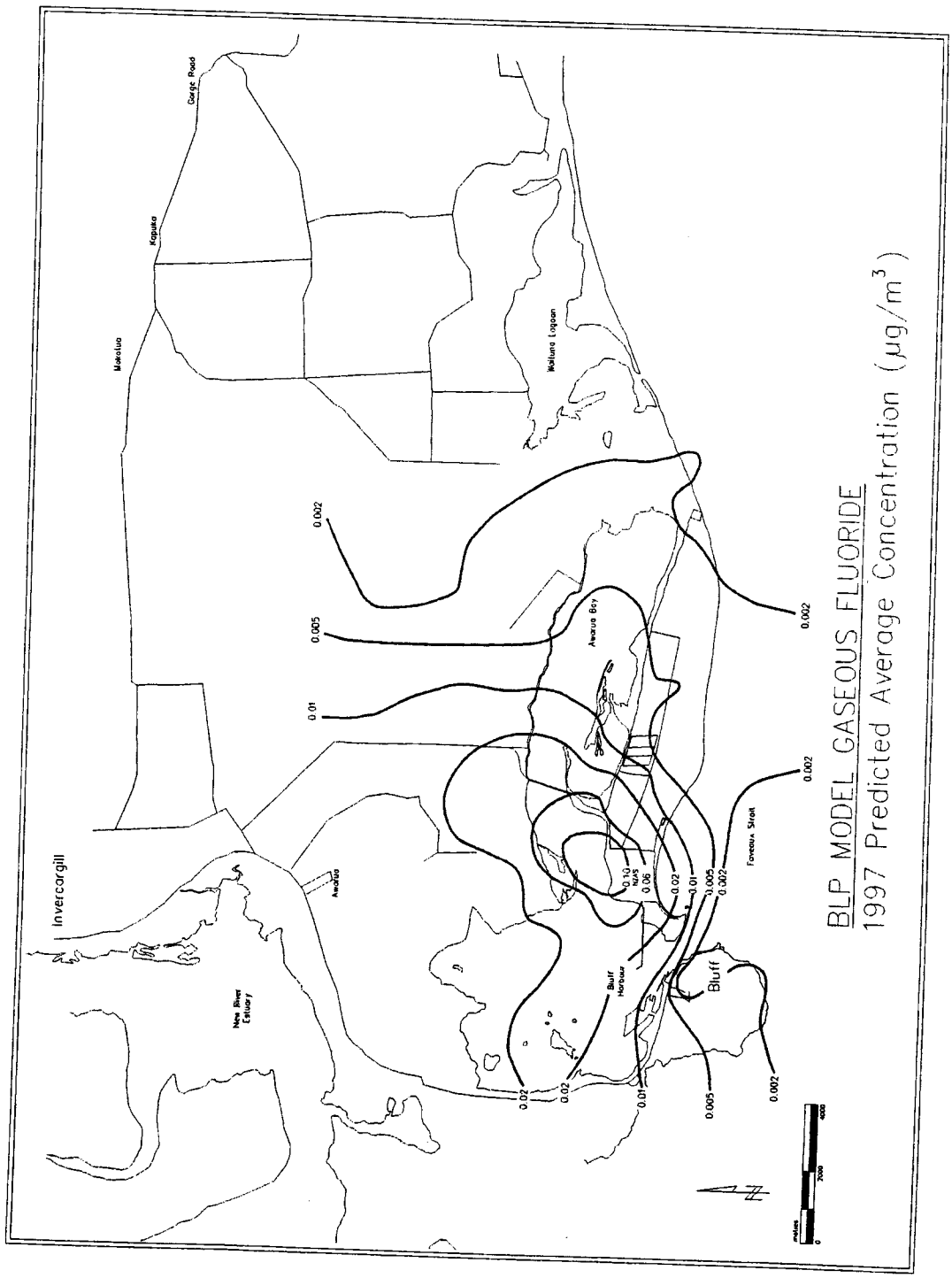
Ambient Air Model Prediction

Introduction

Pacific Air and Environment Pty Ltd is contracted to the smelter to model the dispersion of the smelter's discharges to air. The BLP model was chosen to predict the dispersion of gaseous fluoride discharges.

Predicted concentrations

The predicted mean ambient air gaseous fluoride concentrations due to the discharge from the smelter during 1997 are shown in the following map.



Chapter 5

Atmospheric Deposition

Introduction

This chapter covers the monitoring of atmospheric deposition at nine monitoring sites.

The sources of deposited fluoride include

- NZAS operations,
- burning of fossil fuels,
- application of fertiliser, and
- wind borne salt spray and dusts.

Permit guidelines

The guidelines for atmospheric deposition covered by the Air Discharge Permit are:

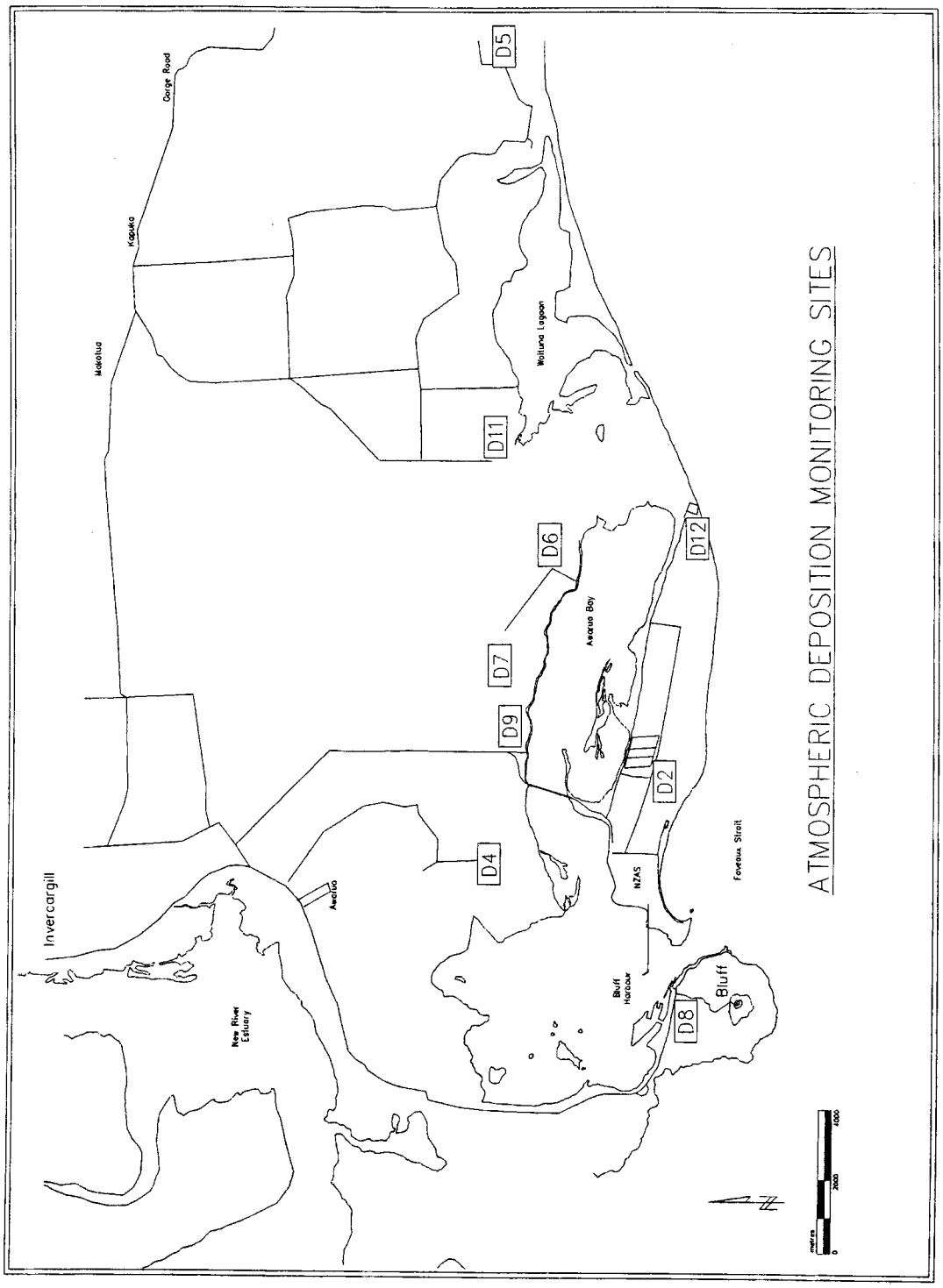
- fluoride 0.9 to 1.1 g/m^3, and
- reactive aluminium
  - aesthetic highest desirable 0.05 g/m^3
  - aesthetic excessive 0.20 g/m^3

The guidelines apply only to land off Tiwai Peninsula.

Introduction, Continued

Site Locations

The locations of the monitoring sites are shown in the following map.



Atmospheric Deposition Monitoring Results

Fluoride Deposition

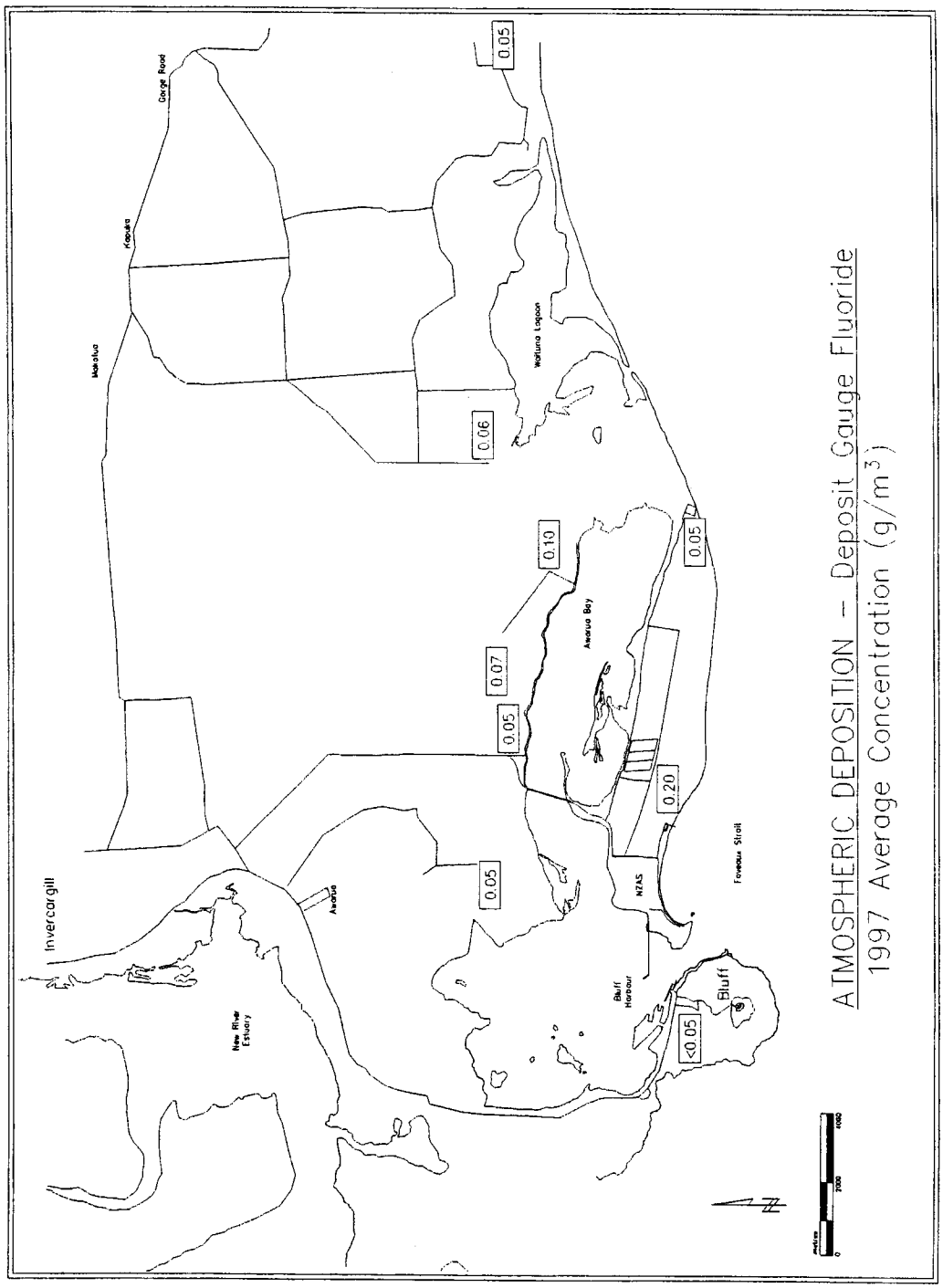
The fluoride atmospheric deposition during 1997 is summarised in the following table.

Site	Units	1997 average	Maximum for any month	Minimum for any month
D2. No.1 Bore[1]	g/m^3	0.20	0.30	0.11
D12 TEF2[1]	g/m^3	0.05	0.09	<0.05
D4 Duck Creek	g/m^3	0.05	0.15	<0.05
D5 Waituna	g/m^3	0.05	0.17	<0.05
D6 Buddle Road	g/m^3	0.10	0.25	<0.05
D7 Gibson's Farm	g/m^3	0.07	0.15	<0.05
D8 Bluff	g/m^3	<0.05	0.08	<0.05
D9 Awarua Bay Road	g/m^3	0.05	0.10	<0.05
D11 Marshall Road	g/m^3	0.06	0.13	<0.05

1. Site located on Tiwai Peninsula and excluded from permit guideline.

The average fluoride concentration of samples collected during 1997 is shown in the map on the following page.

Fluoride Deposition, continued



Atmospheric Deposition Monitoring Results, Continued

Reactive Aluminium Deposition

The reactive aluminium atmospheric deposition during 1997 is summarised in the following table.

Site	Units	1997 average	Maximum for any month	Minimum for any month
D2. No.1 Bore[1]	g/m^3	0.04	0.09	<0.03
D12 TEF2[1]	g/m^3	<0.03	<0.03	<0.03
D4 Duck Creek	g/m^3	<0.03	<0.03	<0.03
D5 Waituna	g/m^3	<0.03	0.06	<0.03
D6 Buddle Road	g/m^3	<0.03	0.03	<0.03
D7 Gibson's Farm	g/m^3	<0.03	<0.03	<0.03
D8 Bluff	g/m^3	<0.03	<0.03	<0.03
D9 Awarua Bay Road	g/m^3	<0.03	<0.03	<0.03
D11 Marshall Road	g/m^3	<0.03	<0.03	<0.03

1. Site located on Tiwai Peninsula and excluded from permit guideline.

Atmospheric Deposition Monitoring Results, Continued

Comments

The atmospheric deposition of fluoride was lower at all sites during 1997 than during 1996. The decreased fluoride deposition was consistent with the decreased fluoride discharge from the smelter's main stack due to the commissioning of all the dry scrubbing equipment which was completed in January 1997.

The atmospheric deposition of reactive aluminium at No.1 Bore was lower than 1996. Reactive aluminium deposition at the other sites remained at or near the detection limit of the method.

All permit guidelines were met during 1997.

Chapter 6

Fluoride in Ungrazed Grasses

Introduction

This chapter covers the monitoring of fluoride in ungrazed grasses at 25 monitoring sites located at Bluff, Green Hills, Awarua Plains, Waituna Wetlands and Tiwai Peninsula.

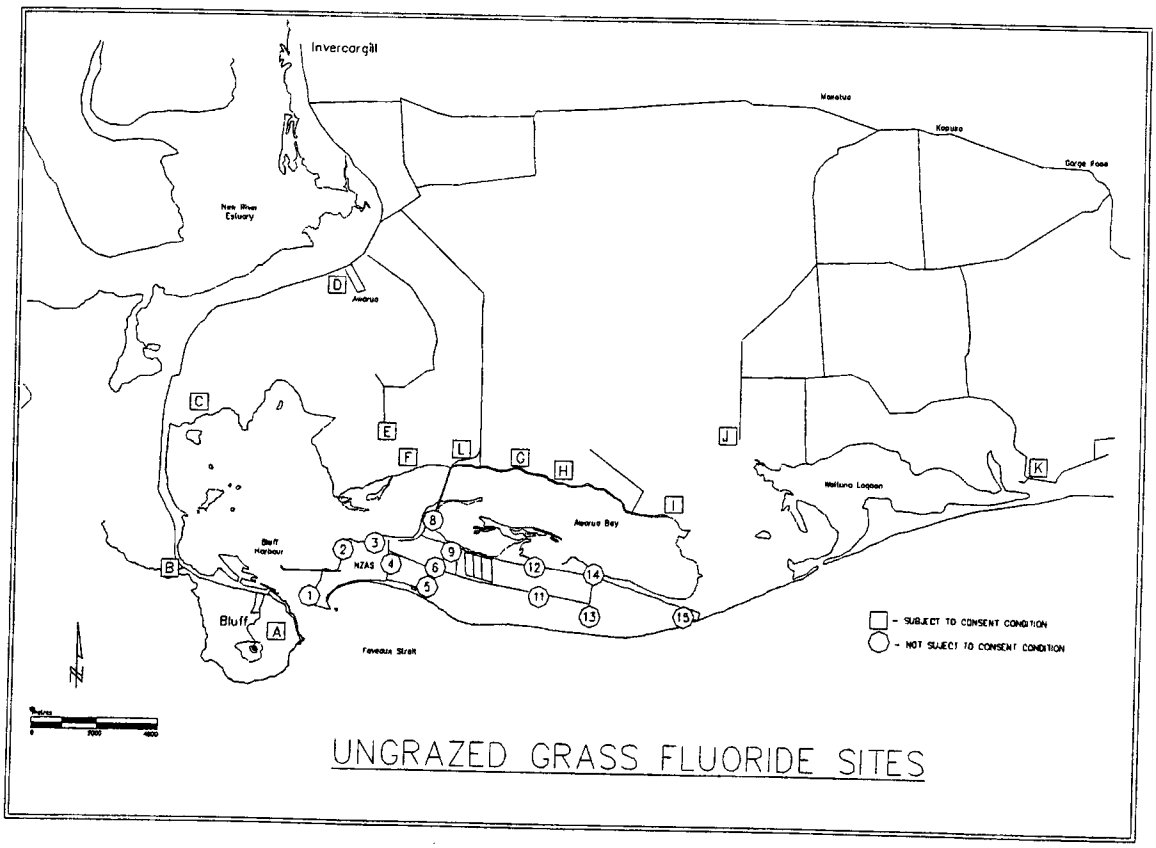
Permit guidelines

The guidelines in ungrazed grasses (on an unwashed, dry weight basis) on land off Tiwai Peninsula are detailed below. These guidelines came into effect in April 1994.

- Monthly sample shall not exceed 80 µg/g more than once in any 12 consecutive months.
- Running average of any two consecutive months shall not exceed 60 µg/g.
- Running average of any 12 consecutive months shall not exceed 40 µg/g.

Site locations

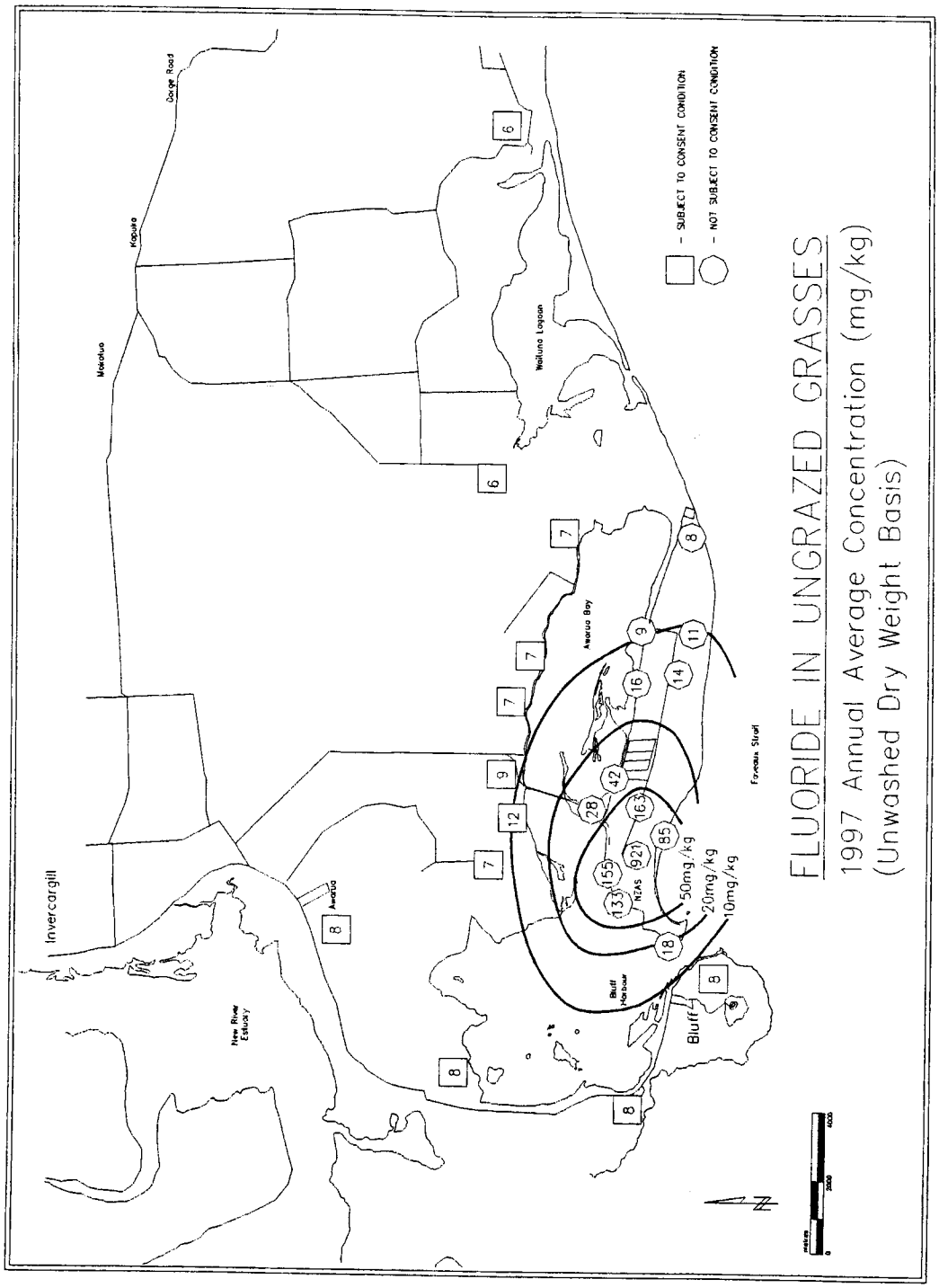
The ungrazed grass monitoring sites are shown on the following map.



