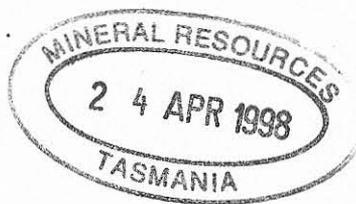


Environmental Management
and Engineering Consultants

Principal Office:
41b Tasma Street, North Hobart, Tas. 7000
G.P.O. Box 659G, Hobart, Tas. 7001
Telephone: (002) 31 1509
Facsimile: (002) 31 1548

Other Office:
20 Rowntree Street
Balmain New South Wales 2041
Telephone: (02) 810 8100
Facsimile: (02) 810 5542

See file 68081 RT2
come 70868



JOHN MIEDECKE
AND
PARTNERS PTY LTD
A.C.N. 002 488 128



Final

Mineral Resources Tasmania

Storys Creek / Rossarden
Acid Drainage Remediation
Study

PRELIMINARY REPORT

March 1998

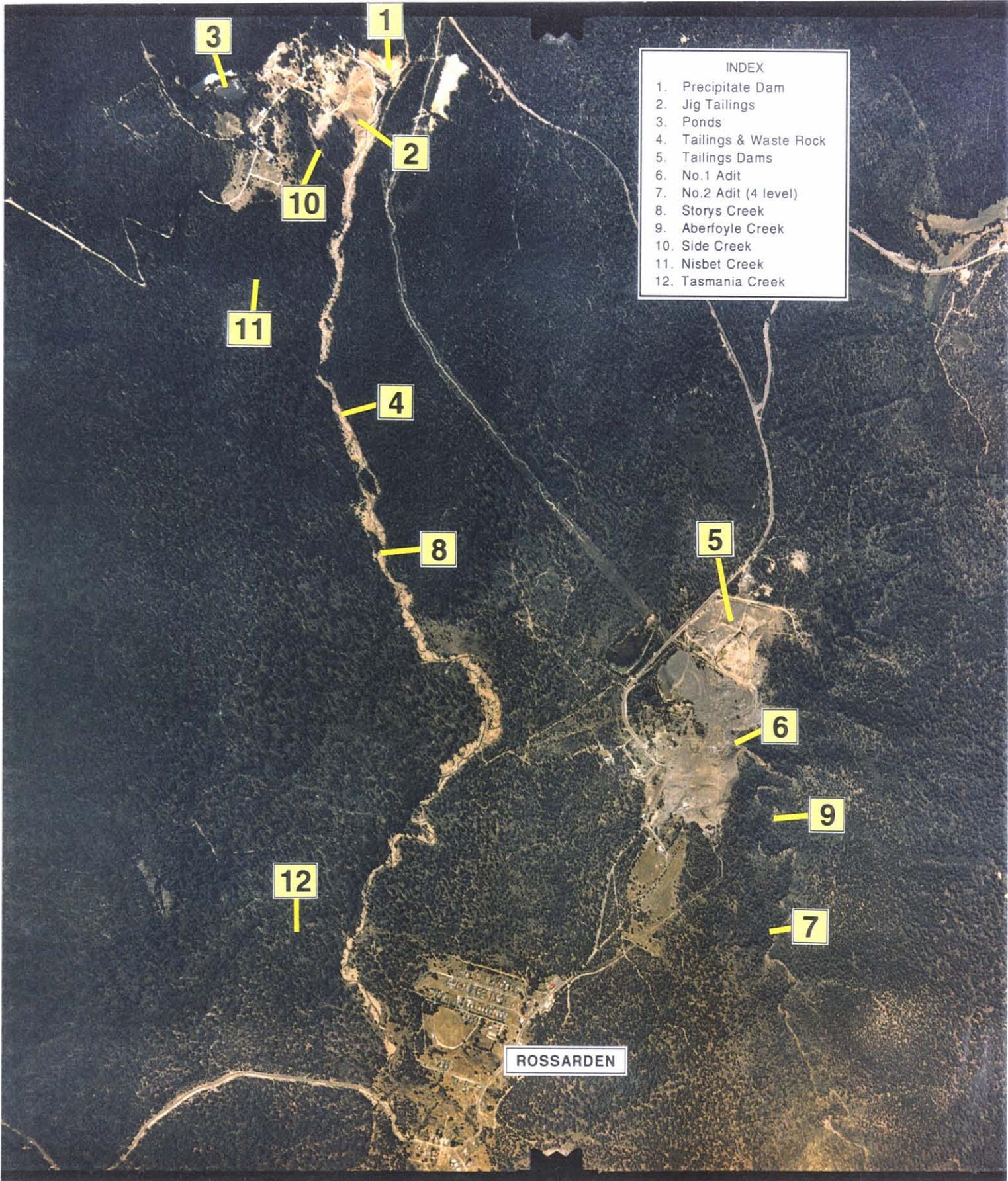
In association with, Environmental Geochemistry International (EGi), Freshwater
Systems, Hydro Electric Commission.