Ungrazed Grass Monitoring Results

1997 annual average fluoride concentrations

The 1997 average ungrazed grass fluoride concentrations are shown in the following map.



Fluoride in Ungrazed Grasses, Continued

Monitoring results

The following table shows the maximum monthly fluoride concentrations for sites off Tiwai Peninsula during 1997.

Sites off Tiwai Peninsula	Permit Guideline not to be exceeded more than once in any 12 consecutive months µgF/g	Maximum Monthly Result During 1997 µgF/g
Ungrazed Grass Site A	80	11
Ungrazed Grass Site B	80	12
Ungrazed Grass Site C	80	19
Ungrazed Grass Site D	80	12
Ungrazed Grass Site E	80	11
Ungrazed Grass Site F	80	15
Ungrazed Grass Site G	80	11
Ungrazed Grass Site H	80	11
Ungrazed Grass Site I	80	12
Ungrazed Grass Site J	80	10
Ungrazed Grass Site K	80	14
Ungrazed Grass Site L	80	18

The monthly fluoride concentration in ungrazed grass was within the permit guideline for all sites during 1997.

Fluoride in Ungrazed Grasses, Continued

Monitoring results, continued

The following table shows the maximum two month running average fluoride concentrations for sites off Tiwai Peninsula during 1997.

Sites off Tiwai Peninsula	Permit Guideline µgF/g	Maximum Two Month Running Average During 1997 µgF/g
Ungrazed Grass Site A	60	11
Ungrazed Grass Site B	60	11
Ungrazed Grass Site C	60	14
Ungrazed Grass Site D	60	11
Ungrazed Grass Site E	60	10
Ungrazed Grass Site F	60	14
Ungrazed Grass Site G	60	10
Ungrazed Grass Site H	60	9
Ungrazed Grass Site I	60	11
Ungrazed Grass Site J	60	10
Ungrazed Grass Site K	60	11
Ungrazed Grass Site L	60	16

The two month running average fluoride concentration in ungrazed grass was within the permit guideline for all sites during 1997.

Fluoride in Ungrazed Grasses, Continued

Monitoring results, continued

The following table shows the maximum 12 month running average fluoride concentrations for sites off Tiwai Peninsula.

Sites off Tiwai Peninsula	Permit Guideline µgF/g	Maximum 12 Month Running Average During 1997 µgF/g
Ungrazed Grass Site A	40	11
Ungrazed Grass Site B	40	12
Ungrazed Grass Site C	40	16
Ungrazed Grass Site D	40	9
Ungrazed Grass Site E	40	14
Ungrazed Grass Site F	40	33
Ungrazed Grass Site G	40	14
Ungrazed Grass Site H	40	12
Ungrazed Grass Site I	40	16
Ungrazed Grass Site J	40	10
Ungrazed Grass Site K	40	11
Ungrazed Grass Site L	40	24

The 12 month running average fluoride concentration in ungrazed grass was within the permit guideline for all sites during 1997. The 12 month running average fluoride concentrations were generally higher in the early months of 1997. This was due to the effect of the higher main stack fluoride discharges before and during the early stages of the progressive commissioning of the dry scrubbing system.

Comments

The fluoride concentrations in ungrazed grass remained within the normal range of results for sites within about two kilometres of the smelter. These sites are affected by fluoride discharges from the reduction line roof louvres.

The fluoride concentrations of sites further from the smelter, particularly north-east and east of the smelter, were lower than in recent years. The decreases are consistent with the decreased fluoride discharge from the smelter's main stack due to the commissioning of all the dry scrubbing equipment which was completed in January 1997.

Chapter 7

Fluoride in Pinus Radiata

Introduction

This chapter covers the monitoring of fluoride in pinus radiata at 15 monitoring sites located at Bluff, Awarua Plains, Waituna and Tiwai Peninsula.

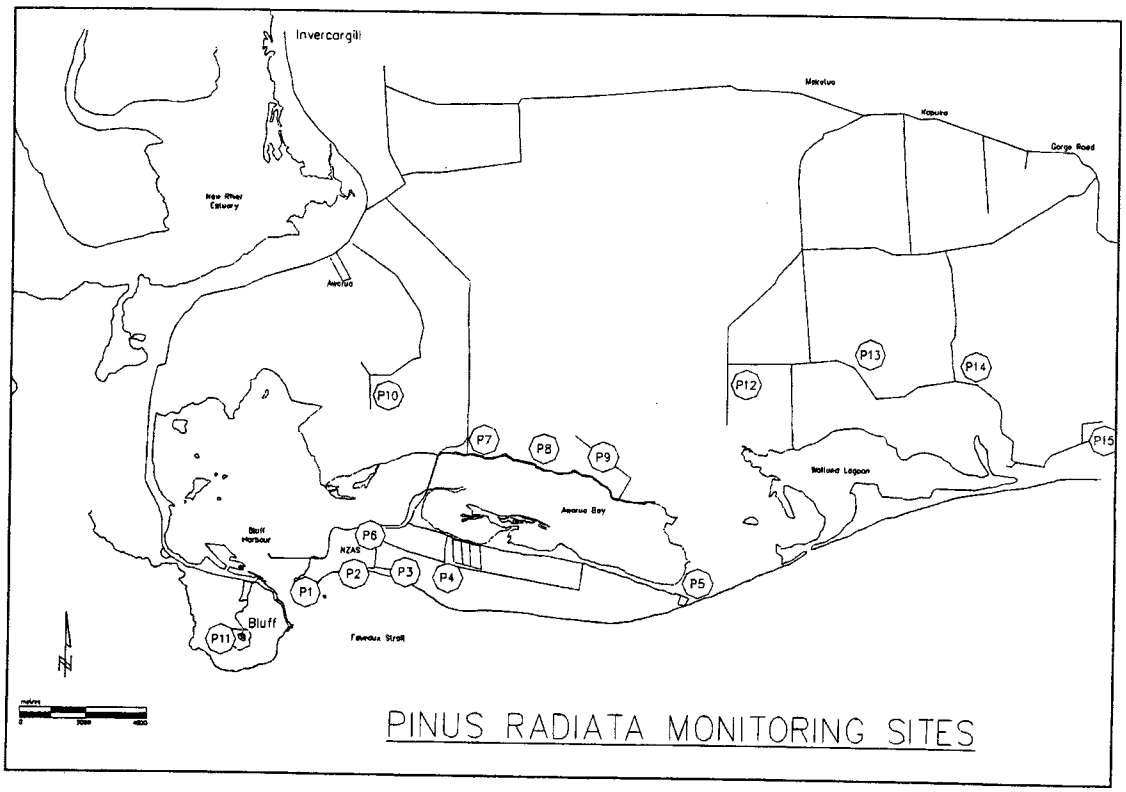
Pine needles between one and two years old are sampled each quarter.

Permit guidelines

The guideline for fluoride content in pinus radiata needles on land off Tiwai Peninsula is 75 mg/kg.

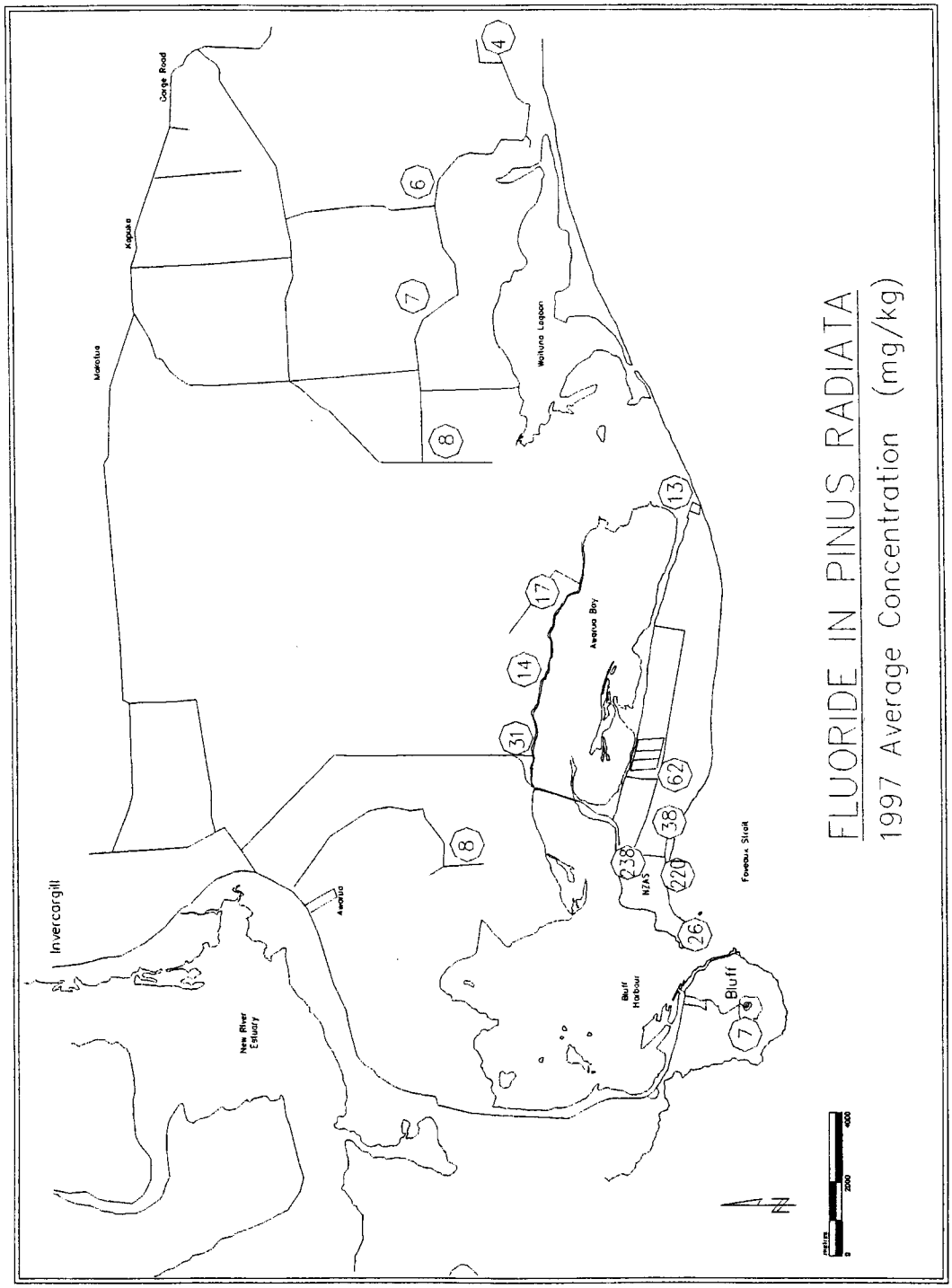
Site locations

The locations of the monitoring sites are shown in the following map.



Pinus Radiata Monitoring Results

The 1997 annual average fluoride concentrations of pine needle samples collected from the monitoring sites are shown in the following map.



Pinus Radiata Monitoring Results, Continued

Comments

The fluoride concentrations in pinus radiata needles were within the permit guideline during 1997 but were generally higher than during 1996.

The increased fluoride concentration of needles sampled within the influence of the reduction line roof louvres, within about two kilometres of the smelter, was most likely due to increased roof louvre gaseous fluoride discharges during the period July 1996 to April 1997.

The fluoride concentration of needles sampled at sites influenced by the main stack discharge was expected to decrease to reflect the decreasing gaseous fluoride discharges from the smelter's main stack. Although higher than 1996 they are lower than the 1995 concentrations when there was no dry scrubbing of the main stack discharge. The magnitude of the reduction since dry scrubbing is less than that of other environmental parameters measured.

Chapter 8

Grazing Monitor Project

Summary

Grazed pasture, cattle urinary, and two year old cattle bone fluoride concentrations indicated decreased exposure to fluoride on all Grazing Monitor Farms (GMF) during 1997. The decreases are consistent with the decreased fluoride discharge from the smelter's main stack due to the commissioning of all the dry scrubbing equipment which was completed in January 1997.

Grazed pasture and cattle bone fluoride concentrations on all farms were within the permit standards and guidelines during 1997.

One cattle urinary fluoride concentration from Grazing Monitor Farm No.4 exceeded the permit guideline of 10 mg/litre. This was the only occasion where a permit guideline was exceeded within the Grazing Monitor Project.

Introduction

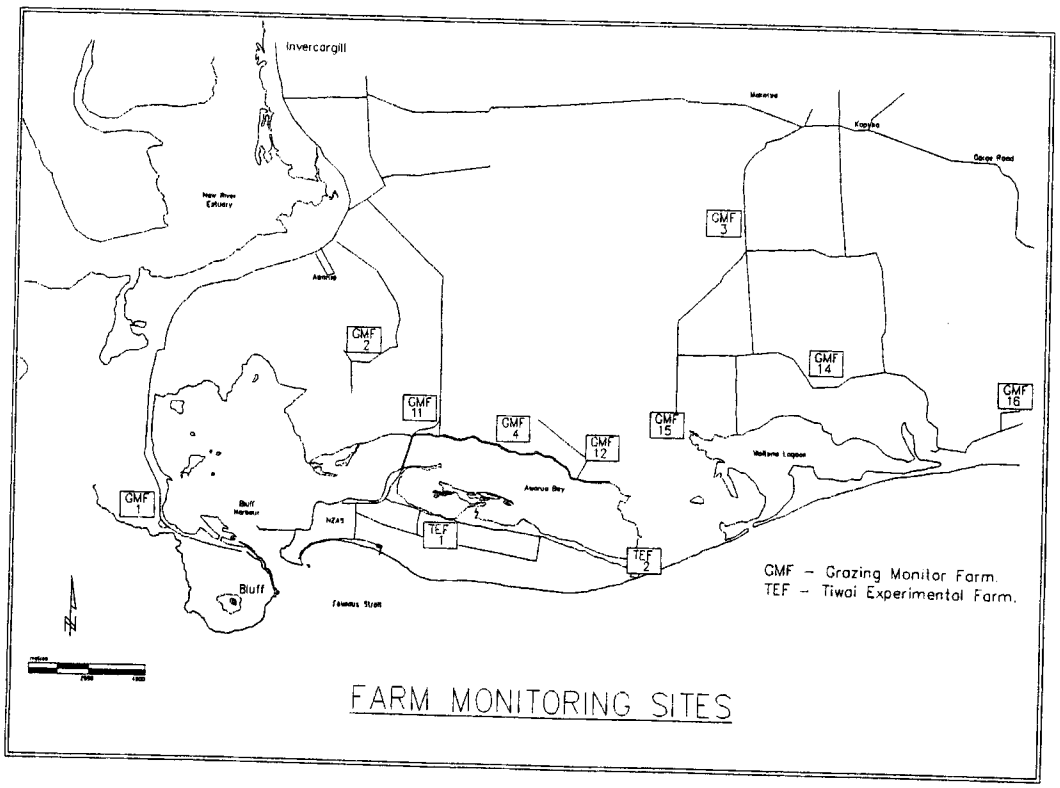
This chapter covers the monitoring of:

- fluoride in grazed pasture,
- fluoride in cattle urine,
- fluoride in cattle bone, and
- cattle dental condition.

The Grazing Monitor Project was established in 1969 prior to the smelter being commissioned. The project has continued since then with modifications as part of the smelter's Environmental Monitoring Program.

Site locations

The following map shows the location of the farms included in the Grazing Monitor Project. Also included in the map are the locations of the two Tiwai Experimental Farms discussed in Chapter 9, Tiwai Experimental Farms.



Introduction, Continued

Monitoring requirements

The Air Discharge Permit requires that fluoride in grazed pasture be monitored at nine sites off Tiwai Peninsula. Nine sites were monitored during 1997:

- Grazing Monitor Farm No. 1,
- Grazing Monitor Farm No. 2,
- Grazing Monitor Farm No. 3,
- Grazing Monitor Farm No. 4,
- Grazing Monitor Farm No. 11,
- Grazing Monitor Farm No. 12,
- Grazing Monitor Farm No. 14,
- Grazing Monitor Farm No. 15, and
- Grazing Monitor Farm No. 16.

The Air Discharge Permit requires that cattle be monitored on two dairy and two beef farms.

The dairy farms monitored are:

- GMF14, and
- GMF16.

The two beef farms monitored are:

- GMF1, and
- GMF4.

Details of the cattle parameters to be monitored to comply with the Air Discharge Permit are given below.

Urinary Fluoride

The urinary fluoride concentrations are corrected to a specific gravity of 1.030.

Bone Fluoride

The bone samples collected for measuring fluoride concentrations are from tail bone biopsies. The tailbone fluoride concentrations are converted to a metacarpal/metatarsal bone fluoride concentration using the method developed by J. Suttie.

Fluoride (F) in dry fat free metacarpal/metatarsal bone = F in ashed tailbone * 0.5.

Monitoring requirements, continued

Dental Condition

The tooth scoring system follows the method of J. Suttie. As most effects on teeth occur prior to eruption, when the teeth are forming, the tooth scores are given in relation to the year during which the tooth was formed. There is over 1 year between formation and eruption so the dental condition cannot be assessed until 1 to 2 years after any effects have occurred.

The inspection results from past years are combined to provide a table summarising the dental condition of the cattle's' permanent incisor teeth for the years when the teeth are forming.

Permit standards

The permit contains a number of standards. A standard is defined in the permit as a limit which is not to be breached.

The standards for fluoride in grazed pasture (on an unwashed, dry weight basis) on land off Tiwai Peninsula are:

- monthly sample shall not exceed 80 µg/g more than once in any 12 consecutive months,
- the average of any two consecutive months samples shall not exceed 60 µg/g,
- running averages of monthly samples for a period of twelve months shall not exceed 40 µg/g.

Permit guidelines

The permit also contains a number of guidelines. A guideline is defined in the permit as a level which is set on best current knowledge, the exceeding of which requires further investigation or other action.

The guidelines for animal health monitoring are:

- urinary fluoride in dairy and beef cattle should not exceed 10 mg/L corrected to S.G. 1.030,
- bone fluoride concentrations as measured in metacarpal/metatarsal bones are:
  - 1605 mg/kg for two year olds,
  - 2379 mg/kg for four year olds, and
  - 2794 mg/kg for six year olds.

Grazing Monitor Farm No.1

The following information is contained in this section:

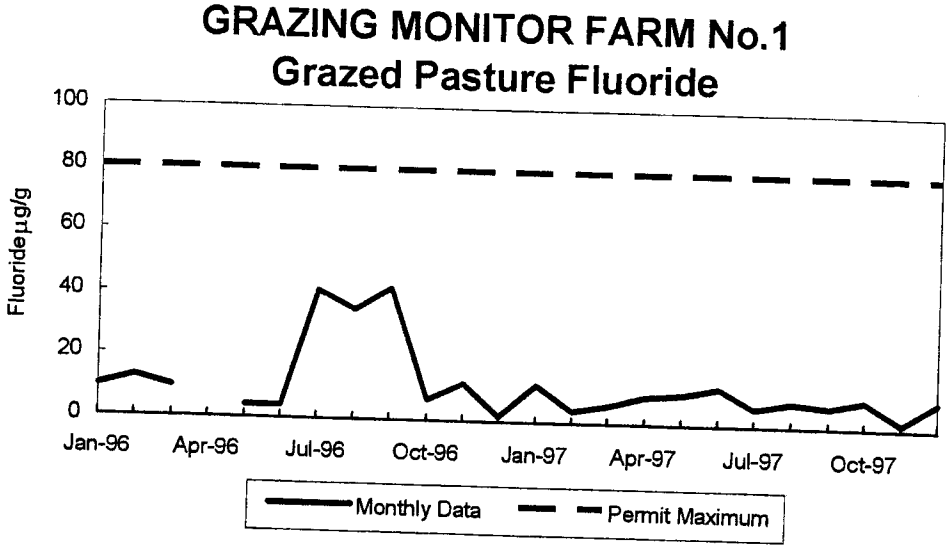
- fluoride in grazed pasture,
- cattle urinary fluoride,
- cattle bone fluoride,
- cattle dental condition, and
- comments on the monitoring.

Fluoride in grazed pasture

The following table shows the grazed pasture monitoring results for 1997.

	Units	Standard	1997
Monthly sample maximum	µg/g	80	12
Two monthly average maximum	µg/g	60	11
Twelve monthly running average maximum	µg/g	40	17
Annual average	µg/g		8

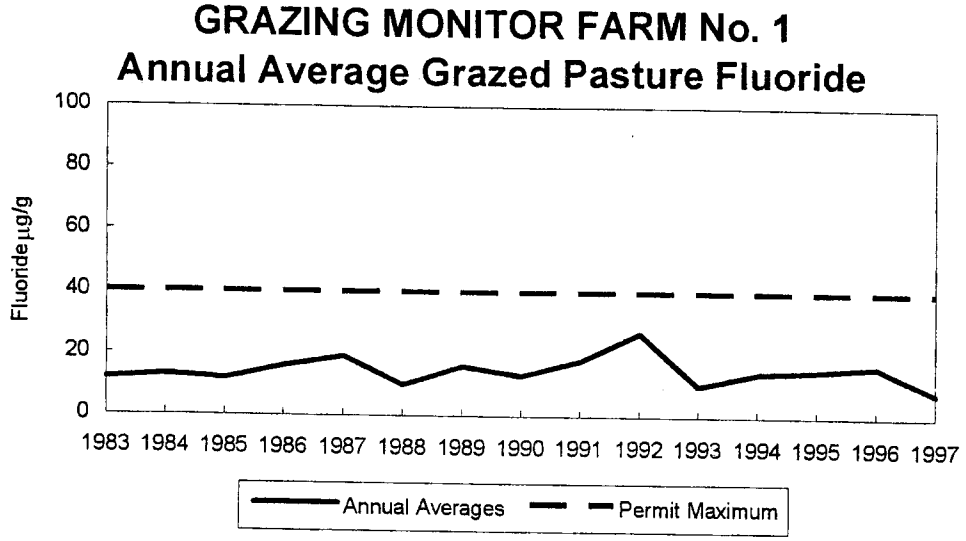
The following graph shows the results of monthly fluoride monitoring of grazed pasture during 1996 and 1997.



Grazing Monitor Farm No.1, Continued

Fluoride in grazed pasture, continued

The following graph shows the annual average fluoride concentration in grazed pasture.



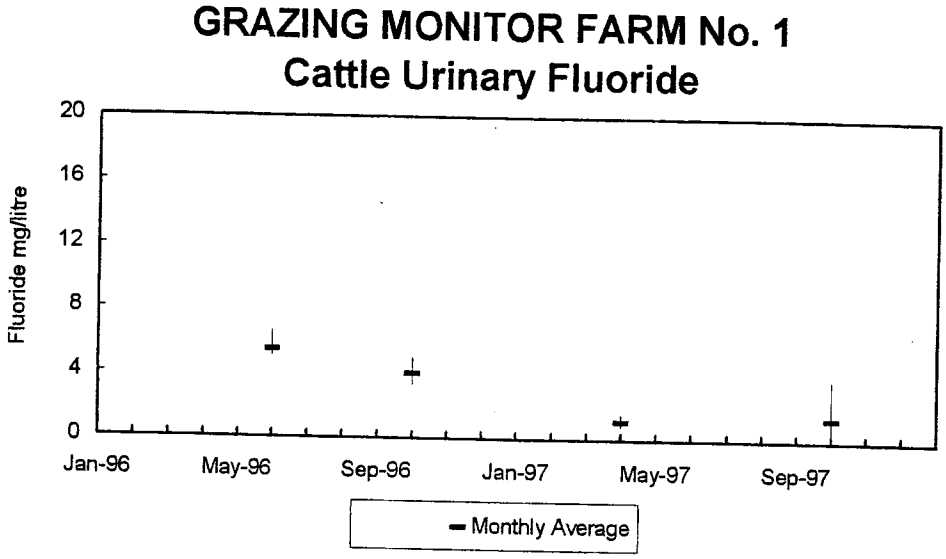
Grazing Monitor Farm No.1, Continued

Cattle urinary fluoride

The following table summarises the results of cattle urinary fluoride monitoring during 1997.

	Units	Guideline	1997
Average fluoride concentration	mg/L	-	1.3
Maximum fluoride concentration	mg/L	10	3.8
Minimum fluoride concentration	mg/L	-	<0.5
No. of samples	mg/L	-	9

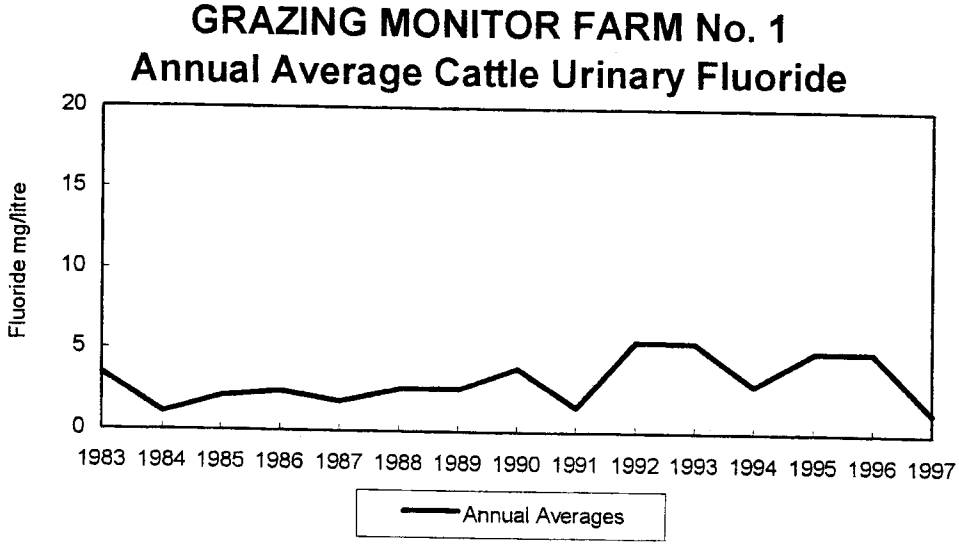
The following graph shows the results of urinary fluoride monitoring of cattle during 1996 and 1997. The horizontal bars show the average concentration of the samples and the vertical bars show the range of concentrations.



Grazing Monitor Farm No.1, Continued

Cattle urinary fluoride, continued

The following graph shows the annual average fluoride concentration in cattle urine.



Cattle bone fluoride

The following table shows the results of bone fluoride monitoring during 1997.

Identification	Age	Units	Guideline	1997
Heifer	2	mg/kg	1605	425
Bull	2	mg/kg	1605	525

Cattle dental condition

The following table summarises the results of the dental inspection of cattle.

Year of tooth formation	1996	1997
Average tooth score	2	2
Maximum tooth score	2	2
Minimum tooth score	2	2
No. of cattle inspected	2	1

Grazing Monitor Farm No.1, Continued

Comments

The monitoring results of grazed pasture fluoride, cattle urinary fluoride and cattle bone fluoride concentrations on GMF 1 were lower during 1997 than during 1996 and all were within the permit standards and guidelines. The decreases are consistent with the decreased fluoride discharge from the smelter's main stack due to the commissioning of all the dry scrubbing equipment which was completed in January 1997. In previous years there has been evidence that this site is sometimes affected by sources of fluoride other than the smelter. There was no evidence of the other sources during 1997.

The 1997 annual average grazed pasture fluoride concentration of 8 µg/g was 50% lower than the 16 µg/g measured during 1996.

The 1997 annual average urinary fluoride concentration of 1.3 mg/litre was about 70% lower than the 4.7 mg/litre measured during 1996.

The fluoride concentration of bones samples from two year old cattle was 475 mg/kg which was about 60% lower than the 1325 mg/kg measured in a sample from a two year old cow in 1996. A direct comparison between the two years' samples is not strictly valid. The 1996 sample was collected in June when the animal was about 32 months old. The 1997 samples were collected in October when the animals were about 25 months old. Animals aged between 24 and 35 months are all classed as two year olds for the purpose of comparison with the permit guidelines. As fluoride accumulates in bone the concentration generally increases with age even with a steady fluoride intake. A seven month age difference can result in a significant difference in bone fluoride concentration.

The tooth scores for the recently erupted teeth were within the normal range of results for this farm.

Grazing Monitor Farm No. 2

Introduction

The following information is contained in this section:

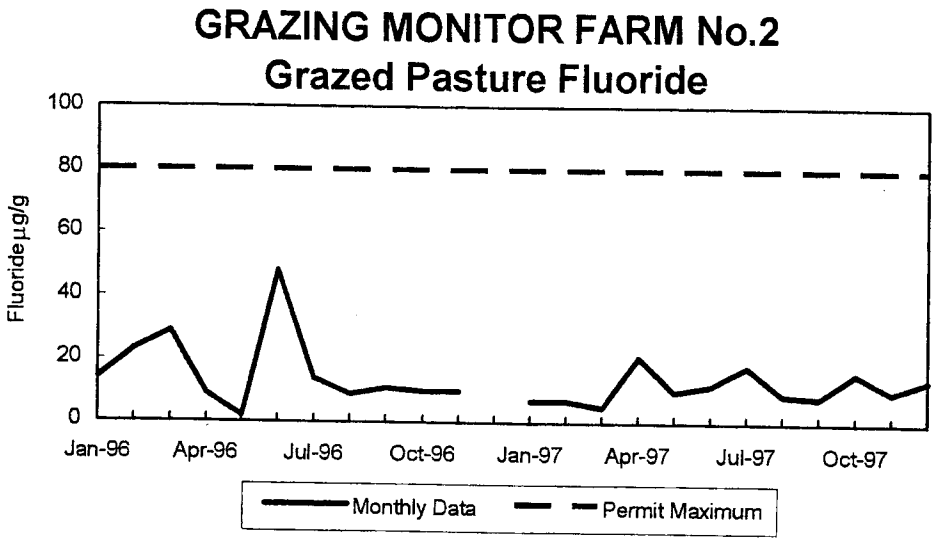
- fluoride in grazed pasture, and
- comments on the monitoring.

Fluoride in grazed pasture

The following table shows the grazed pasture monitoring results for 1997.

	Units	Standard	1997
Monthly sample maximum	µg/g	80	21
Two monthly average maximum	µg/g	60	16
Twelve monthly running average maximum	µg/g	40	16
Annual average	µg/g		11

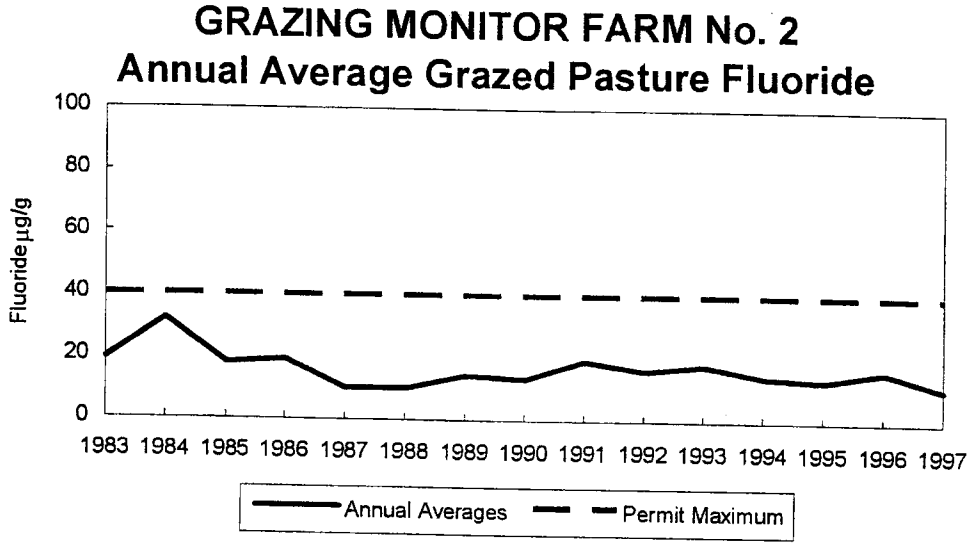
The following graph shows the results of monthly fluoride monitoring of grazed pasture during 1996 and 1997.



Grazing Monitor Farm No. 2, Continued

Fluoride in grazed pasture, continued

The following graph shows the annual average fluoride concentration in grazed pasture.



Comments

The fluoride in grazed pasture was within the permit standards. The 1997 average grazed pasture fluoride concentration of 11 µg/g was about 30% lower than the 16 µg/g measured during 1996 and was within the normal range of results at this farm during the past 10 years. The larger decrease in fluoride exposure observed at other sites was not expected on this farm. This is due to the minimal dispersion of smelter sourced discharges north towards this farm.

Grazing Monitor Farm No. 3

Introduction

The following information is contained in this section:

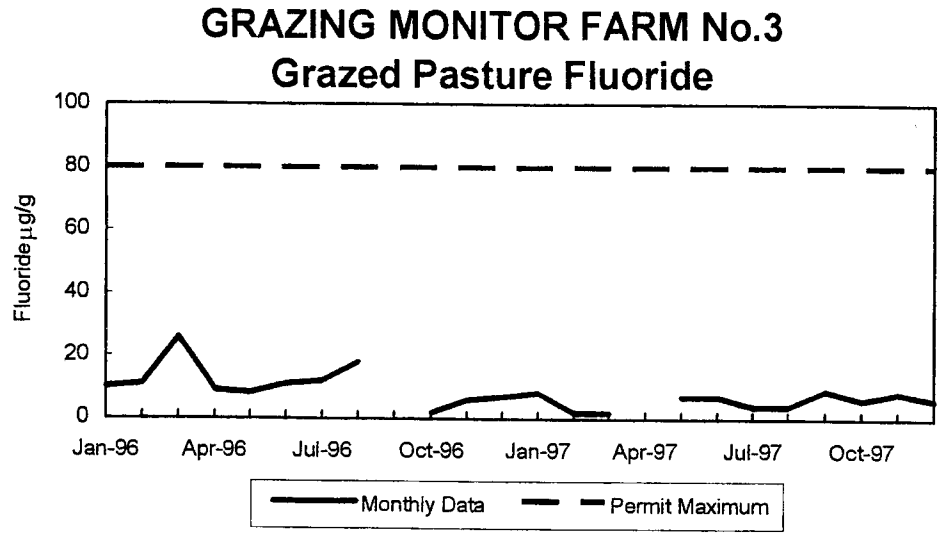
- fluoride in grazed pasture, and
- comments on the monitoring.

Fluoride in grazed pasture

The following table shows the maximum grazed pasture monitoring results for 1997.

	Units	Standard	1997
Monthly sample maximum	µg/g	80	9
Two monthly average maximum	µg/g	60	8
Twelve monthly running average maximum	µg/g	40	11
Annual average	µg/g		6

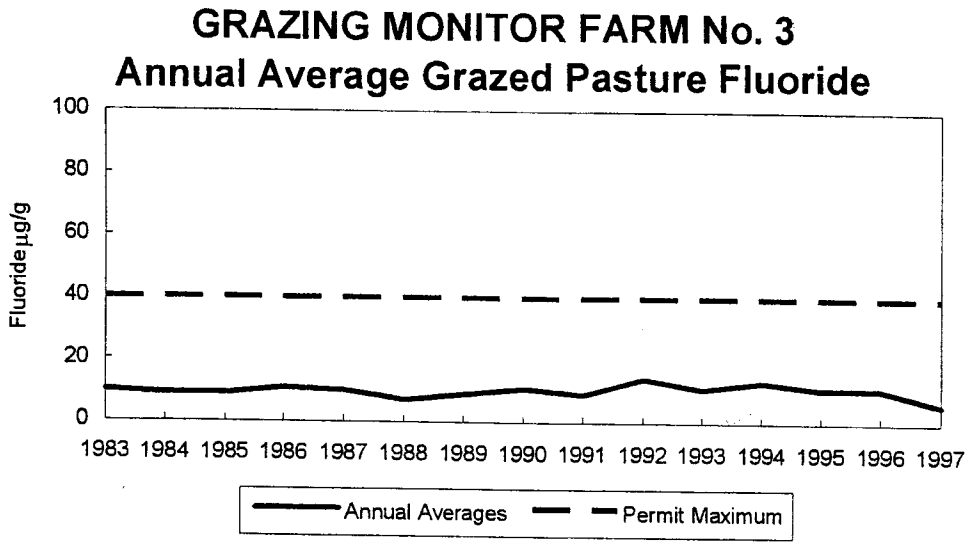
The following graph shows the results of monthly fluoride monitoring of grazed pasture during 1996 and 1997.



Grazing Monitor Farm No. 3, Continued

Fluoride in grazed pasture, continued

The following graph shows the annual average fluoride concentration in grazed pasture.



Comments

The fluoride in grazed pasture was within the permit standards. The 1997 annual average grazed pasture fluoride concentration of 6 µg/g was about 45% lower than the 11 µg/g measured during 1996. The 1997 annual average is approaching background levels.

No sample was collected from this farm during April as the site was being topdressed on the day that sampling was scheduled. Condition C2.2 of the Air Discharge Permit exempts samples collected within 28 day of topdressing from the permit standards.

Grazing Monitor Farm No. 4

Introduction

The following information is contained in this section:

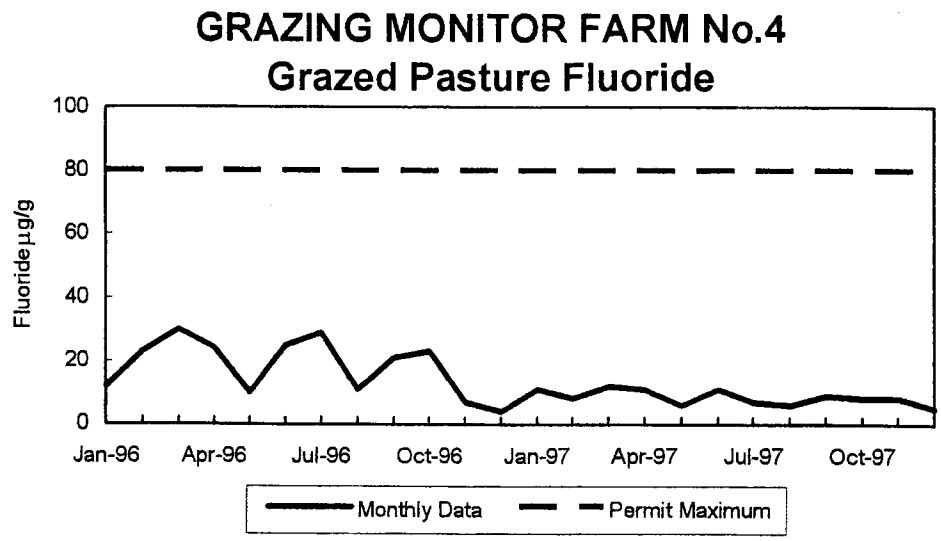
- fluoride in grazed pasture,
- cattle urinary fluoride,
- cattle bone fluoride,
- cattle dental condition, and
- comments on the monitoring.

Fluoride in grazed pasture

The following table shows the grazed pasture monitoring results for 1997.

	Units	Standard	1997
Monthly sample maximum	µg/g	80	12
Two monthly average maximum	µg/g	60	12
Twelve monthly running average maximum	µg/g	40	18
Annual average	µg/g		9

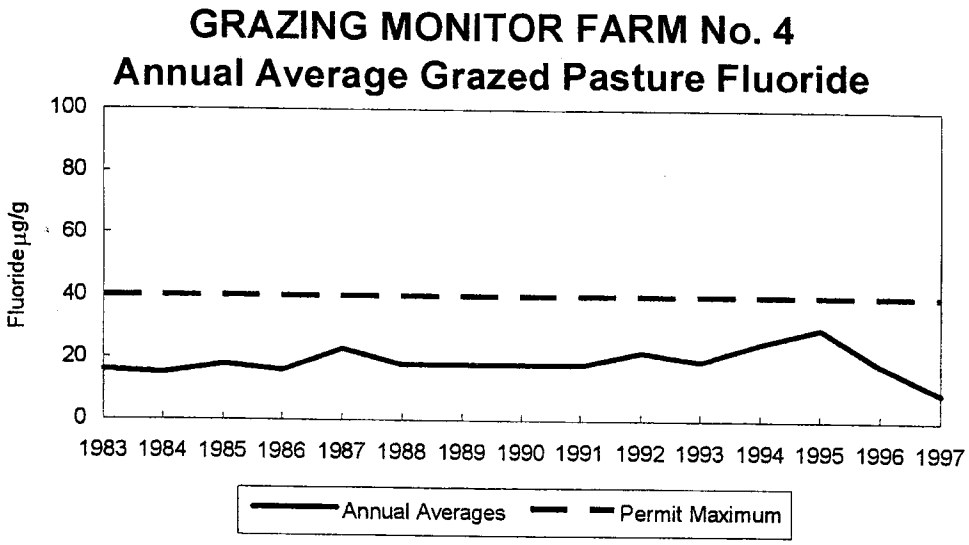
The following graph shows the results of monthly fluoride monitoring of grazed pasture during 1996 and 1997.



Grazing Monitor Farm No. 4, Continued

Fluoride in grazed pasture, continued

The following graph shows the annual average fluoride concentration in grazed pasture.



Cattle urinary fluoride

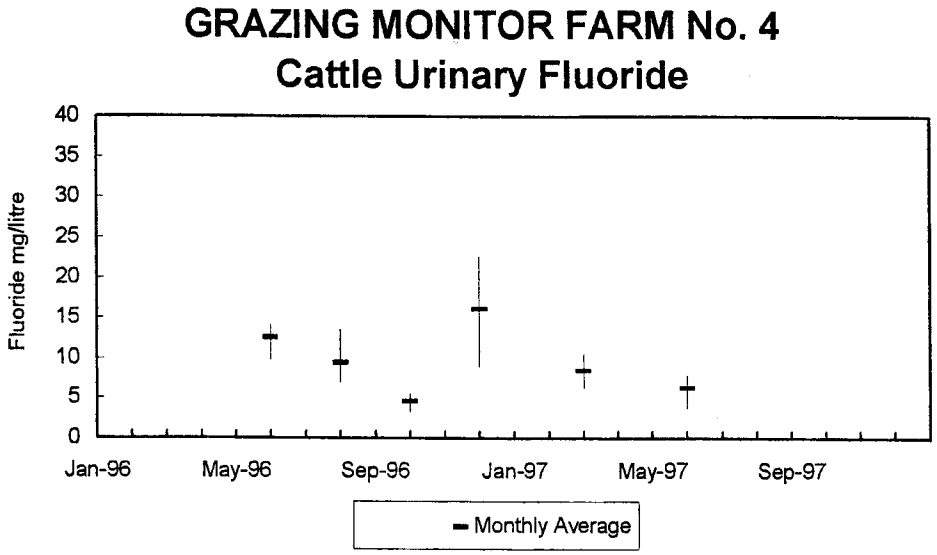
The following table summarises the results of cattle urinary fluoride monitoring during 1997.

	Units	Guideline	1997
Average fluoride concentration	mg/L	-	7.3
Maximum fluoride concentration	mg/L	10	10.6
Minimum fluoride concentration	mg/L	-	3.8
No. of samples	mg/L	-	9

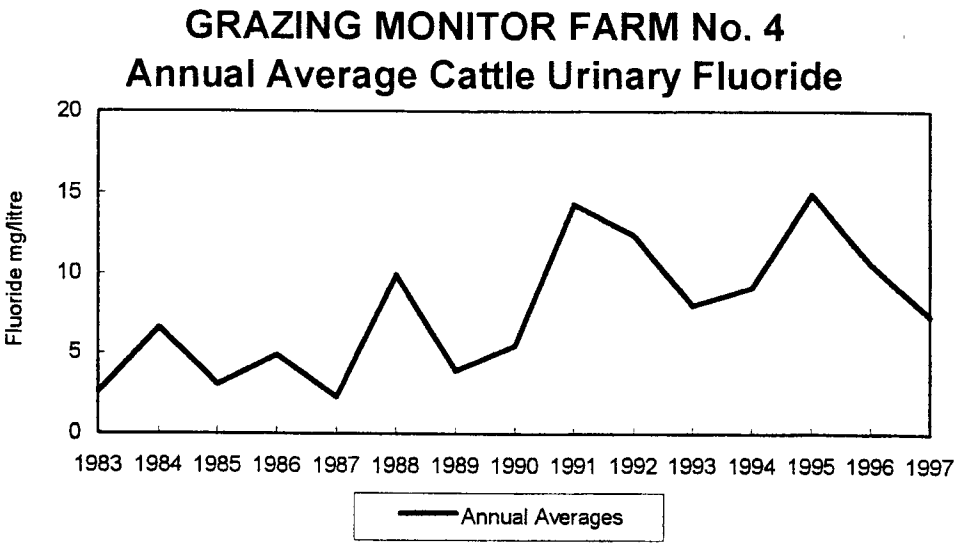
Grazing Monitor Farm No. 4, Continued

Cattle urinary fluoride, continued

The following graph shows the results of urinary fluoride monitoring of cattle during 1996 and 1997. The horizontal bars show the average concentration of the samples and the vertical bars show the range of concentrations.



The following graph shows the annual average fluoride concentration in cattle urine.