333.765153 ROS

963963

Mineral Resources Tasmania : Storys Creek /
Rossarden acid drainage remediation study :
preliminary report : a cooperative project
between mineral Resources Tasmania (MRT),
the Department of the Environment and Land





INDEX	
1.	Precipitate Dam
2.	Jig Tailings
3.	Ponds
4.	Tailings & Waste Rock
5.	Tailings Dams
6.	No.1 Adit
7.	No.2 Adit (4 level)
8.	Storys Creek
9.	Aberfoyle Creek
10.	Side Creek
11.	Nisbet Creek
12.	Tasmania Creek

STORYS CREEK - ROSSARDEN MINES AREA (SCALE 1:20 000)

5 cm

TABLE OF CONTENTS

1.0	INTRODUCTION	1
2.0	SCOPE AND CONDUCT OF STUDY	1
2.1	Scope	1
2.2	Study Team	1
2.3	Conduct of the Study	2
3.0	STUDY AREA ACID DRAINAGE AND METAL LOADS	3
3.1	Introduction	3
3.2	Pollutant Sources	3
3.3	Water Quality and Pollutant Indicators	4
3.3.1	Water Quality	4
3.3.2	Pollutant Indicators	4
3.4	Pollutant Loads and Source Evaluation	5
3.4.1	Storys Creek Catchment	6
3.4.2	Aberfoyle Creek	7
3.4.3	Pollutant Load Summary	8
3.5	Control of Metal Release and Solubility	8
4.0	AQUATIC FAUNA ASSESSMENT AND ENVIRONMENTAL QUALITY OBJECTIVES	10
4.1	Introduction	10
4.2	Sediment Chemistry Data	10
4.3	Biological Data	10
4.3.1	Sources	10
4.3.2	Norris Study	11
4.3.3	DPIF Study	12
4.3.4	Fishery Data	13
4.3.5	Summary	13
4.4	Other Effects	14
4.5	Environmental Quality Objectives (EQOs)	15
4.5.1	Overall Objectives	15
4.5.2	Water Quality Objectives	16
4.5.3	Sediment Quality Objectives	16
4.5.4	Biological Health	16
4.5.5	Physical Quality	18
4.6	Probable Effects of Neutralisation	18
5.0	GENERAL SCREENING OF REMEDIAL TECHNOLOGIES	19
5.1	Introduction	19
5.2	Review and Applicability	19
5.2.1	Study Findings	19
5.2.2	Applicability	20
6.0	REMEDICATION TECHNOLOGIES AND SELECTION OF SITE SPECIFIC TRIALS	22
6.1	Introduction	22
6.2	Load Reduction	22
6.2.1	Flooding of Old Workings and Drainage and Drainage Diversions	22
6.2.2	Covering of Waste Rock Dumps (Oxidation Control)	23
6.2.3	Geochemical Control	23
6.2.4	Removal of AD Sources	23
6.2.5	Surface Water Diversion	24
6.3	Load Treatment	24
6.3.1	Passive Treatment of Acid Drainage	24