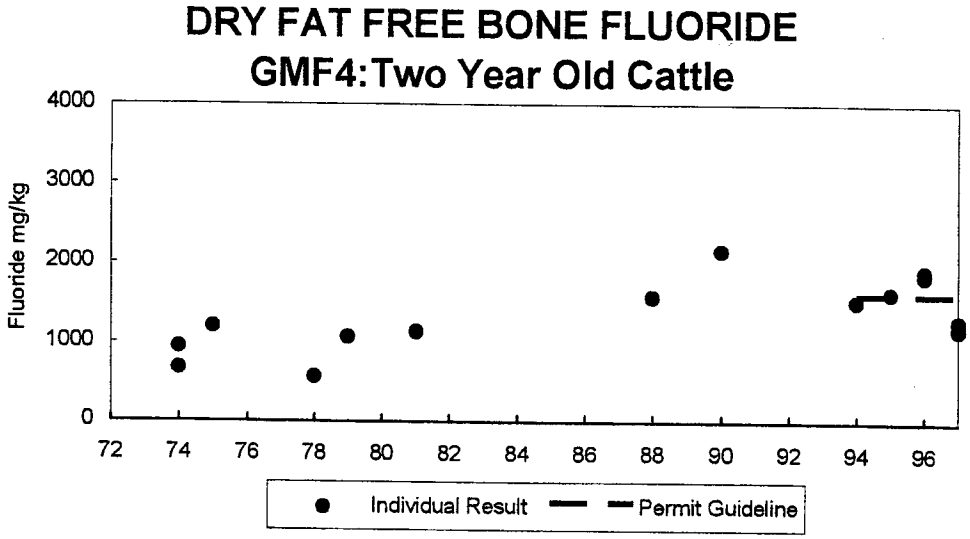
Grazing Monitor Farm No. 4, Continued

Cattle bone fluoride

The following table shows the results of bone fluoride monitoring during 1997.

Identification	Age	Units	Guideline	1997
Limosin heifer	2	mg/kg	1605	1275
Black heifer	2	mg/kg	1605	1175
DG54	3	mg/kg	-	1750
DG72	4	mg/kg	2379	1900

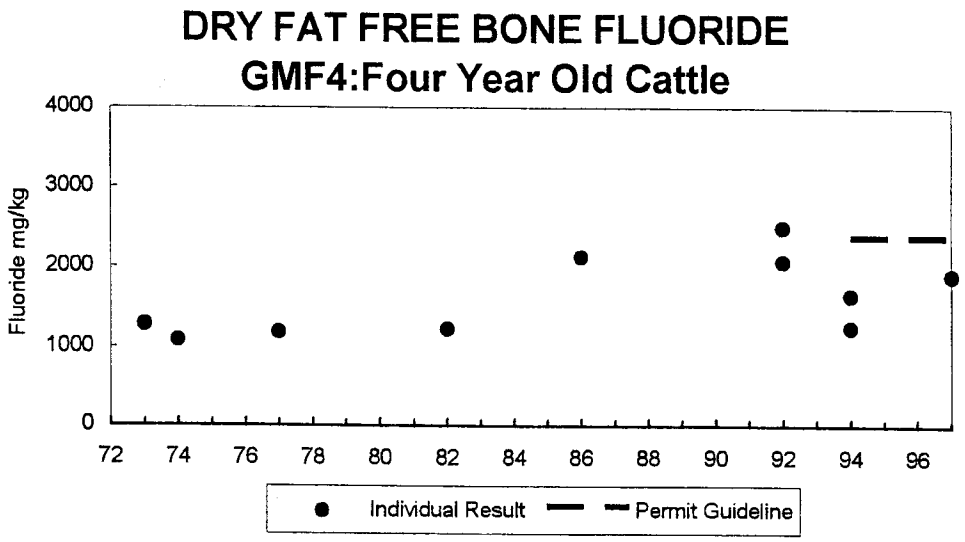
The following graph shows the bone fluoride concentration of individual biopsies collected from two year old cattle since the project began.



Grazing Monitor Farm No. 4, Continued

Cattle bone fluoride, continued

The following graph shows the bone fluoride concentration of individual biopsies collected from four year old cattle since the project began.



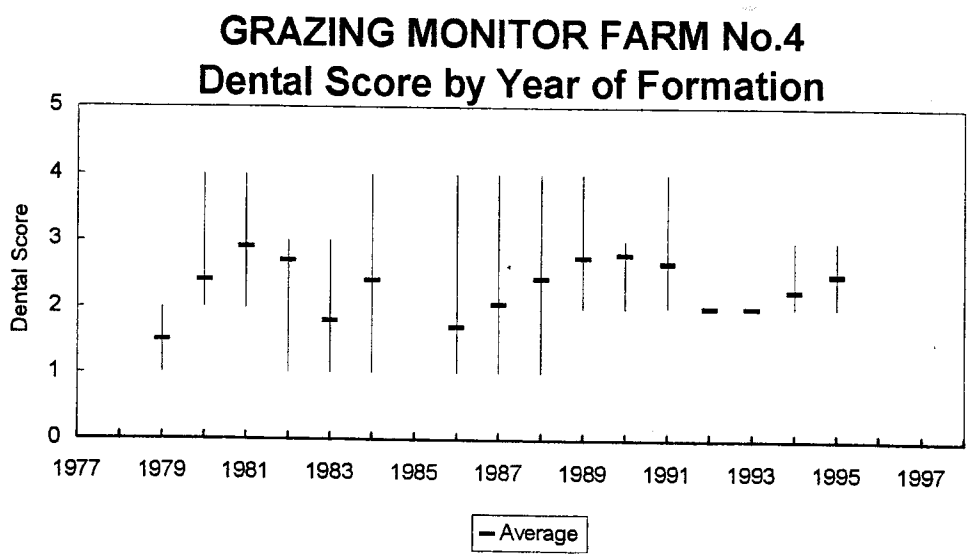
Grazing Monitor Farm No. 4, Continued

Cattle dental condition

The following table summarises combined results of the dental inspection of cattle.

Year of tooth formation	1994	1995
Average tooth score	2.25	2.5
Maximum tooth score	3	3
Minimum tooth score	2	2
No. of cattle inspected	3	4

The following graph shows the average tooth score and range of tooth scores for the teeth of cattle formed since monitoring began.



Grazing Monitor Farm No. 4, Continued

Comments

Grazed pasture fluoride, cattle urinary fluoride and two year old cattle bone fluoride concentrations were lower during 1997 than during 1996. The decreases are consistent with the decreased fluoride discharge from the smelter's main stack due to the commissioning of all the dry scrubbing equipment which was completed in January.

The fluoride in grazed pasture was within the permit standards. The 1997 annual average grazed pasture fluoride concentration of 9 μg/g was about 50% lower than the 19 μg/g measured during 1996.

The annual average urinary fluoride concentration measured during 1997 was 7.3 mg/litre which was about 30% lower than the 10.6 mg/litre measured during 1996. The maximum individual urinary fluoride concentration measured during 1997 was 10.6 mg/litre which is above the permit guideline of 10 mg/litre. This compares with a maximum of 22.6 mg/litre measured during 1996. Nine urine samples were collected during two visits to this farm during 1997 compared to 19 samples collected during 1996. The reason for the lower number of samples was the difficulty in organising additional visits with the farmer and the decision that the additional samples were not required because of the lower fluoride concentrations measured earlier in 1997. The additional visits during 1996 were discussed in the 1996 report and followed the higher cattle urinary fluoride concentrations measured during 1995.

All cattle bone fluoride concentrations measured during 1997 were within the permit guidelines. The average fluoride concentration of bones sampled from two year old cattle during 1997 was about 35% lower than for 1996. The fluoride concentration of a three year old cow's bone was similar to the 1996 result. The fluoride concentration of a four year old cow's bone was about 30% higher than the most recent four year old samples, collected during 1994, but 10% lower than samples collected during 1992. This is normal variation for this farm and little reduction in four year old cattle bones was expected.

The dental scores in cattle inspected during 1997 were higher than those inspected during 1996. This is due to the time delay between formation and eruption so that the tooth scores reflect the fluoride exposures during previous years. New teeth inspected during 1997 were formed during 1995 when fluoride concentrations measured on this farm were at their highest. Dental scores for teeth formed after 1995 are expected to decrease in response to the lower fluoride concentrations measured on this farm since the commissioning of all the dry scrubbing equipment.

Grazing Monitor Farm No. 11

Introduction

The following information is contained in this section:

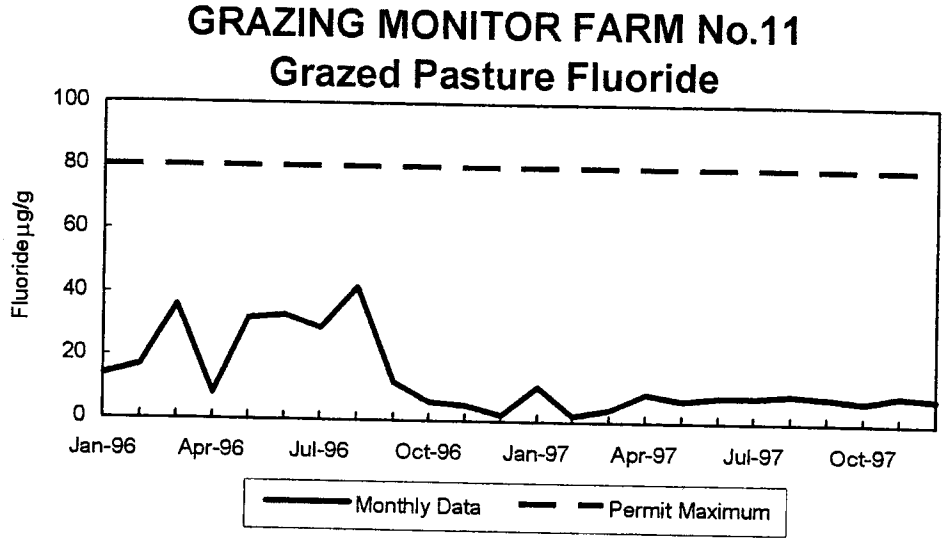
- fluoride in grazed pasture, and
- comments on the monitoring.

Fluoride in grazed pasture

The following table shows the grazed pasture monitoring results for 1997.

	Units	Standard	1997
Monthly sample maximum	µg/g	80	11
Two monthly average maximum	µg/g	60	9
Twelve monthly running average maximum	µg/g	40	19
Annual average	µg/g		8

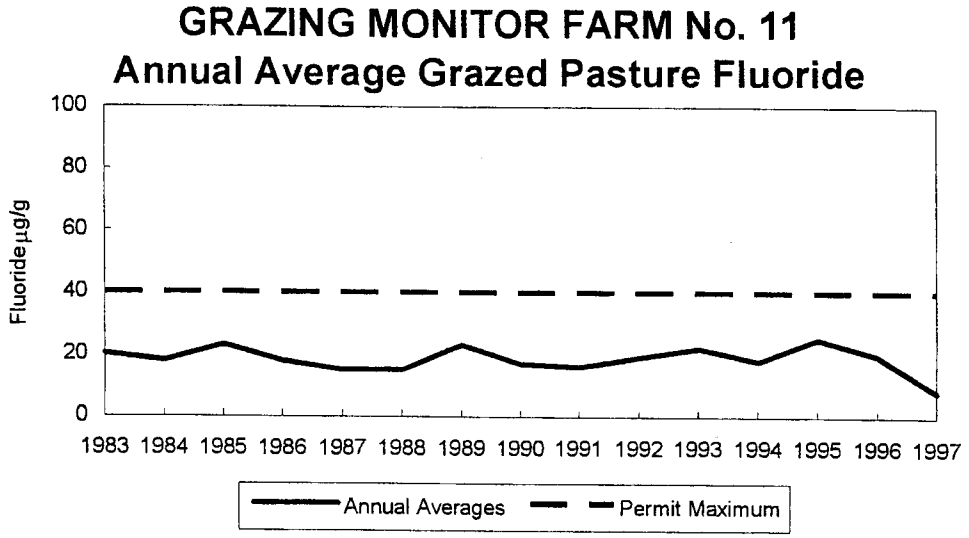
The following graph shows the results of monthly fluoride monitoring of grazed pasture during 1996 and 1997.



Grazing Monitor Farm No. 11, Continued

Fluoride in grazed pasture, continued

The following graph shows the annual average fluoride concentration in grazed pasture.



Comments

The fluoride in grazed pasture was within the permit standards. The 1997 annual average grazed pasture fluoride concentration of 8 µg/g was about 60% lower than the 20 µg/g recorded during 1996. The decreases are consistent with the decreased fluoride discharge from the smelter's main stack due to the commissioning of all the dry scrubbing equipment which was completed in January.

Grazing Monitor Farm No. 12

Introduction

The following information is contained in this section:

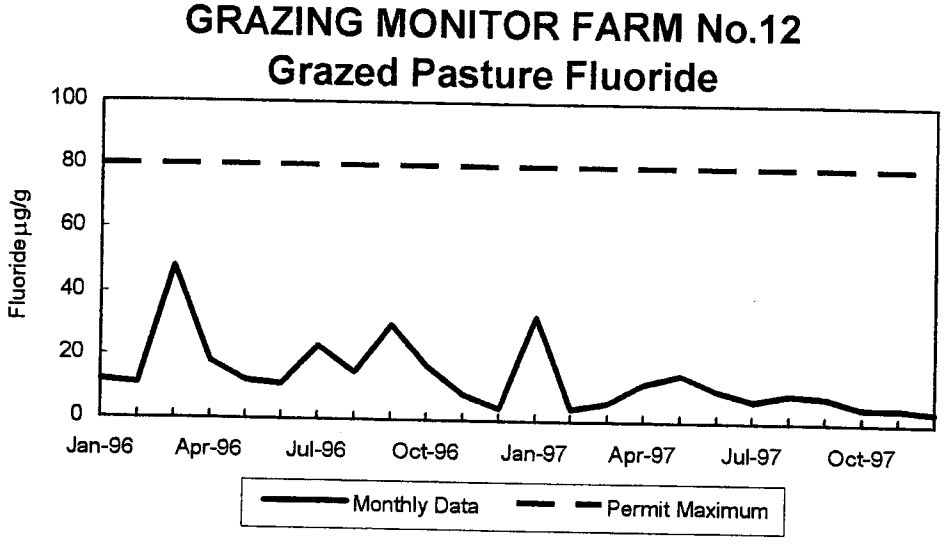
- fluoride in grazed pasture, and
- comments on the monitoring.

Fluoride in grazed pasture

The following table shows the maximum grazed pasture monitoring results for 1997.

	Units	Standard	1997
Monthly sample maximum	µg/g	80	33
Two monthly average maximum	µg/g	60	19
Twelve monthly running average maximum	µg/g	40	19
Annual average	µg/g		10

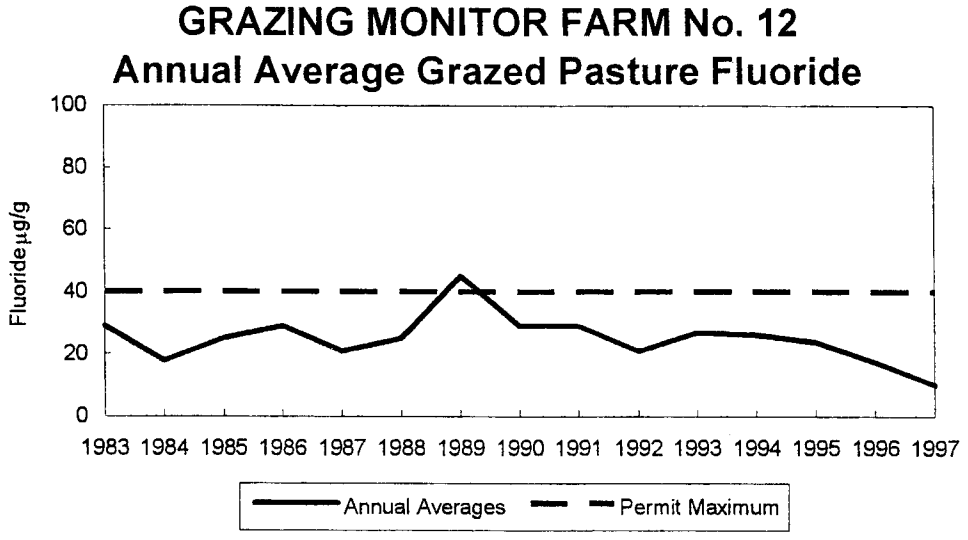
The following graph shows the results of monthly fluoride monitoring of grazed pasture during 1996 and 1997.



Grazing Monitor Farm No. 12, Continued

Fluoride in grazed pasture, continued

The following graph shows the annual average fluoride concentration in grazed pasture.



Comments

The fluoride in grazed pasture was within the permit standards. The 1997 annual average grazed pasture fluoride concentration of 10 µg/g was about 40% lower than the 17 µg/g measured during 1996. The decreases are consistent with the decreased fluoride discharge from the smelter's main stack due to the commissioning of all the dry scrubbing equipment which was completed in January.

Grazing Monitor Farm No. 14

Introduction

The following information is contained in this section:

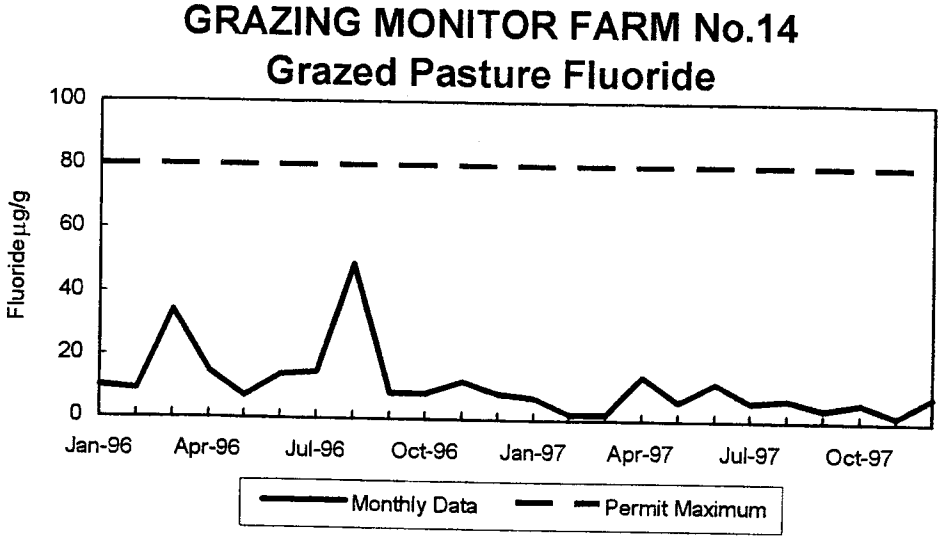
- fluoride in grazed pasture,
- cattle urinary fluoride,
- cattle bone fluoride
- cattle dental condition, and
- comments on the monitoring.

Fluoride in grazed pasture

The following table shows the grazed pasture monitoring results for 1997.

	Units	Standard	1997
Monthly sample maximum	µg/g	80	14
Two monthly average maximum	µg/g	60	10
Twelve monthly running average maximum	µg/g	40	16
Annual average	µg/g		6

The following graph shows the results of monthly fluoride monitoring of grazed pasture during 1996 and 1997.



GMF 14 was included in the monitoring program in May 1994. An annual pasture graph has not been produced due to the small amount of data available.

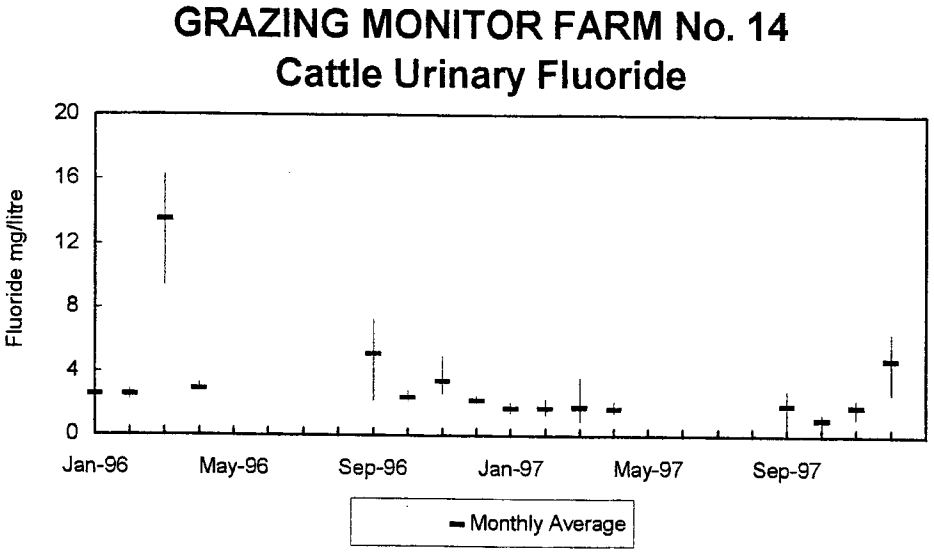
Grazing Monitor Farm No. 14, Continued

Cattle urinary fluoride

The following table summarises the results of cattle urinary fluoride monitoring during 1997.

	Units	Guideline	1997
Average fluoride concentration	mg/L	-	2.0
Maximum fluoride concentration	mg/L	10	6.5
Minimum fluoride concentration	mg/L	-	<0.5
No. of samples	mg/L	-	45

The following graph shows the results of urinary fluoride monitoring of cattle during 1996 and 1997. The horizontal bars show the average concentration of the samples and the vertical bars show the range of concentrations.



GMF 14 was included in the monitoring program in May 1994. An annual cattle urinary fluoride graph has not been produced due to the small amount of data available.

Grazing Monitor Farm No. 14, Continued

Cattle bone fluoride

The following table shows the results of bone fluoride monitoring during 1997.

Identification	Age	Units	Guideline	Fluoride
629	2	mg/kg	1605	925
1405	2	mg/kg	1605	925
1501	2	mg/kg	1605	1025
1222	3	mg/kg	-	1675
1261	3	mg/kg	-	1375

Cattle dental condition.

The following table summarises the results of the cattle dental inspections.

Year of tooth formation	1994	1995	1996
Average tooth score	2.1	2.2	2
Maximum tooth score	3	3	2
Minimum tooth score	1	2	2
No of cattle inspected	11	7	2

Grazing Monitor Farm No. 14, Continued

Comments

Grazed pasture and cattle urinary fluoride concentrations were lower during 1997 than during 1996. The decreases are consistent with the decreased fluoride discharge from the smelter's main stack due to the commissioning of the dry scrubbing equipment which was completed in January.

The fluoride in grazed pasture was within the permit standards. The 1997 annual average grazed pasture fluoride concentration of 6 μg/g was about 60% lower than the 16 μg/g measured during 1996.