6.4	Possible Trials	26
6.4.1	Storys Creek	26
6.4.2	Rossarden	26
6.5	Further Monitoring and Investigations	27
6.5.1	Introduction	27
6.5.2	Water Quality	27
6.5.3	Sediment Quality	28
6.5.4	Biological Health	28
6.5.5	Data Analysis	29

REFERENCES

APPENDIX A WATER QUALITY DATA REPORT

APPENDIX B FRESHWATER SYSTEMS REPORT

APPENDIX C LIMESTONE TO RIVER BANK TAILINGS SMALL SCALE TRIAL

APPENDIX D WATER MONITORING PROPOSAL

APPENDIX E AQUATIC FAUNA MONITORING PROPOSAL

LIST OF FIGURES

		on/after page number
Figure 1.1	Location Plan	1
Figure 3.1	Concept Drainage Model	3
Figure 3.2	October 1997 Water Sampling Locations	3
Figure 3.3	October 1997 Water Sampling Locations	3
Figure 3.4	Storys Creek Mine Area	6
Figure 3.5	Storys Creek - Sources and Loads	6
Figure 3.6	Rossarden Mine Area	7
Figure 3.7	Rossarden Mine Area - Sources and Loads	7
Figure 3.8	Catchment Loads as a % of Loads in Storys Creek above South Esk River	8
Figure 3.9	pH Dependent Solubilities for Al, Cd, Cu and Zn	9
Figure 3.10	pH versus Cu, Cd and Zn for Storys Creek	9
Figure 3.11	Buffering Curves	9
Figure 6.1	Storys Creek Mine Area Trials	25

LIST OF TABLES

		on/after page number
Table 3.1	Water Quality Data: Storys Creek, Aberfoyle Creek and South Esk River - Compilation of Historical Data	4
Table 3.2	Storys Creek and Aberfoyle Creek Water Quality - October 1997	4
Table 3.3	Acid Drainage and Metals Loads in Storys Creek - October 1997	6
Table 3.4	Acid Forming Characteristics of Storys Creek Tailings	7
Table 3.5	Storys Creek Water Quality Trends	7
Table 3.6	AD and Metal Loads in Aberfoyle Creek - October 1997	7
Table 3.7	Loads in Storys Creek, Aberfoyle Creek and the South Esk	8
Table 4.1	Recommended Water Quality Targets for Storys Creek and South Esk River and Ambient Median and Maximum Concentrations	17

1.0 Introduction

The Storys Creek/Rossarden remediation project is a cooperative project between Mineral Resources Tasmania (MRT), the Department of the Environment and Land Management (DELM) and the Commonwealth Department of the Environment. The aim is to design a design and implement a remediation strategy for the Storys Creek and Rossarden abandoned mine sites to reduce acid and heavy metal discharge into the South Esk River system.

Figure 1.1 shows the location of the study area and major catchments.

An interim data report was completed and submitted (John Miedecke and Partners Pty Ltd, 1997) in September 1997 and a Draft Preliminary Report in December 1997. After a period of review, this draft has been finalised and includes additional details and proposals for trials.

This Preliminary Report has been prepared as the preliminary report into the investigations. It is anticipated that this report will be followed by on site trials and a final report on the remediation of the study area.

It contains;

Section 2 - a description of the scope and conduct of the study;

Section 3 - a description of the study area acid drainage , metal loads and sources;

Section 4 - an evaluation of downstream effects on the downstream environment, and a discussion of environmental quality objectives;

Section 5 - a general discussion of remedial technologies, including a review of the Mount Lyell study findings;

Section 6 - a selection of appropriate remedial technologies and a discussion of site specific trials, and recommended monitoring and investigations.

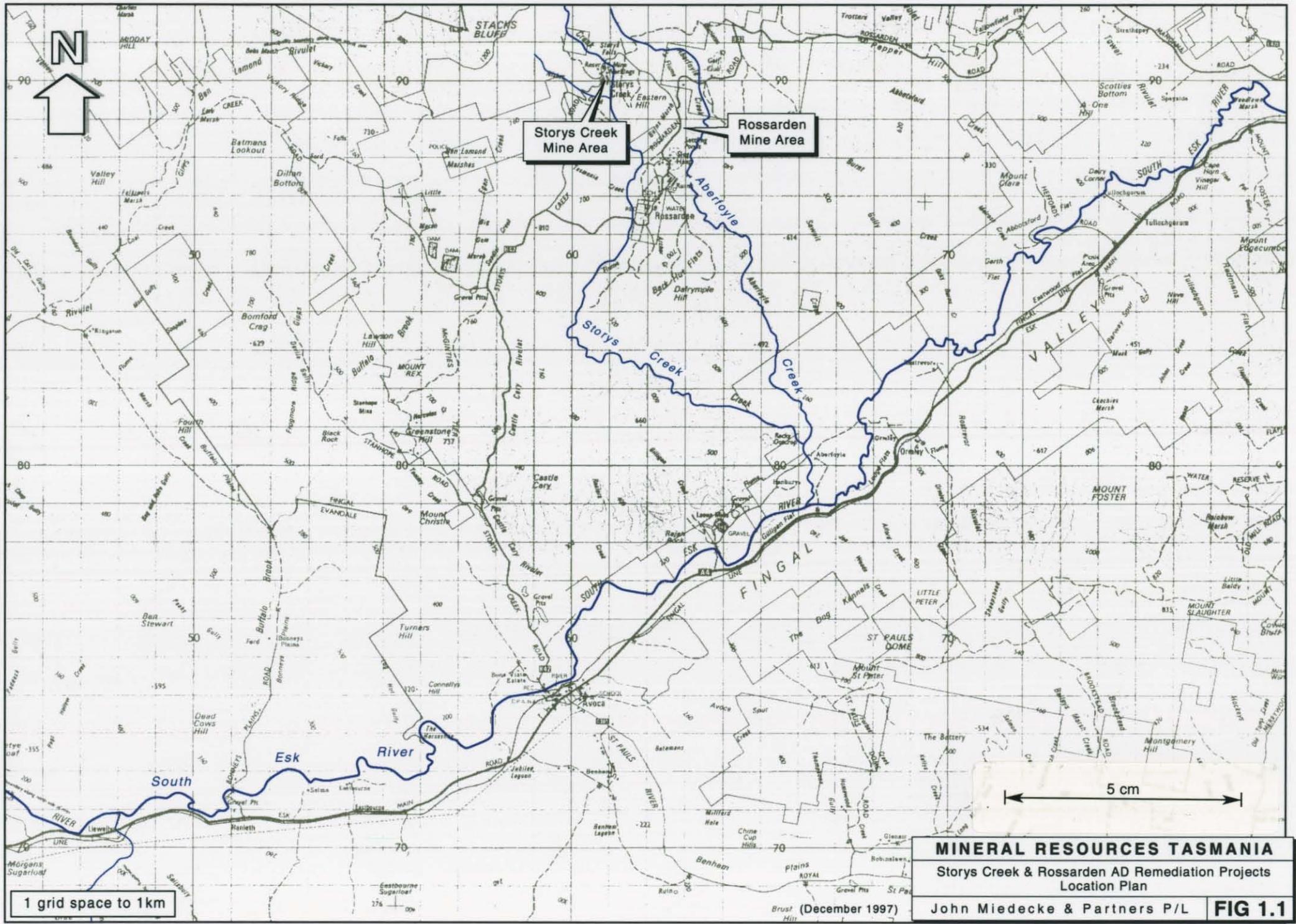
Appendices with detailed information.

2.0 Scope and Conduct of Study

2.1 Scope

The consultancy brief set out by MRT was as follows:

- Review historical data and literature and design remediation works.
- Identify any gaps in data which must be filled to permit design work.
- Design and quote on instrumentation and analysis required.
- Identify potential options for managing effluent water from the adits, mine sites, tailings and other waste materials in the general vicinity of the creeks.
- Recommend site works to control metal and acid discharges.
- In the event of doubt of the success of recommended options design demonstration programs.
- Construction and evaluation of pilot works if required.