The cattle urinary fluoride concentrations measured during 1997 were within the permit guideline. The annual average cattle urinary fluoride concentration measured during 1997 was 2.0 mg/l which was about 50% lower than the 4.3 mg/l measured during 1996. The higher urinary fluoride concentrations measured during December may be the result of an anti-bloat supplement used on this farm. Urine samples were not collected between April and September because cattle were not milked during this time.

All cattle bone fluoride concentrations measured during 1997 were within the permit guidelines. The bone fluoride concentrations in samples collected from two year old cattle during 1997 averaged 960 mg/kg which was similar to the average of 990 mg/kg measured during 1996.

Tooth scores measured in cattle during 1997 indicate a slight decrease in the average score for teeth formed during 1996 compared to teeth formed during 1995. The sample size was small but the decrease is supported by other measurements of the exposure to fluoride by cattle on this farm towards the end of 1996.

Grazing Monitor Farm No. 15

Introduction

The following information is contained in this section:

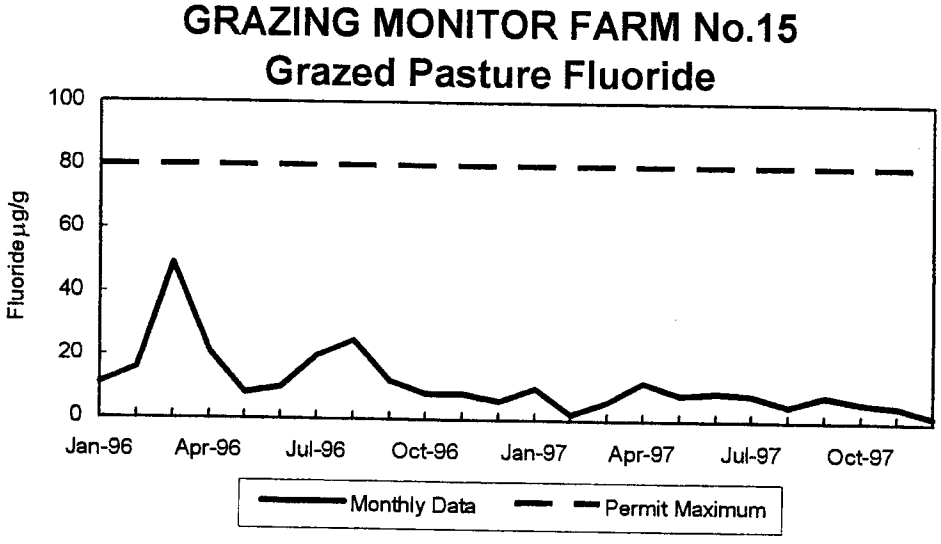
- fluoride in grazed pasture, and
- comments on the monitoring.

Fluoride in grazed pasture

The following table shows the grazed pasture monitoring results for 1997.

	Units	Standard	1997
Monthly sample maximum	µg/g	80	12
Two monthly average maximum	µg/g	60	10
Twelve monthly running average maximum	µg/g	40	16
Annual average	µg/g		7

The following graph shows the results of monthly fluoride monitoring of grazed pasture during 1996 and 1997.



GMF 15 was included in the monitoring program in January 1994. An annual pasture graph has not been produced due to the small amount of data available.

Grazing Monitor Farm No. 15, Continued

Comments

The fluoride concentrations in grazed pasture were within the permit standards. The 1997 annual average grazed pasture fluoride concentration of 7 μg/g was about 55% lower than the 16 μg/g measured during 1996. The decrease is consistent with the decreased fluoride discharge from the smelter's main stack due to the commissioning of all the dry scrubbing equipment which was completed in January.

Grazing Monitor Farm No. 16

Introduction

The following information is contained in this section:

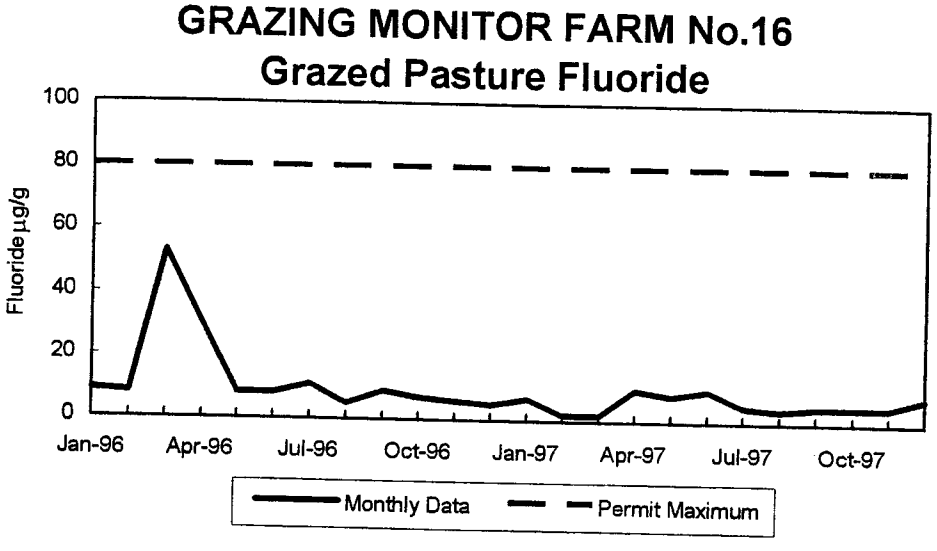
- fluoride in grazed pasture,
- cattle urinary fluoride,
- cattle bone fluoride,
- cattle dental condition, and
- comments on the monitoring.

Fluoride in grazed pasture

The following table shows the grazed pasture monitoring results for 1997.

	Units	Standard	1997
Monthly sample maximum	µg/g	80	10
Two monthly average maximum	µg/g	60	9
Twelve monthly running average maximum	µg/g	40	13
Annual average	µg/g		6

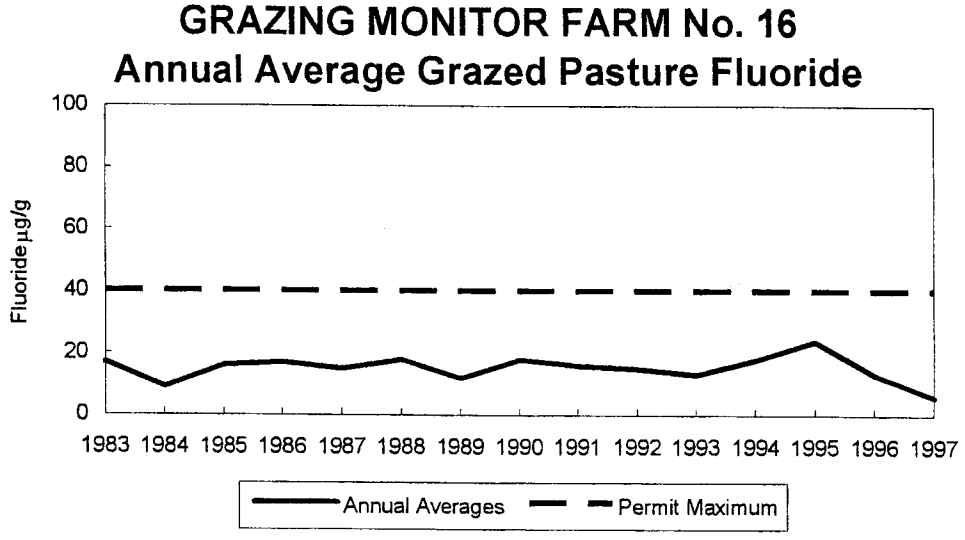
The following graph shows the results of monthly fluoride monitoring of grazed pasture during 1996 and 1997.



Grazing Monitor Farm No. 16, Continued

Fluoride in grazed pasture, continued

The following graph shows the annual average fluoride concentration in grazed pasture. Although GMF 16 was only included in the monitoring program in August 1994 an annual pasture graph has been produced including pre 1994 data from the neighbouring GMF 10 site. GMF10 was removed from the program in February 1997 as it is in the same ownership as GMF16 and pasture samples from the two farms during the years 1994 to 1997 indicated similar results.



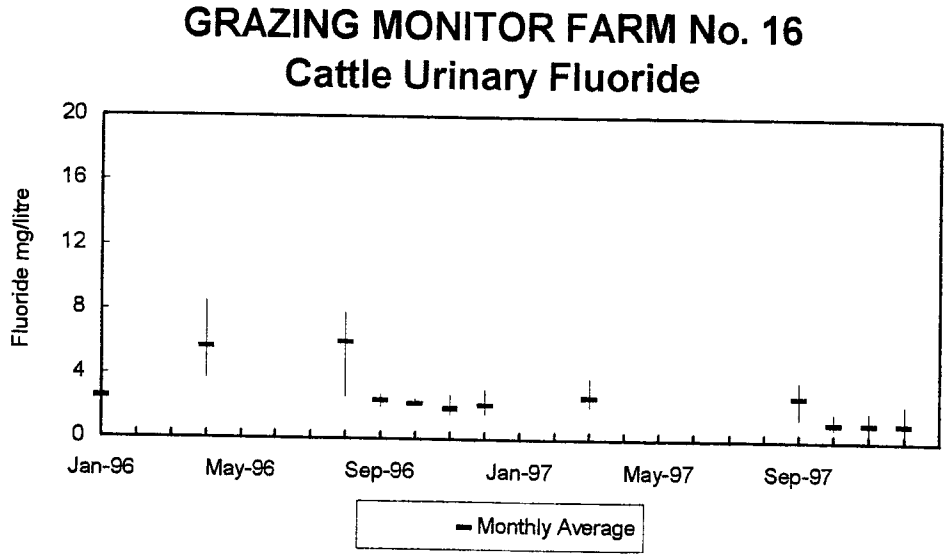
Grazing Monitor Farm No. 16, Continued

Cattle urinary fluoride

The following table summarises the results of cattle urinary fluoride monitoring during 1997.

	Units	Guideline	1997
Average fluoride concentration	mg/L	-	1.7
Maximum fluoride concentration	mg/L	10	3.8
Minimum fluoride concentration	mg/L	-	0.5
No. of samples	mg/L	-	24

The following graph shows the results of urinary fluoride monitoring of cattle during 1996 and 1997. The horizontal bars show the average concentration of the samples and the vertical bars show the range of concentrations.



GMF 16 was included in the monitoring program in August 1994. An annual cattle urinary fluoride graph has not been produced due to the small amount of data available. Annual average urinary fluoride results from GMF10 could not be used in the same manner as the grazed pasture results because urine samples were not collected from GMF10 after 1982.

Grazing Monitor Farm No. 16, Continued

Cattle bone fluoride

The following table shows the results of bone fluoride monitoring during 1997.

Identification	Age	Units	Permit Guideline	Fluoride
16	2	mg/kg	1605	925
27	2	mg/kg	1605	800
399	2	mg/kg	1605	950
62	3	mg/kg	-	1050
449	4	mg/kg	2379	1275

Cattle dental condition

The following table summarises the results of the dental inspection of cattle.

Year of tooth formation	1994	1995	1996
Average tooth score	2	2	2
Maximum tooth score	2	2	2
Minimum tooth score	2	2	2
No of cattle inspected	2	4	1

Grazing Monitor Farm No. 16, Continued

Comments

Grazed pasture and cattle urinary fluoride concentrations were lower during 1997 than during 1996. The decreases are consistent with the decreased fluoride discharge from the smelter's main stack due to the commissioning of the dry scrubbing equipment which was completed in January.

The fluoride in grazed pasture was within the permit standards. The 1997 annual average grazed pasture fluoride concentration of 6 μg/g which was about 55% lower than the 13 μg/g recorded during 1996.

The cattle urinary fluoride concentrations measured during 1997 were within the permit guidelines. The average urinary fluoride concentration of 1.7 mg/L was about 45% lower than the 3.2 mg/L recorded in 1996. Routine urine samples were not collected between January and August as cattle were not milked during this time. Additional urine samples were collected in April during the visit for teeth inspection and tail bone sampling.

All cattle bone fluoride concentrations measured during 1997 were within the permit guidelines. The average fluoride concentration of bones sampled from two year old cattle during 1997 was 890 mg/kg which was about 10% lower than for 1996. The fluoride concentration of bone sampled from a four year old cow was 1275 mg/kg compared with 950 mg/kg for the previous four year old sample collected in 1995. The fluoride concentration of bone sampled from a three year old cow was similar to that measured in 1995.

Tooth scores measured in cattle during 1997 indicated no change in the scores for teeth formed during the years 1994 to 1996.

Chapter 9

Tiwai Experimental Farms

Summary

Sheep jawbone and grazed pasture fluoride concentrations indicated decreased exposure to fluoride on both Tiwai Experimental Farm No.1 (TEF1) and Tiwai Experimental Farm No.2 (TEF2) during 1997. The decreases are consistent with the decreased fluoride discharge from the smelter's main stack due to the commissioning of all the dry scrubbing equipment which was completed in January 1997.

Teeth formed on TEF1 during 1997 had an average tooth score of 2.4 compared with 2.8 for teeth formed during 1996. Teeth formed on TEF2 during 1997 had an average tooth score of 2.0 which is similar to the tooth score for teeth formed during 1995 and 1996.

Introduction

The Tiwai Experimental Farm (TEF) Project was established to support the Grazing Monitor Farms Project. The aims of the TEF project were:

- to assess the condition of the smelter's discharges to air on sheep, and
- provide local veterinarians with experience in diagnosing fluorosis.

TEF1 is located on the Tiwai Peninsula, 3.5 kilometres east of the smelter. TEF1 was established in 1971.

TEF2 is at the east end of the Tiwai Peninsula, about ten kilometres east of the smelter. TEF2 was established in 1973.

The locations of the two Tiwai Experimental Farms are shown on the map in Chapter 8, Grazing Monitor Project, Introduction.

Tiwai Experimental Farm No.1

Introduction

The following information is contained in this section:

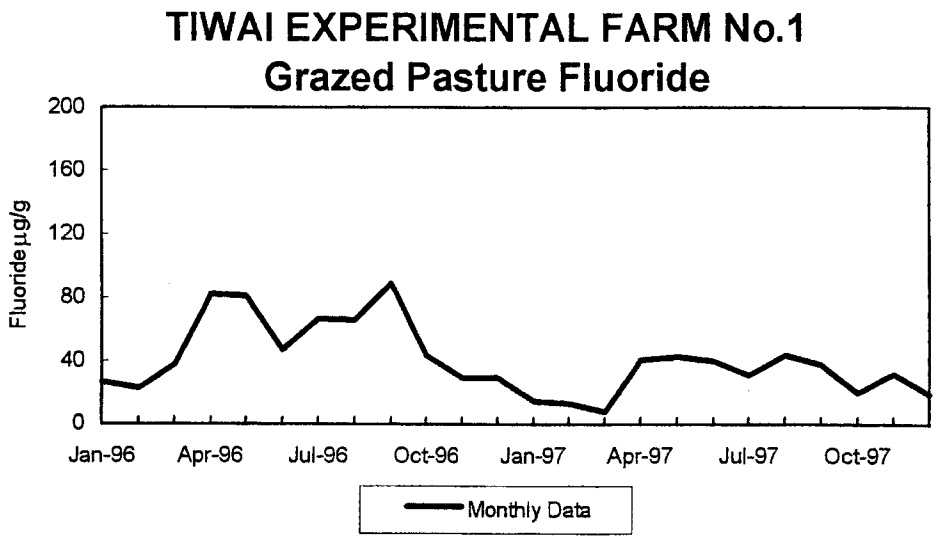
- fluoride in grazed pasture,
- sheep bone fluoride
- dental condition,
- animal weights,
- lambing percentage,
- animal health monitoring, and
- comments on the monitoring.

Fluoride in grazed pasture

The following table shows the grazed pasture monitoring results for 1997.

	Units	1997
Monthly sample maximum	µg/g	44
Two monthly average maximum	µg/g	42
Twelve monthly running average maximum	µg/g	56
Annual average	µg/g	29

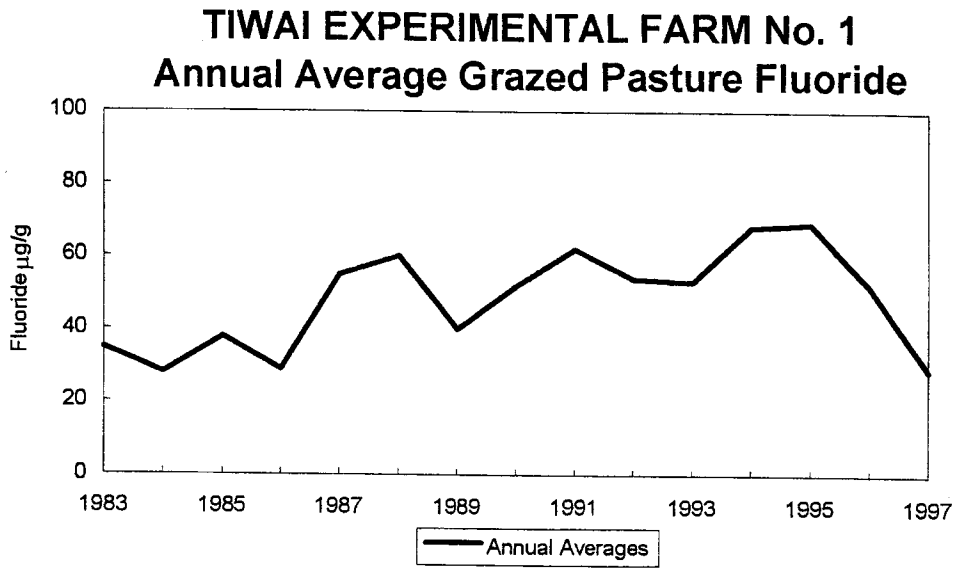
The following graph shows the results of monthly fluoride monitoring of grazed pasture during 1996 and 1997.



Tiwai Experimental Farm No.1, Continued

Fluoride in grazed pasture, continued

The following graph shows the annual average fluoride concentration in grazed pasture.



Tiwai Experimental Farm No.1, Continued

Sheep Bone Fluoride

Jawbone samples were collected from sheep in January, September, October and December during 1997. The results are presented in two tables:

- those samples collected in January 1997 and
- those samples collected in September, October and December.

Until 1993 sheep born on TEF1 were grazed on TEF2 from about four to 16 months of age and then returned to TEF1. Since 1994 sheep have remained on TEF1 since birth.

The following table shows the jawbone fluoride concentration as ashed bone for samples collected during January 1997.

Age	No. of samples	Average Fluoride mg/kg	Maximum Fluoride mg/kg	Minimum Fluoride mg/kg
2	4	5875	7000	5200
4	5	7560	8400	6850
5	2	8375	8650	8100
≥6	3	7850	8900	7050

The following table shows the jawbone fluoride concentration as ashed bone for samples collected during September, October and December 1997.

Age	No. of samples	Average Fluoride mg/kg	Maximum Fluoride mg/kg	Minimum Fluoride mg/kg
1	4	1850	1950	1800
2	4	2850	3250	2000
3	2	5325	7300	3350
≥6	6	8100	9250	7350

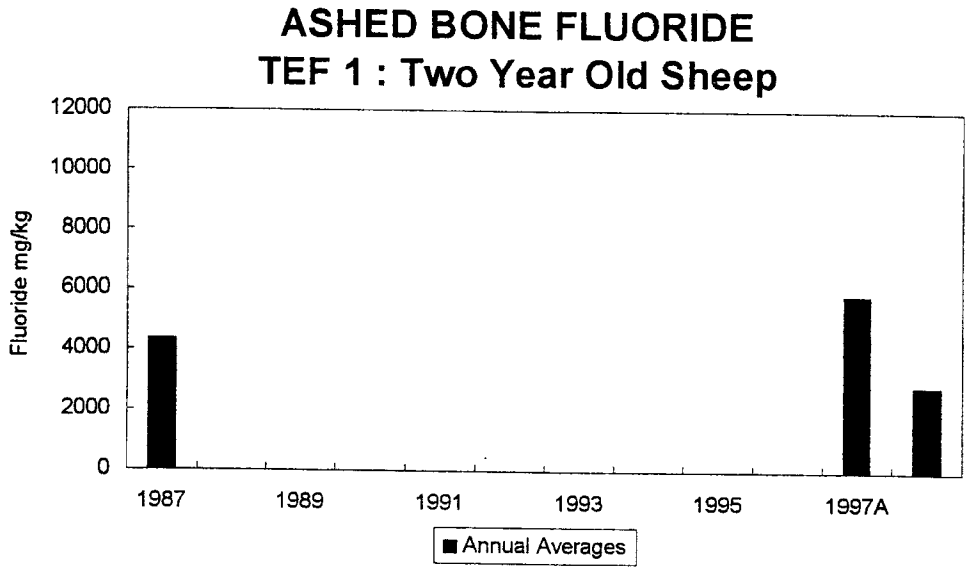
The two data sets are grouped separately in graphs on the following pages.

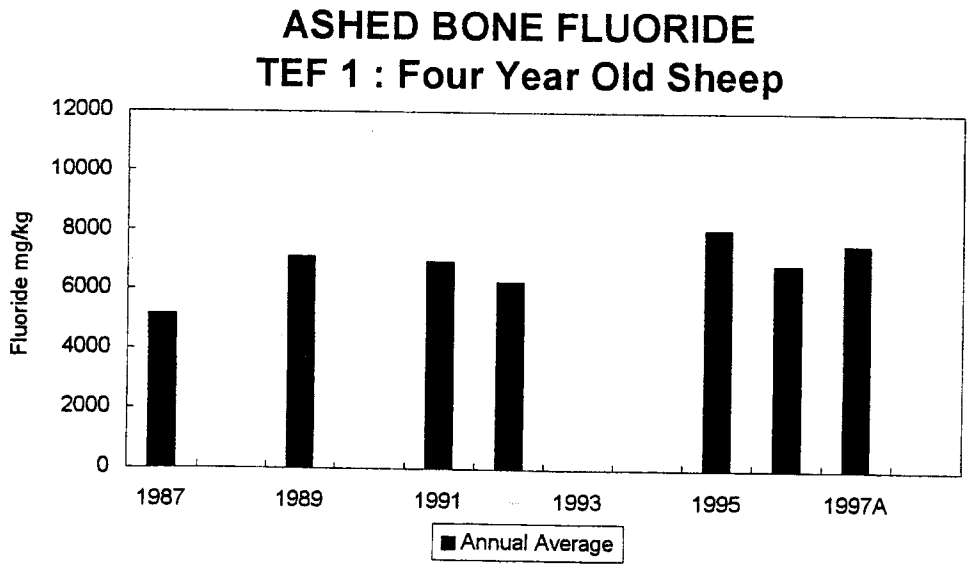
Tiwai Experimental Farm No.1, Continued

Sheep Bone Fluoride continued

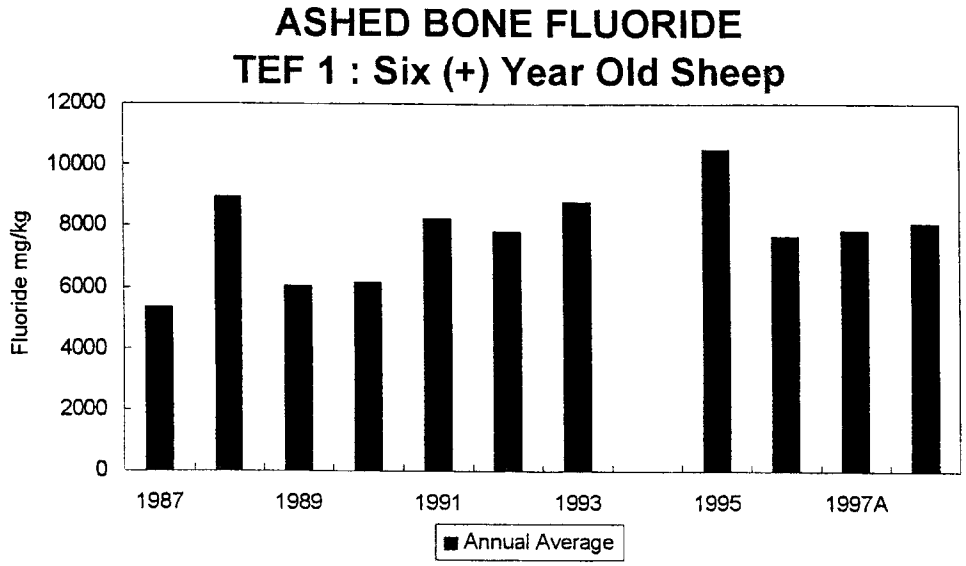
The following three graphs show the annual average jawbone fluoride concentration of two, four, and six plus year old sheep grazing on TEF1 since 1987.

The jawbones sampled in January 1997 are identified as bar 1997A shown in the three graphs. Those sampled from September to December 1997 are shown as the bar to the right of bar 1997A.





Sheep Bone Fluoride, continued



Sheep dental condition

The tooth scoring system follows the method of J Suttie. As most effects on teeth occur prior to eruption when the teeth are forming, the tooth scores are given in relation to the year during which the tooth was formed. The inspection results from past years have been combined to provide a table summarising the dental condition of permanent incisors formed during each year.

The following table summarises the results of the dental inspection of sheep on TEF1.

Year of tooth formation	1994	1995	1996	1997
Average tooth score	2.8	3.1	2.8	2.4
Maximum tooth score	3	4	4	4
Minimum tooth score	2	2	2	2
No. of pairs of teeth inspected	8	38	48	39

Tiwai Experimental Farm No.1, Continued

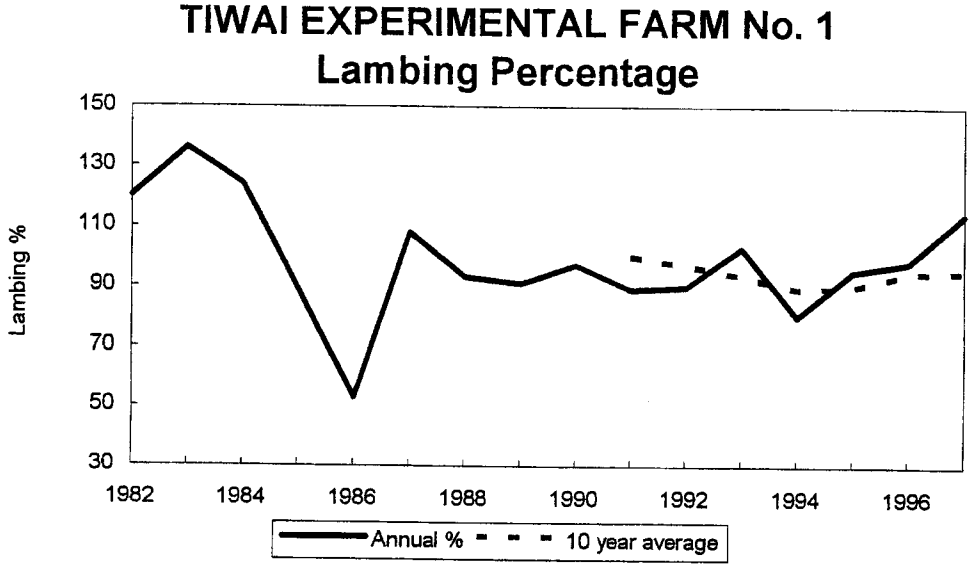
Animal weights

The following table shows the maximum, minimum, and average weights of sheep grazing on TEF1 measured during April 1997.

Age of sheep	Number of sheep	Average weight kg	Maximum weight kg	Minimum weight kg
Lambs	29	24.8	30.0	13.8
1 year old	30	42.3	51.5	33.0
2 year old	17	42.8	51.0	35.8
3 year old	-	-	-	-
4 year old	12	47.6	59.5	39.8
5 year old	3	46.3	52.0	41.6
6 year old	3	46.7	48.8	46.3

Lambing percentage

The following graph shows the lambing percentage recorded at TEF1 since 1982.



Tiwai Experimental Farm No.1, Continued

Animal health monitoring

Pre lamb blood samples collected from ewes on TEF1 during August showed the ewes were in good health. Liver samples collected from lambs grazed on TEF1 showed there were no issues indicative of health problems.

Comments

Sheep dental scores, two year old sheep jawbone fluoride concentrations, and grazed pasture fluoride concentrations indicated decreased exposure to fluoride on TEF1 during 1997. The decreases are consistent with the decreased fluoride discharge from the smelter's main stack due to the commissioning of all the dry scrubbing equipment which was completed in January 1997.

The 1997 annual average grazed pasture fluoride concentration of 29 µg/g was about 45 % lower than the 52 µg/g measured during 1996.

The average fluoride concentration of jawbones sampled from one year old sheep in December 1997 was 1850 mg/kg which is about 40% lower than the 3190 mg/kg measured in a single one year old jawbone in 1986. A 40% reduction between a 1986 sample and 1997 samples was not expected as grazed pasture fluoride concentrations during the period 1984 to 1986 were similar to that during 1997. Comparisons with a single result may be inaccurate because of normal variation within the population.

The average fluoride concentration of jawbones from two year old sheep sampled in December was 2850 mg/kg which was about 50% lower than the 5875 mg/kg measured in the samples collected in January. The sheep sampled in January were born in the spring of 1994 and were exposed to unscrubbed main stack discharges until progressive commissioning of the dry scrubbing system began in April 1996. The sheep sampled in December were born in the spring of 1995 and were exposed to the unscrubbed main stack discharges for only a short time before the progressive commissioning of the dry scrubbing system began in April 1996. The two year old samples collected during 1997 were the first collected from two year olds born on TEF1 since 1987.

The fluoride concentration of jawbones from older sheep are similar to those sampled during recent years. No significant decrease in fluoride concentration was expected in the older sheep as fluoride is accumulated within the bone and generally increases with age. Some fluoride may be released from the bone in response to a reduced fluoride intake but this is not apparent on TEF1.

Teeth formed on TEF1 during 1997 had an average tooth score of 2.4 which is 0.4 lower than the average of 2.8 for teeth formed during 1996. The 1997 average may change as additional teeth formed during 1997 will erupt before the next inspection in late 1998. The 1996 average score is higher than the 2.5 reported in the 1996 report because additional teeth formed during 1996 erupted between the 1996 and 1997 inspections.

Tiwai Experimental Farm No.1, Continued

Comments, continued

The lambing percentage for TEF1 during 1997 was 111% compared with 98% during 1996. This was the best lambing percentage since 1984. The reason for the improved lambing is unknown but there is no evidence that it is associated with the lower fluoride exposure experienced at this farm during 1997.

Generally the older sheep were a little lighter when weighed in April 1997 than in 1996 but the lambs and one year old sheep were of a similar weight.

Blood samples and liver analysis indicated that the health of sheep and lambs on TEF1 was normal.

Tiwai Experimental Farm No.2

Introduction

The following information is contained in this section:

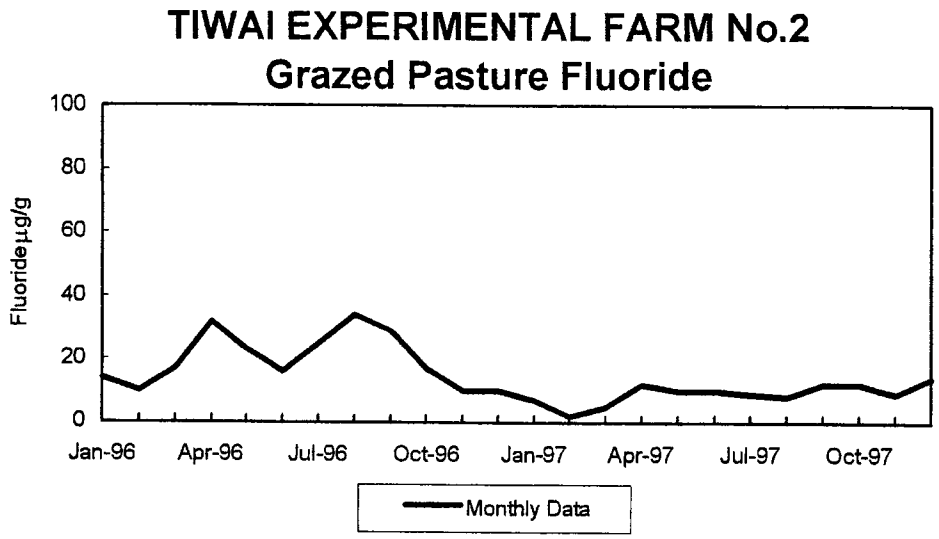
- fluoride in grazed pasture,
- sheep bone fluoride
- dental condition,
- animal weights,
- lambing percentage,
- animal health monitoring, and
- comments in the monitoring.

Fluoride in grazed pasture

The following table shows the grazed pasture monitoring results for 1997.

	Units	1997
Monthly sample maximum	µg/g	12
Two monthly average maximum	µg/g	14
Twelve monthly running average maximum	µg/g	21
Annual average	µg/g	9

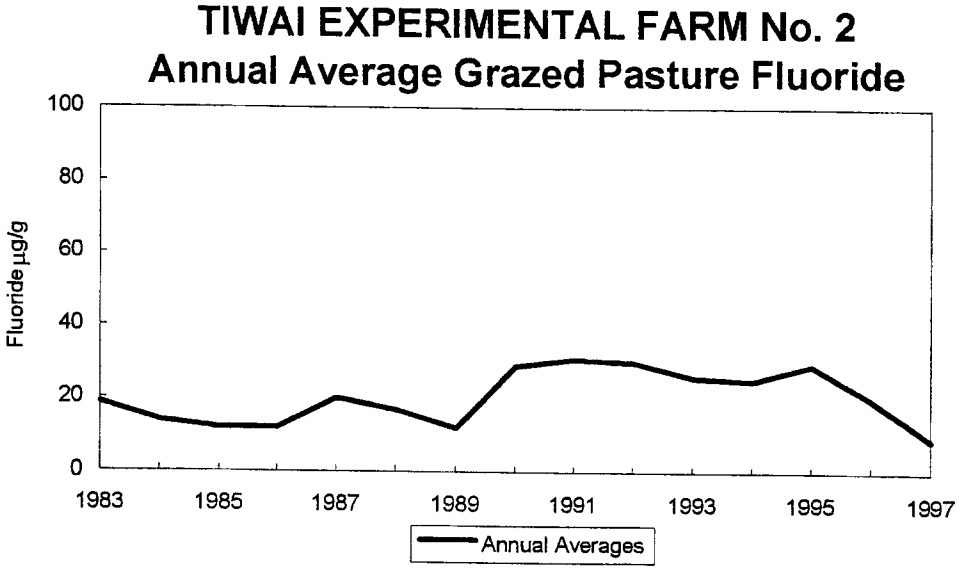
The following graph shows the results of monthly fluoride monitoring of grazed pasture during 1996 and 1997.



Tiwai Experimental Farm No.2, Continued

Fluoride in grazed pastures, continued

The following graph shows the annual average fluoride concentration in grazed pasture.



Sheep bone fluoride

The following table shows the jawbone fluoride concentration as ashed bone on TEF2 during 1997. The samples were collected in December. The four year old sheep were born on TEF1 but were transferred to TEF2 after being weaned in December 1993. All other sheep have remained on TEF2 since birth.

Age	No. of samples	Average Fluoride mg/kg	Maximum Fluoride mg/kg	Minimum Fluoride mg/kg
1	3	450	500	400
2	4	900	1150	750
4	2	1925	2000	1850

Sheep dental condition

The tooth scoring system follows the method of J Suttie. As most effects on teeth occur prior to eruption when the teeth are forming, the tooth scores are given in relation to the year during which the tooth was formed.

The following table summarises the results of the dental inspection of sheep on TEF2.

Year of tooth formation	1995	1996	1997
Average tooth score	1.9	2.1	2.0
Maximum tooth score	3	3	2
Minimum tooth score	1	1	2
No. of pairs of teeth inspected	12	26	8

Animal weights

The following table shows the maximum, minimum, and average weights of sheep grazing on TEF2 measured during April 1997. The three year old ewes were born on TEF1 but have grazed on TEF2 since being weaned in December 1993. All other sheep have remained on TEF2 since birth.

Age of sheep	Number of sheep	Average weight kg	Maximum weight kg	Minimum weight kg
ewe lambs	23	25.4	33.6	12.8
1 year old	23	38.1	44.8	32.0
3 year old	13	51.3	57.0	44.0

Lambing percentage

The lambing percentage recorded on TEF2 during 1997 was 91% compared with 111% in 1996.

Tiwai Experimental Farm No.2, Continued

Comments

Sheep jawbone and grazed pasture fluoride concentrations indicated decreased exposure to fluoride on TEF2 during 1997. The decreases are consistent with the decreased fluoride discharge from the smelter's main stack due to the commissioning of all the dry scrubbing equipment which was completed in January 1997.

The 1997 annual average grazed pasture fluoride concentration of 9 μg/g was 55 % lower than the 20 μg/g measured during 1996.

The jawbone fluoride concentration in adult sheep was measured on TEF2 for the first time since 1988. The 1997 results indicate a decreasing fluoride concentration for sheep up to four years of age but very small sample numbers and changes in management of the TEF project make accurate comparisons difficult. Before 1987 the sheep grazed on TEF2 were introduced from outside of the TEF properties usually as one year old sheep. These sheep remained on TEF2 for the remainder of there lives, normally to about seven years of age. The exposure to fluoride of the introduced sheep before they were brought to TEF2 is unknown but it would most likely be lower than the exposure to fluoride on either of the TEF farms.

The average fluoride concentration of jawbones from one year old sheep during 1997 was 450 mg/kg. The average fluoride concentration of jawbones from two year old sheep during 1997 was 900 mg/kg compared with individual samples of 1050 mg/kg in 1983 and 1150 mg/kg in 1982. The average fluoride concentration of jawbones from four year old sheep during 1997 was 1925 mg/kg compared with 3570 mg/kg for a single four year old sample in 1982. The lower 1997 fluoride concentration for four year old sheep is unexpected as these sheep would have been exposed to the higher fluoride concentrations experienced on this farm prior to the commissioning of the dry scrubbing equipment. The fluoride concentration in jawbones of older sheep on TEF1 has remained similar to recent years and this was expected on TEF2 as well (See Tiwai Experimental Farm No.1, Comments).

The average tooth score for teeth formed during 1997 was 2.0 which is similar to the tooth scores for teeth formed during 1995 and 1996.

The lambing percentage for TEF2 during 1997 was 91% compared with 111% during 1996. This was the lowest lambing percentage since lambing was started on TEF2 in 1995. There is no known reason for the decreased lambing during 1997.

The sheep and lambs were generally heavier when weighed in April 1997 compared with 1996.

Blood samples and liver analysis indicated that the health of sheep and lambs on TEF2 was normal.

Chapter 10

Discharges to Water and Their Effects

Introduction

The liquid discharges from the smelter are covered by seven Coastal and Discharge Permits issued by the Southland Regional Council. These permits commenced in October 1996.

This chapter gives details of the monitoring results for each permit.

Permit limits

The following table shows the permit limits applying to the discharges to water.

	Units	Limit
North, South, and West Drain		
• Quarterly average total suspended solids	g/m^3	30
Treated effluent		
• Maximum daily discharge	m^3/day	140
• Total suspended solids	g/m^3	100
• Free cyanide	g/m^3	20
Treated sewage		
• Maximum daily flow	m^3/day	295
• Biochemical oxygen demand	g/m^3	18
• Total suspended solids	g/m^3	8

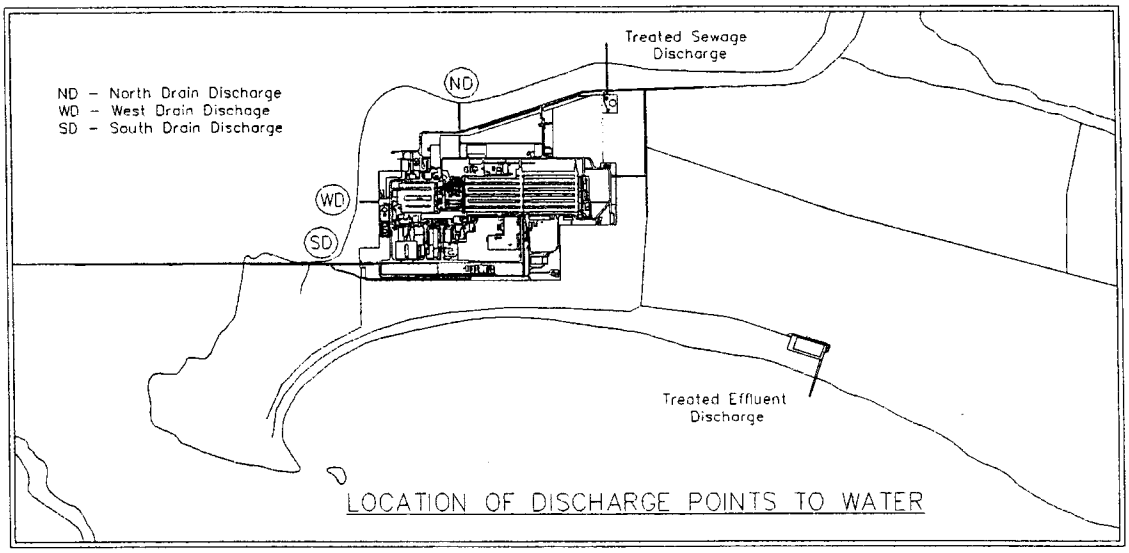
The following permit limits apply to coastal water monitoring sites:

- the natural temperature shall not be changed by more than three degrees Celsius,
- the natural pH shall not be changed by more than 0.1 unit and at no time shall be less than 6.7 or greater than 8.5,
- there shall be no destruction of natural aquatic life by reason of a concentration of toxic substances nor shall the waters emit objectionable odours,
- the natural colour and clarity of the water shall not be changed to a conspicuous extent,
- the dissolved oxygen in solution in the waters shall not be reduced below 5 mg/litre,
- based on not fewer than five samples taken over not more than a 30 day period, the median value of the faecal coliform bacteria content of the waters shall not exceed 200/100 ml,
- there shall be no production of any conspicuous oil or grease films,
- the fluoride concentration of coastal water relating to drain discharges shall not exceed 5.0 g/m^3, and
- the quarterly average fluoride concentration of coastal water relating to drain discharges shall not exceed 2.0 g/m^3.

Introduction, Continued

Site locations

The locations of the discharge to water monitoring sites are shown in the following map.



Discharge monitoring

The discharges from the North, South and West Drains are sampled once each week. The temperature of each discharge is measured once each year as part of the annual seawater quality monitoring survey.

The discharge of treated sewage is sampled over a 24 hour period once each month.

The discharge of treated effluent is sampled once each discharge.

Coastal water monitoring

Coastal water quality is determined by comparing the results of monitoring at coastal water monitoring sites with the results at control sites where:

- coastal water monitoring sites are chosen to monitor the effects of discharges on coastal waters and
- control sites are chosen to best represent the background coastal water quality.

Some coastal water monitoring is undertaken each time a drain discharge is sampled. Additional coastal water monitoring for drain discharges is undertaken annually.

Annual coastal water monitoring is undertaken for the discharge of treated effluent and treated sewage.

North Drain Discharges

Introduction

Discharges from the North Drain are covered by Coastal Permit 94501 which commenced on 8 October 1996.

Discharge monitoring results

The following table summarises the North Drain discharge monitoring results during 1997.

Parameter	Units	Limit	1997 Result
Total suspended solids			
• Annual average	g/m^3	-	17.2
• Maximum quarterly average	g/m^3	30	26.4
• No. of times quarterly average > 30 g/m^3		0	0

Coastal water monitoring results

The following table summarises the North Drain weekly coastal water monitoring results during 1997.

Parameter	Units	Limit	1997 Result
Fluoride			
• Annual average	g/m^3	-	1.4
• Maximum quarterly average	g/m^3	2.0	1.5
• No. of times quarterly average > 2.0 g/m^3		0	0
• Maximum individual sample	g/m^3	5.0	2.5
• No. of times individual sample > 5.0 g/m^3		0	0
pH			
• Maximum difference		0.1	0.3
• No. of times > 0.1		0	1
Visible oil			
• No. of times observed		0	0

The following table summarises the North Drain annual coastal water monitoring results during 1997.

Parameter	Units	Limit	1997 Result
Difference in temperature	°C	3.0	0.1
Minimum dissolved oxygen concentration	mg/litre	5.0	8.2

North Drain Discharges, Continued

Comments

Discharges from the North Drain were within permit limits during 1997.

Although the difference between the North Drain coastal water and control seawater pH was 0.3 on one occasion during August it was not considered a breach of the permit maximum difference of 0.1. The pH of the coastal water was 8.1 which is within the normal range for Awarua Bay while the pH of the control seawater was 8.4 which is higher than normal. The cause of the high control seawater pH is unknown. The pHs measured at both sites were within 0.1 of each other and within the normal range of results for the remainder of 1997.

The maximum quarterly average suspended solids concentration of 26.4 g/m^3 was determined during Quarter Four. The suspended solids concentrations have decreased during Quarter One 1998. Additional sampling initiated during Quarter One 1998 failed to show the cause of the increased suspended solids concentration measured during Quarter Four 1997.

South Drain Discharges

Introduction

Discharges from the South Drain are covered by Coastal Permit 94503 which commenced on 8 October 1996.