MINERAL RESOURCES TASMANIA
 Stors Creek & Rossarden AD Remediation Projects
 Location Plan
 John Miedecke & Partners P/L **FIG 1.1**

2.2 Study Team

The study is being conducted by a project team consisting of John Miedecke and Partners Pty Ltd (JMP), Environmental Geochemistry International Pty Ltd (EGi), Hydro Electric Commission, Freshwater Systems (Dr P Davies), William Wood and Associates, MPA Williams and Dr F Baynes.

John Miedecke and Partners were the primary consultant and project managers, The Project Team consisted of;

John Miedecke (JMP)	Project Manager, hydrology, environmental engineering, remediation options.
Simon Wheeler (JMP).	Field work, data base, support services.
Dr Stuart Miller and Clayton Rumble (EGi)	Chemistry, geochemistry, remediation, cover design.
David Wilson (HEC)	Hydrology, hydrogeology.
Mark Johnson (HEC)	Hydrology, field work, monitoring.
Helen Locher (HEC)	Data gathering, data base.
Dr Fred Baynes (Eng Geol)	Engineering geology, geotechnical.
Dr Bill Wood (Consultant)	Site data, investigations.
Dr Peter Davies	Water quality criteria, aquatic life.
Keith Seddon (MPA, Williams Geotech Engineers)	Geotechnical and civil engineering

In addition, Dr Robert Hedin, Hedin Environmental from Pennsylvania USA has provided advice on limestone alkalinity addition.

2.3 Conduct of the Study

The study commenced in July 1997 and has included site visits by the study team, additional sample collection to identify acid drainage sources and to quantify loads from the site, and project team meetings to review remediation options and the study program.

This was assisted by a number of individuals who provided invaluable historic records and observations. These included, Wojciech Grun (MRT), Mr Harry Stacpoole, Mr John Scales, and Mr Bill Bourke (DELM).

A considerable amount of information was obtained regarding the operation of the mines and also environmental data from previous investigations in the area. This was documented in the September Report. Water quality data was compiled and analyzed to achieve a reliable data set. Site visits enabled the study team to observe the study area and gain an understanding of the nature of the site.

A number of monitoring sites were established and water quality analysis carried out to determine metal loads in Storys and Aberfoyle Creeks, and to assist in formulating remediation options.

3.0 Study Area Acid Drainage and Metal Loads

3.1 Introduction

The purpose of this section of the report is to provide the findings of the detailed evaluation of the available data to provide a best-estimate of the pollutant sources and loads and to allow the effect of previous and proposed control strategies to be evaluated.

Water quality and flow data has been collected from numerous locations at Storys Creek and Rossarden mine sites since the early 1980s. This data has been summarised and presented in previous reports prepared by the former Mines Department Metallurgical Laboratory, Helen Locher (1993), and DELM (data only). In addition, there has been sampling in the South Esk River by DPI and the HEC.

Water quality data collected prior to 1993 has been summarised by Locher (1993) and it is not intended to reproduce the information contained in this document in this report. The data has been critically evaluated and updated for this report. In addition, a computer data base has been compiled which contains all data that is currently available on water quality and flows for the study area.

As a result of the deficiencies in the data base, and in particular the lack of integration of water quality sampling with flows, a single event sampling was conducted in October 1997. This incorporated rigorous stream flow and water quality sample collection and provided data on pollutant loads.

There are two main water quality data sets of use in determining current water quality in the South Esk and Storys Creek systems, those reported by DELM (unpub. data for 1996-97) and those cited in this report. A single collection of samples at a range of sites was also performed by DPIF in March 1995 (Bobbi et al. 1996). The DELM data consists of nine samples collected over 12 months in 1996-97 in Storys Creek at Rossarden and in the South Esk at Avoca, as well as three samples collected in Aberfoyle Creek downstream of Adit 4. These data are considered reliable in terms of precision and accuracy and are the only data with sufficient (though minimally) data to estimate interim median and maximum values. The median DELM values are consistent with those recorded at the same sites in the present HEC survey and in the 1995 DPIF survey (Bobbi et al. 1996).

3.2 Pollutant Sources

Figure 3.1 is a conceptual drainage model of the system which incorporates the study area. All of the October 1997 water sampling sites are shown on this Figure.