Discharge monitoring results

The following table summarises the South Drain discharge monitoring results during 1997.

Parameter	Units	Limit	1997 Result
Total suspended solids			
• Annual average	g/m^3	-	4.5
• Maximum quarterly average	g/m^3	30	5.2
• No. of times quarterly average > 30 g/m^3		0	0

Coastal water monitoring results

The following table summarises the South Drain weekly coastal water monitoring results during 1997.

Parameter	Units	Limit	1997 Result
Fluoride			
• Annual average	g/m^3	-	1.4
• Maximum quarterly average	g/m^3	2.0	1.4
• No. of times quarterly average > 2.0 g/m^3		0	0
• Maximum individual sample	g/m^3	5.0	2.4
• No. of times individual sample > 5.0 g/m^3		0	0
pH			
• Maximum difference		0.1	0.1
• No. of times > 0.1		0	0
Visible oil			
• No. of times observed		0	0

The following table summarises the South Drain annual coastal water monitoring results during 1997.

Parameter	Units	Limit	1997 Result
Difference in temperature	°C	3.0	0.1
Minimum dissolved oxygen concentration	mg/litre	5.0	7.9

Comments

Discharges from the South Drain were within permit limits during 1997.

West Drain Discharges

Introduction

Discharges from the West Drain are covered by Coastal Permit 94502 which commenced on 8 October 1996.

Discharge monitoring results

The following table summarises the West Drain discharge monitoring results during 1997.

Parameter	Units	Limit	1997 Result
Total suspended solids			
• Annual average	g/m^3	-	12.7
• Maximum quarterly average	g/m^3	30	29.5
• No. of times quarterly average > 30 g/m^3		0	0

Coastal water monitoring results

The following table summarises the West Drain weekly coastal water monitoring results during 1997.

Parameter	Units	Limit	1997 Result
Fluoride			
• Annual average	g/m^3	-	1.3
• Maximum quarterly average	g/m^3	2.0	1.4
• No. of times quarterly average > 2.0 g/m^3		0	0
• Maximum individual sample	g/m^3	5.0	1.6
• No. of times individual sample > 5.0 g/m^3		0	0
pH			
• Maximum difference		0.1	0.1
• No. of times > 0.1		0	0
Visible oil			
• No. of times observed		0	0

The following table summarises the West Drain annual coastal water monitoring results during 1997.

Parameter	Units	Limit	1997 Result
Difference in temperature	°C	3.0	0.1
Minimum dissolved oxygen concentration	mg/litre	5.0	8.2

West Drain Discharges, Continued

Comments

Discharges from the West Drain were within permit limits during 1997.

The maximum quarterly average suspended solids of 29.5 g/m^3 occurred during Quarter Four. The most likely cause of the higher concentration was rain water washing fugitive dust from the drain's catchment areas. Work to reduce the amount of suspended solids in the West Drain included:

- minimising fugitive refractory dust from the work to upgrade CBF1,
- regular inspection and clean-out of drain sumps,
- removing sediment from the drain outlet, and
- improving housekeeping around the coke delivery system.

West Drain suspended solids concentrations decreased during December 1997 and were well within the permit limit for Quarter One 1998.

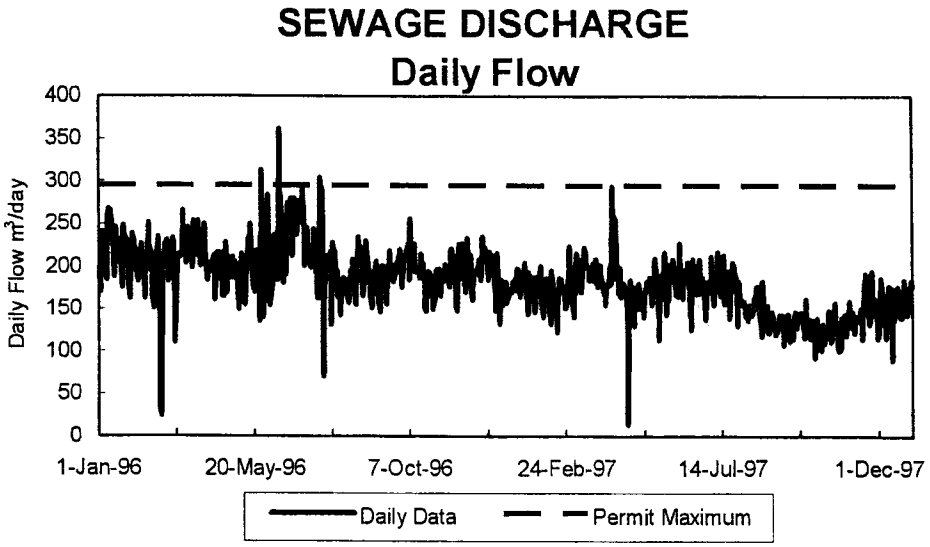
Treated Sewage Discharges

Introduction

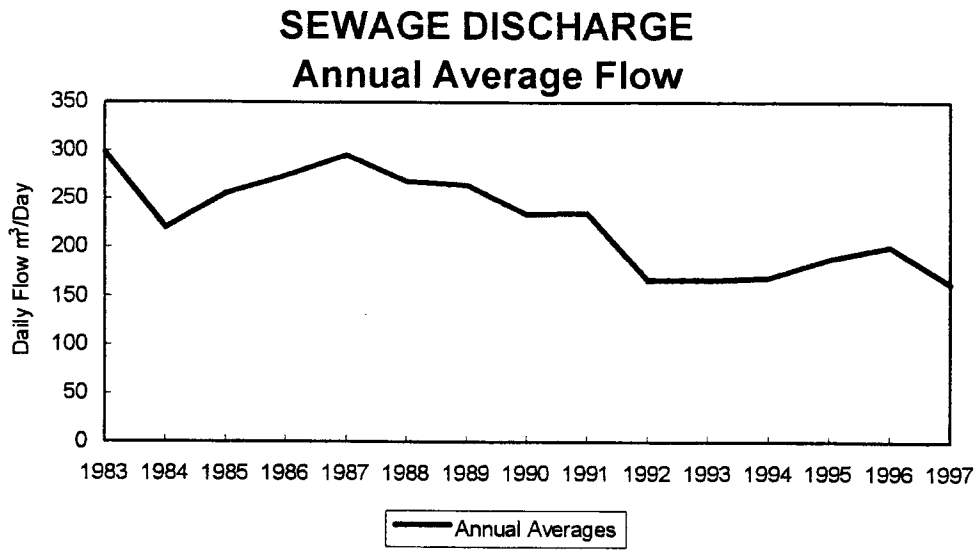
Discharges of treated sewage into Awarua Bay are covered by Coastal Permit Number 94487 which commenced on 15 October 1996.

Discharge monitoring results

The following graph shows the daily sewage discharge flow during 1996 and 1997.



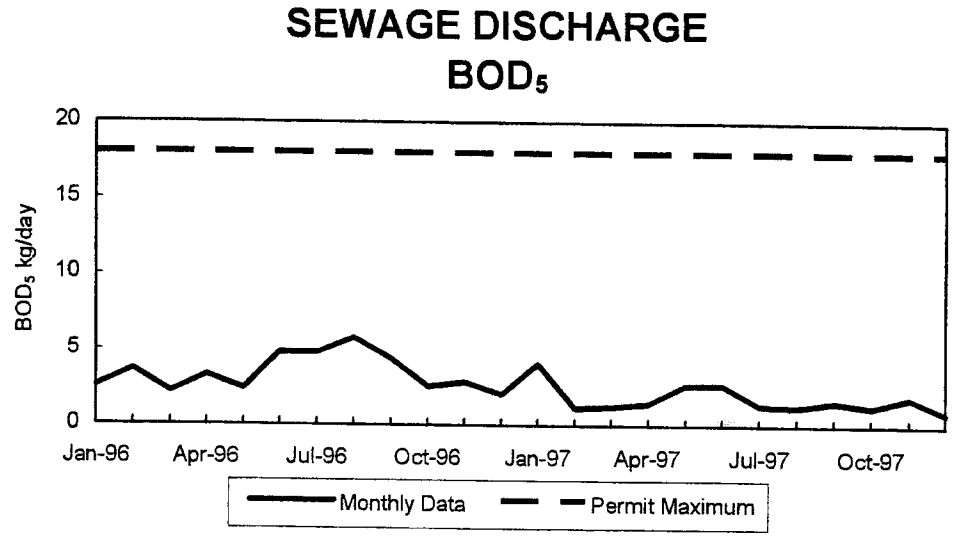
The following graph shows the annual average daily sewage discharge flow.



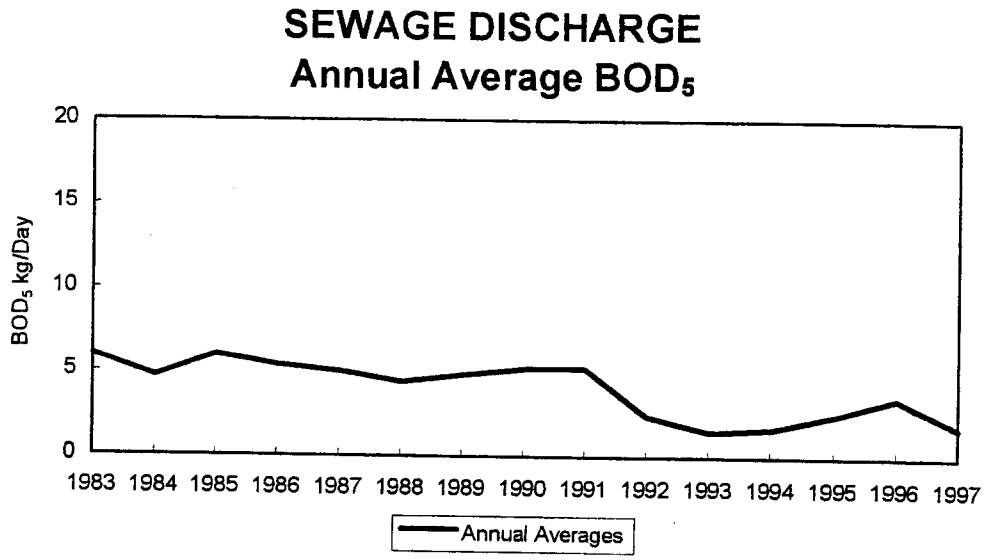
Treated Sewage Discharges, Continued

Discharge monitoring results, continued

The following graph shows the monthly biochemical oxygen demand (BOD_5) discharge from the sewage treatment plant during 1996 and 1997.

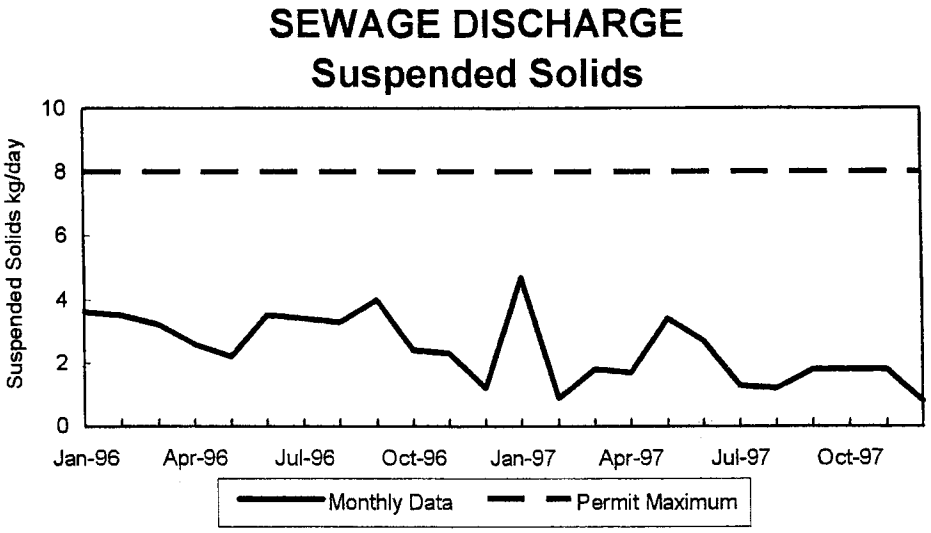


The following graph shows the annual average BOD_5 discharge from the sewage treatment plant.

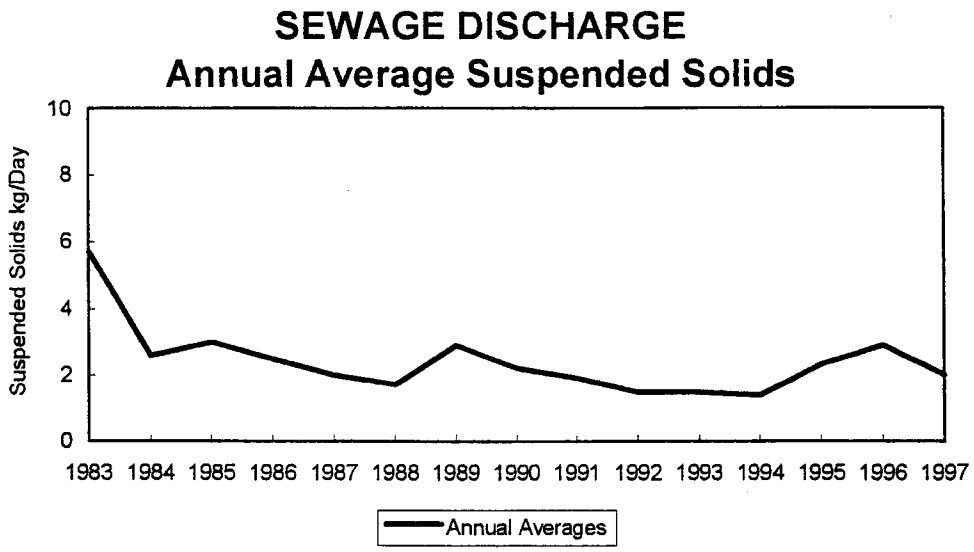


Discharge monitoring results, continued

The following graph shows the monthly suspended solids discharge from the sewage treatment plant during 1996 and 1997.



The following graph shows the annual average suspended solids discharge from the sewage treatment plant.



Treated Sewage Discharges, Continued

Coastal water monitoring results

The following table summarises the treated sewage annual coastal water monitoring results during 1997.

Parameter	Units	Limit	1997 Result
Temperature • Maximum difference • No. of times >3.0	^{0}C	 3.0 0	 0.3 0
pH • Maximum difference • No. of times >0.1		 0.1 0	 0.1 0
Dissolved oxygen • Minimum concentration • No. of times < 5.0	mg/litre	 5.0 0	 8.8 0
Visible oil • No. of times observed		 0	 0
Faecal coliforms Median concentration (highest of the two coastal water sites)	MPN/100ml	200	2

Comments

The discharges of treated sewage were within permit limits during 1997.

The maximum daily volume discharged during 1997 was 294 m^3 compared with the permit limit of 295 m^3. This high discharge was measured during April and is attributed to stormwater entering the sewerage system through leaking manholes. Manholes were progressively upgraded and no further unusually high daily discharge volumes were measured during 1997.

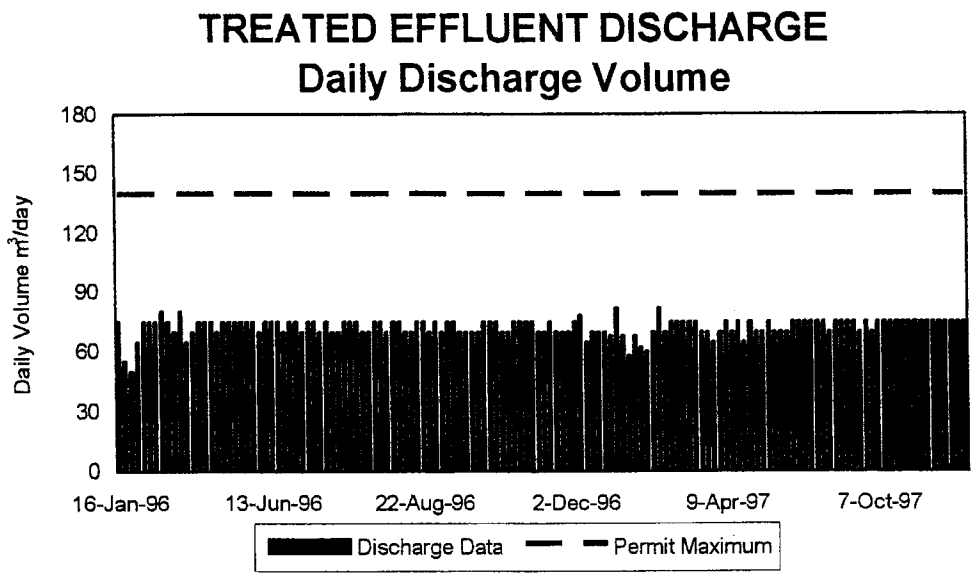
Treated Effluent Discharges

Introduction

Discharges of treated effluent into Foveaux Strait are covered by Coastal Permit Number 94488 which commenced on 11 October 1996.

Discharge monitoring results

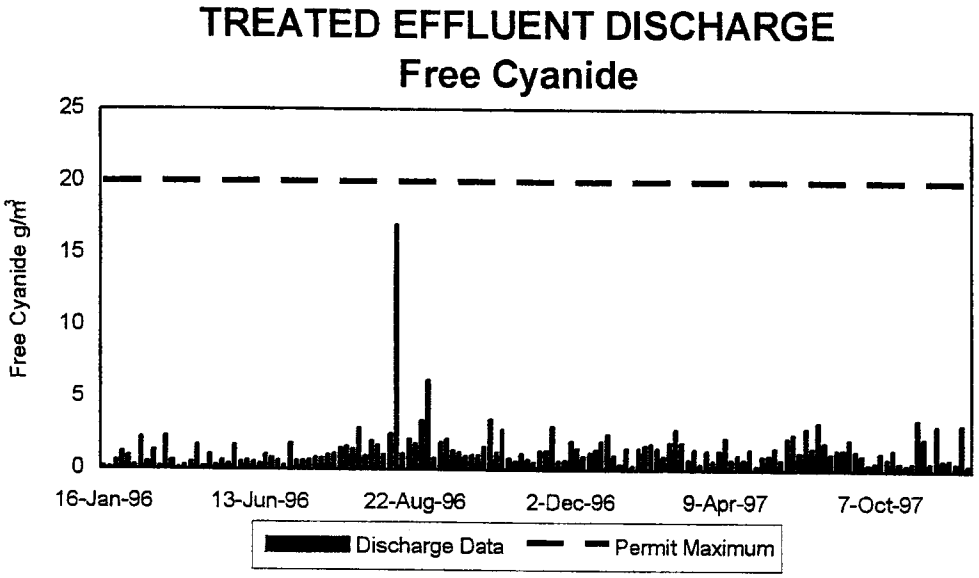
The following graph shows the volume of individual discharges of treated effluent during 1996 and 1997.



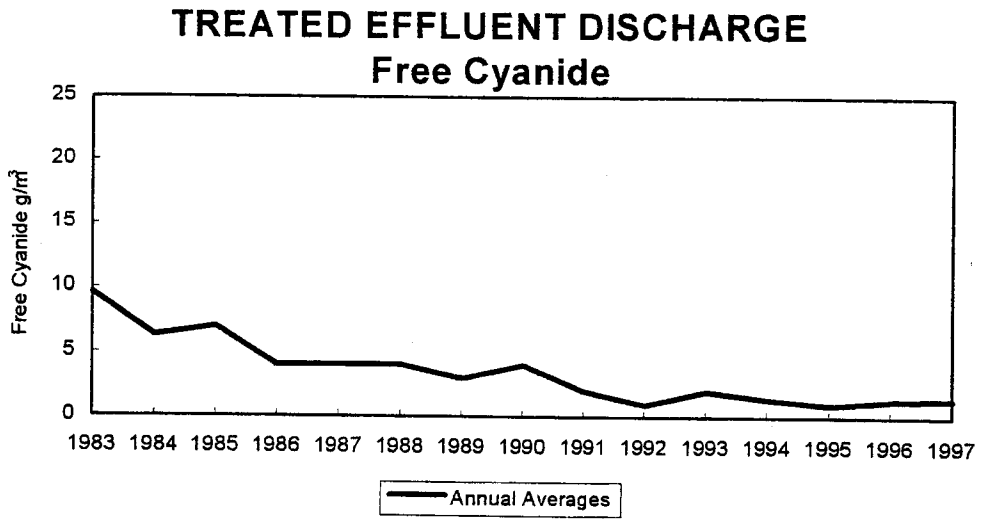
Treated Effluent Discharges, Continued

Discharge monitoring results, continued

The following graph shows the free cyanide concentration of individual discharges of treated effluent during 1996 and 1997.

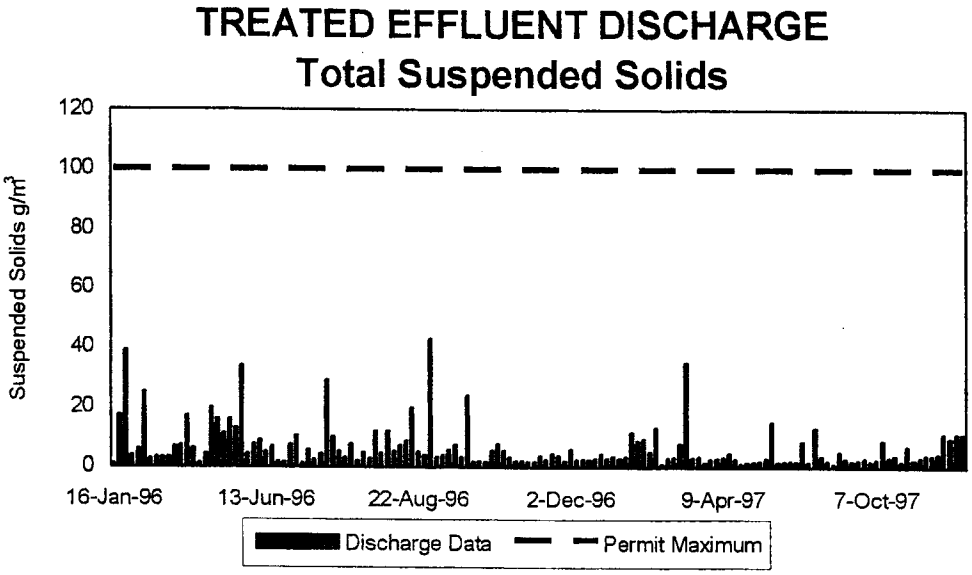


The following graph shows the annual average free cyanide concentration of treated effluent discharged.

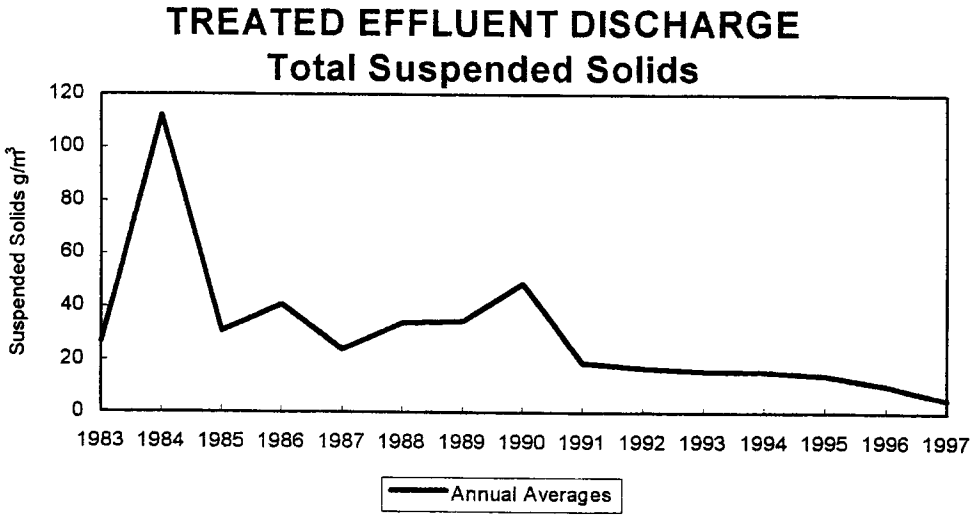


Discharge monitoring results, continued

The following graph shows the total suspended solids concentration of individual discharges of treated effluent during 1996 and 1997.



The following graph shows the annual average total suspended solids concentration of treated effluent discharged.



Treated Effluent Discharges, Continued

Coastal water monitoring results

The following table summarises the treated effluent annual coastal water monitoring results during 1997.

Parameter	Units	Limit	1997 Result
Difference in temperature	° C	3.0	0.0
Minimum dissolved oxygen concentration	mg/litre	5.0	8.8
Change to pH		0.1	0.0

Comments

All discharges of treated effluent were within permit limits during 1997.

Chapter 11

Landfill

Introduction

Discharges onto and into land from the smelter are covered by Discharge Permit No. 94460 issued by the Southland Regional Council which commenced on 30 October 1995.

This chapter gives a summary and interpretation of monitoring results during 1997.

Amount and Type of Materials Deposited

Introduction

Each year the smelter surveys the amount and type of material deposited at the Tiwai Point Landfill. The survey is usually conducted over a period of about four weeks during early summer.

Survey procedure

The survey generally follows the following procedure:

- taken over 28 days during November,
- each truck load of waste is weighed, and
- the contents and source of each truck load is recorded.

Results for 1996 and 1997

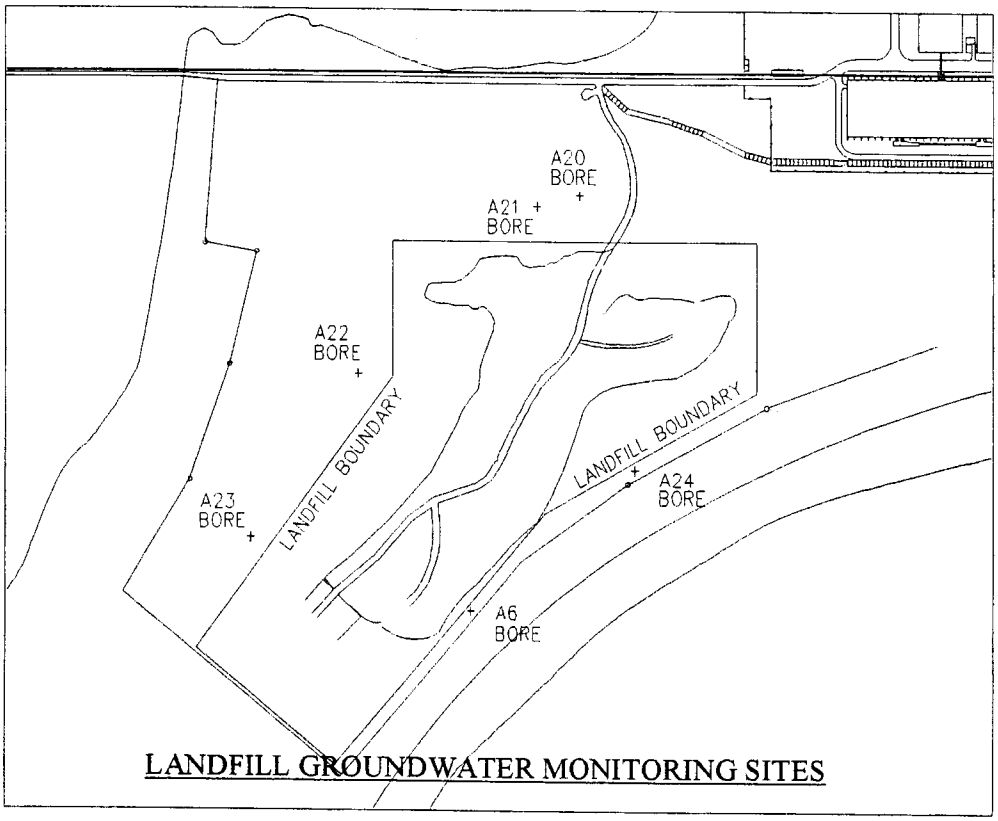
The following table shows the results of the surveys of waste deposited at the Tiwai Point Landfill during 1996 and 1997.

Type of waste	1996 tonnes	1997 tonnes
Metal Reclaim Plant fines	2,029	1,827
Carbon fines	1,668	2,949
Bricks	1,373	1,029
General	1,314	1,039
Butt material	605	155
Furnace slag	367	242
Alumina	285	132
Coke	199	141
Plastic	88	94
Concrete	82	282
Timber	54	0
Man made mineral fibre	0	38
Paper	0	4
Other	148	341
Total	**8212**	**8273**

Landfill Groundwater Monitoring

Site locations

The locations of the groundwater monitoring bores are as shown in the following map. Two of the bores are north (upstream) of the landfill, and there are two bores south east and two bores west (downstream) of the landfill.



LANDFILL GROUNDWATER MONITORING SITES

Landfill Groundwater Monitoring, Continued

Change of Permit Conditions

The Southland Regional Council approved a proposal from NZAS to change the frequency of monitoring of groundwater at the smelter's landfill on 10 July 1997. The request was in accordance with condition 5(iv) of the permit and followed discussion with Council staff. The new groundwater monitoring program is shown in the following table

Frequency	Analytes
Six monthly - all bores	pH Conductivity Alkalinity Fluoride Sulphate Total Nitrogen Ammonia-Nitrogen Carbonaceous BOD_5 Total Fe
Six monthly - bores A6, A21 and A24	PAH - anthracene, naphthalene, phenanthrene, fluoranthrene.
Annually - all bores	Analytes as for the six monthly monitoring TPH
Every two years - all bores	Analytes as for the six monthly and annual monitoring Total Kjeldahl Nitrogen Nitrate-Nitrogen Nitrite-Nitrogen Potassium Weak Acid Dissociable Cyanide Boron Manganese Nickel Vanadium Temperature

The first samples resulting from the changed permit conditions were collected during Quarter Four 1997.

Bore A20 monitoring results

The table below shows a summary of results from samples collected from bore A20 during 1996 and 1997. Bore A20 is located north of the landfill (upstream).

Parameter	Units	1996	1997	
		Average	Average	Range
pH	-	6.7	6.1	5.8 - 6.3
Total Nitrogen	$g.m^{-3}$	-	1.3	one sample only
Total Kjeldahl Nitrogen	$g.m^{-3}$	0.54	0.36	0.31 - 0.4
Ammonia Nitrogen	$g.m^{-3}$	0.06	<0.1	<0.1
Nitrate Nitrogen	$g.m^{-3}$	3.701	<0.1	<0.1
Nitrite Nitrogen	$g.m^{-3}$	0.005	<0.005	<0.005
Alkalinity	$g.m^{-3}$	114	68	38 - 111
Carbonaceous BOD_5	$g.m^{-3}$	2.5	3	<2 - 6
Potassium	$g.m^{-3}$	3.5	3.8	3.5 - 4.0
Boron	$g.m^{-3}$	0.052	0.04	0.038 - 0.040
Fluoride	$g.m^{-3}$	0.08	0.09	0.06 - 0.11
Sulphate	$g.m^{-3}$	39.25	33	32 - 39
Temperature	°C	10.2	10.2	8.9 - 11.6
Conductivity	$\mu S.cm^{-1}$	784.3	747	676 - 804
Total Iron	$g.m^{-3}$	4.3	6.9	1.8 - 13.5
Manganese	$g.m^{-3}$	0.257	0.320	0.245 - 0.394
Vanadium	$g.m^{-3}$	0.00225	0.003	0.003
Nickel	$g.m^{-3}$	0.0073	0.003	0.002 - 0.005
Total Petroleum Hydrocarbons	$g.m^{-3}$	3.4	<0.1	<0.1
Weak Acid Dissociable Cyanide	$g.m^{-3}$	<0.02	0.006	<0.005 - 0.01
Naphthalene	$mg.m^{-3}$	0.011	<0.01	<0.01
Anthracene	$mg.m^{-3}$	0.016	<0.01	<0.01
Phenanthrene	$mg.m^{-3}$	<0.01	<0.01	<0.01
Fluoranthrene	$mg.m^{-3}$	<0.01	<0.01	<0.01

Bore A21 monitoring results

The table below shows a summary of results from samples collected from bore A21 during 1996 and 1997. Bore A21 is located north of the landfill (upstream).

Parameter	Units	1996	1997	
		Average	Average	Range
pH	-	5.4	5.7	5.5 - 6.1
Total Nitrogen	$g.m^{-3}$	-	2.26	one sample only
Total Kjeldahl Nitrogen	$g.m^{-3}$	2.09	1.94	1.62 - 2.26
Total Ammoniacal Nitrogen	$g.m^{-3}$	0.44	0.51	0.42 - 0.60
Nitrate Nitrogen	$g.m^{-3}$	11.3	<0.1	<0.1
Nitrite Nitrogen	$g.m^{-3}$	0.015	0.027	0.026 - 0.027
Alkalinity	$g.m^{-3}$	14	37	26 - 47
Carbonaceous BOD_5	$g.m^{-3}$	2.9	3	3 - 4
Potassium	$g.m^{-3}$	10.1	7.6	7.1 - 8.0
Boron	$g.m^{-3}$	0.122	0.111	0.097 - 0.125
Fluoride	$g.m^{-3}$	0.59	0.30	0.28 - 0.31
Sulphate	$g.m^{-3}$	89	77	68 - 83
Temperature	°C	10	10.7	9.2 - 13.0
Conductivity	$\mu S.cm^{-1}$	1,514	1,056	1,014 - 1,140
Total Iron	$g.m^{-3}$	12.7	27.5	14.9 - 34.6
Manganese	$g.m^{-3}$	0.399	0.26	0.238 - 0.281
Vanadium	$g.m^{-3}$	0.0076	0.026	0.018 - 0.033
Nickel	$g.m^{-3}$	0.0063	0.005	0.004 - 0.006
Total Petroleum Hydrocarbons	$g.m^{-3}$	2.2	<0.1	<0.1
Weak Acid Dissociable Cyanide	$g.m^{-3}$	<0.2	0.05	<0.005 - 0.1
Naphthalene	$mg.m^{-3}$	0.038	<0.01	<0.01 - 0.01
Anthracene	$mg.m^{-3}$	0.018	<0.01	<0.01
Phenanthrene	$mg.m^{-3}$	0.009	<0.01	<0.01
Fluoranthrene	$mg.m^{-3}$	0.04	<0.01	<0.01

Bore A22 monitoring results

The table below shows the averages of results from samples collected from bore A22 during 1996 and 1997. Bore A22 is located west of the landfill.

Parameter	Units	1996	1997	
		Average	Average	Range
pH	-	6.5	4.8	4.2 - 5.6
Total Nitrogen	$g.m^{-3}$	-	2.6	one sample only
Total Kjeldahl Nitrogen	$g.m^{-3}$	1.03	2.55	2.35 - 2.75
Total Ammoniacal Nitrogen	$g.m^{-3}$	0.22	0.28	<0.1 - 0.47
Nitrate Nitrogen	$g.m^{-3}$	0.041	0.1	<0.1 - 0.2
Nitrite Nitrogen	$g.m^{-3}$	0.0048	0.038	0.033 - 0.042
Alkalinity	$g.m^{-3}$	161	9	<1 - 26
Carbonaceous BOD_5	$g.m^{-3}$	5	3	<3 - 6
Potassium	$g.m^{-3}$	2.19	4.1	4.0 - 4.1
Boron	$g.m^{-3}$	0.055	0.036	0.006 - 0.066
Fluoride	$g.m^{-3}$	0.95	1.99	1.63 - 2.26
Sulphate	$g.m^{-3}$	27	27	26 - 27
Temperature	°C	9.8	9.8	9.0 - 10.5
Conductivity	$\mu S.cm^{-1}$	862	711	671 - 750
Total Iron	$g.m^{-3}$	2.01	2.66	1.96 - 3.31
Manganese	$g.m^{-3}$	0.172	0.027	0.005 - 0.040
Vanadium	$g.m^{-3}$	0.016	0.006	0.002 - 0.009
Nickel	$g.m^{-3}$	0.0041	<0.001	<0.001 - 0.001
Total Petroleum Hydrocarbons	$g.m^{-3}$	3.55	<0.1	<0.1
Weak Acid Dissociable Cyanide	$g.m^{-3}$	<0.20	0.05	<0.005 - 0.1
Naphthalene	$mg.m^{-3}$	0.009	<0.01	<0.01
Anthracene	$mg.m^{-3}$	0.026	<0.01	<0.01
Phenanthrene	$mg.m^{-3}$	0.008	<0.01	<0.01
Fluoranthrene	$mg.m^{-3}$	0.011	<0.01	<0.01

Landfill Groundwater Monitoring, Continued

Bore A23 monitoring results

The table below shows a summary of results from samples collected from bore A23 during 1996 and 1997. Bore A23 is located west of the landfill.

Parameter	Units	1996	1997	
		Average	Average	Range
pH	-	5.6	5.5	5.4 - 5.6
Total Nitrogen	$g.m^{-3}$	-	2.7	one sample only
Total Kjeldahl Nitrogen	$g.m^{-3}$	2.03	1.72	1.48 - 1.95
Total Ammoniacal Nitrogen	$g.m^{-3}$	0.76	0.63	<0.1 - 1.28
Nitrate Nitrogen	$g.m^{-3}$	0.042	<0.1	<0.1
Nitrite Nitrogen	$g.m^{-3}$	0.007	0.017	0.015 - 0.019
Alkalinity	$g.m^{-3}$	52	39	33 - 50
Carbonaceous BOD_5	$g.m^{-3}$	2.6	<3	<3
Potassium	$g.m^{-3}$	4.65	4.5	4.0 - 4.9
Boron	$g.m^{-3}$	0.048	0.039	0.038 - 0.040
Fluoride	$g.m^{-3}$	0.14	0.07	<0.05 - 0.1
Sulphate	$g.m^{-3}$	10.4	6	1 - 13
Temperature	°C	10.0	10.1	9.3 - 11.1
Conductivity	$\mu S.cm^{-1}$	666	577	562 - 586
Total Iron	$g.m^{-3}$	10.2	8.5	7.5 - 9.6
Manganese	$g.m^{-3}$	0.095	0.071	0.069 - 0.072
Vanadium	$g.m^{-3}$	0.019	0.018	0.016 - 0.019
Nickel	$g.m^{-3}$	.001	<0.001	<0.001
Total Petroleum Hydrocarbons	$g.m^{-3}$	2.3	<1	<1 - 1
Weak Acid Dissociable Cyanide	$g.m^{-3}$	<0.2	0.05	<0.005 - 0.1
Naphthalene	$mg.m^{-3}$	0.023	<0.01	<0.01
Anthracene	$mg.m^{-3}$	0.033	<0.01	<0.01
Phenanthrene	$mg.m^{-3}$	<0.01	<0.01	<0.01
Fluoranthrene	$mg.m^{-3}$	<0.01	<0.01	<0.01

Bore A24 monitoring results

The table below shows a summary of results from samples collected from bore A24 during 1996 and 1997. Bore A24 is located south east of the landfill.

Parameter	Units	1996	1997	
		Average	Average	Range
pH	-	6.9	7.0	7.0 - 7.1
Total Nitrogen	$g.m^{-3}$	-	81.5	one sample only
Total Kjeldahl Nitrogen	$g.m^{-3}$	77.7	65.8	64.0 - 67.6
Total Ammoniacal Nitrogen	$g.m^{-3}$	58.4	49	44 - 53
Nitrate Nitrogen	$g.m^{-3}$	<0.1	<0.1	<0.1
Nitrite Nitrogen	$g.m^{-3}$	0.21	0.19	0.17 - 0.21
Alkalinity	$g.m^{-3}$	1,102	1,034	937 - 1,095
Carbonaceous BOD_5	$g.m^{-3}$	9	7	7 - 8
Potassium	$g.m^{-3}$	18.2	22	21 - 22
Boron	$g.m^{-3}$	5.15	4.22	4.08 - 4.36
Fluoride	$g.m^{-3}$	1.09	1.04	0.79 - 1.43
Sulphate	$g.m^{-3}$	85	38	28 - 47
Temperature	°C	10.6	10.9	10.6 - 11.1
Conductivity	$\mu S.cm^{-1}$	2,856	2,901	2,797 - 2,970
Total Iron	$g.m^{-3}$	20.2	20.6	18.0 - 22.6
Manganese	$g.m^{-3}$	0.12	0.11	0.11
Vanadium	$g.m^{-3}$	0.361	0.314	0.310 - 0.318
Nickel	$g.m^{-3}$	0.006	<0.01	<0.01
Total Petroleum Hydrocarbons	$g.m^{-3}$	5	<1	<1
Weak Acid Dissociable Cyanide	$g.m^{-3}$	<0.2	0.06	0.025 - 0.1
Naphthalene	$mg.m^{-3}$	39.2	29.6	8.42 - 57.7
Anthracene	$mg.m^{-3}$	0.125	0.049	<0.01 - 0.092
Phenanthrene	$mg.m^{-3}$	0.036	0.22	<0.01 - 0.042
Fluoranthrene	$mg.m^{-3}$	0.011	0.01	64.2 - 67.6

Landfill Groundwater Monitoring, Continued

Bore A6 monitoring results

The table below shows a summary of results from samples collected from bore A6 during 1996 and 1997. Bore A6 is located south east of the landfill.

Parameter	Units	1996	1997	
		Average	Average	Range
pH	-	6.4	6.5	64. - 6.6
Total Nitrogen	$g.m^{-3}$	-	44	one sample only
Total Kjeldahl Nitrogen	$g.m^{-3}$	30.9	31.2	20.8 - 41.5
Total Ammoniacal Nitrogen	$g.m^{-3}$	19.8	25.9	15.1 - 31.5
Nitrate Nitrogen	$g.m^{-3}$	5.03	1.7	0.1 - 3.2
Nitrite Nitrogen	$g.m^{-3}$	0.12	0.15	0.12 - 0.17
Alkalinity	$g.m^{-3}$	723	738	655 - 851
Carbonaceous BOD_5	$g.m^{-3}$	3.5	<3	<3 - 3
Potassium	$g.m^{-3}$	29.3	34	30 - 37
Boron	$g.m^{-3}$	2.23	2.08	1.72 - 2.43
Fluoride	$g.m^{-3}$	8.10	9.1	2.87 - 15.5
Sulphate	$g.m^{-3}$	1,791	1,725	1,630 - 1,700
Temperature	°C	12.0	11.6	10.3 - 12.8
Conductivity	$\mu S.cm^{-1}$	5007	4732	4,510 - 4,907
Total Iron	$g.m^{-3}$	15	17.5	12.2 - 22.6
Manganese	$g.m^{-3}$	0.88	1.35	1.07 - 1.62
Vanadium	$g.m^{-3}$	0.15	0.184	0.148 - 0.220
Nickel	$g.m^{-3}$	0.0069	<0.01	<0.01
Total Petroleum Hydrocarbons	$g.m^{-3}$	2.8	<0.1	<0.1
Weak Acid Dissociable Cyanide	$g.m^{-3}$	0.09	0.06	0.025 - 0.1
Naphthalene	$mg.m^{-3}$	0.04	0.01	<0.01 - 0.02
Anthracene	$mg.m^{-3}$	0.31	0.16	0.05 - 0.28
Phenanthrene	$mg.m^{-3}$	0.041	0.024	<0.01 - 0.037
Fluoranthrene	$mg.m^{-3}$	0.027	<0.01	<0.01

Landfill Groundwater Monitoring, Continued

Comments

The groundwater monitoring data from the bores near the landfill do not indicate any significant trends in the general groundwater quality during 1997.

The decreased pH of groundwater sampled from bore A22 indicates that the water is probably sourced from the swampy surface water in the area near the bore.

Chapter 12

Groundwater

Spent Cathode Pad Leachate

The monitoring of the recovery, by natural dispersion, of the contaminated plume in the groundwater under the cathode pad has continued. An annual report on this monitoring was submitted to the Southland Regional Council (SRC) in July 1997.

A summary of the findings included in the report on the 1997 monitoring of the bores south of the cathode pad is:

- all analyte concentrations in the groundwater had generally decreased during the previous 12 months and several shallow bores were below the clean up criteria,
- the analyte concentrations in the seawater indicated similar levels to previous monitoring,
- biostimulation is not an effective process for removing cyanide from groundwater.

As a result of the monitoring the SRC agreed with NZAS on a reduction to the monitoring program. The changes agreed were to:

- reduce the number of bores monitored from 22 to 17,
- remove chloride from the list of bore water analytes,
- reduce the frequency of bore conductivity measurements from two monthly to six monthly,
- remove the requirement to measure seawater conductivity, fluoride, and pH,
- remove the requirement to measure seawater free cyanide,
- reduce the number of seawater sampling sites from four to two, and
- discontinue the semi-scale groundwater remediation trial.

Bioremediation Of Diesel Contamination

Annual monitoring to confirm that there is no potential for diesel to migrate off site was initiated during 1997. An annual report on this monitoring was submitted to the Southland Regional Council (SRC) in August 1997.

The report concluded that the levels of total petroleum hydrocarbons in the groundwater from four bores surrounding the diesel plume indicate there is no movement of the plume downstream or off site.

Spent Cell Lining Storage Shed

Monitoring of the membranes under the Spent Cell Lining storage shed indicated there were no concerns during 1997.