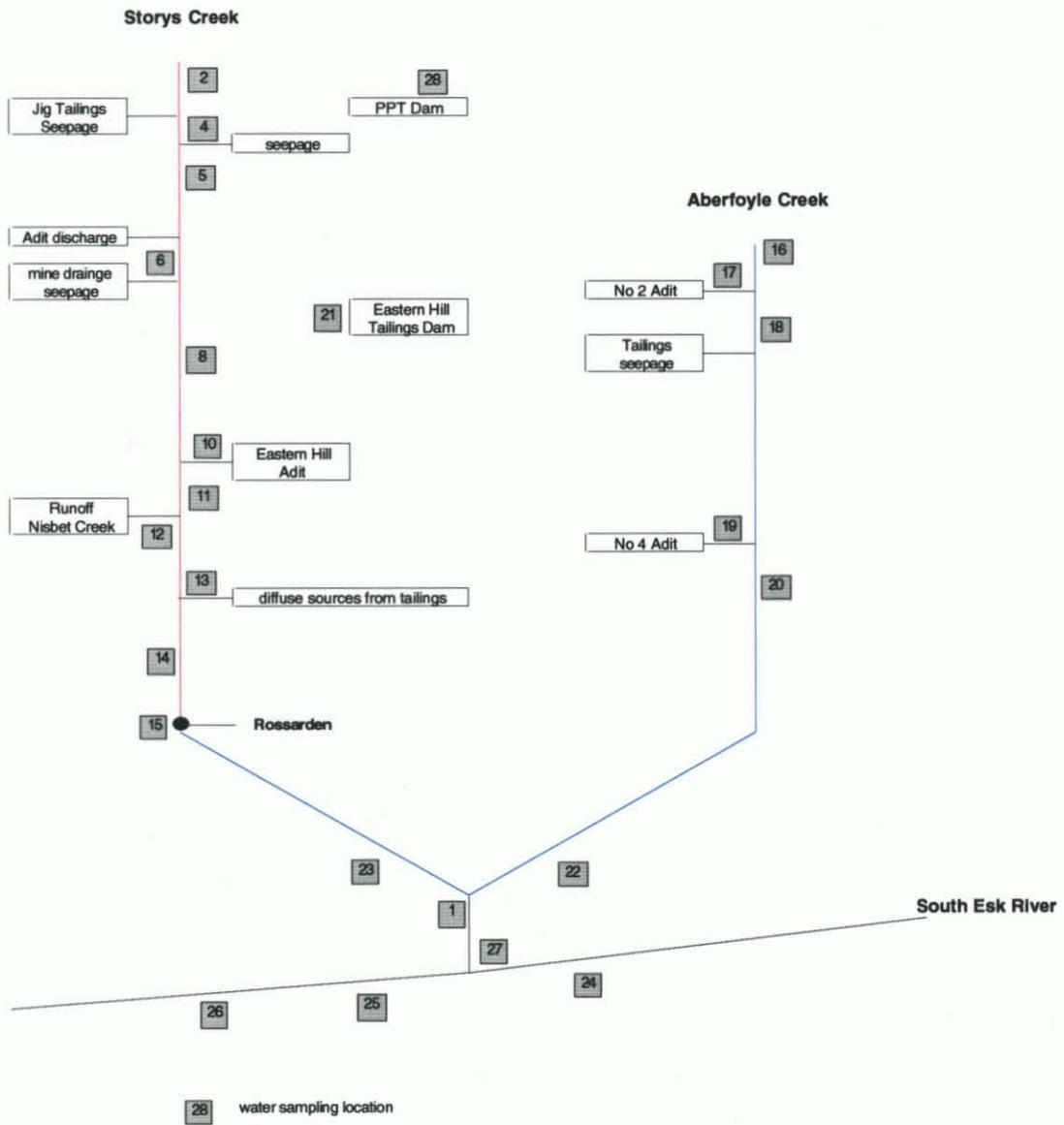
This report focuses on the mine sites and immediate surrounds downstream to the South Esk River. This area consists of the two main catchments as follows:

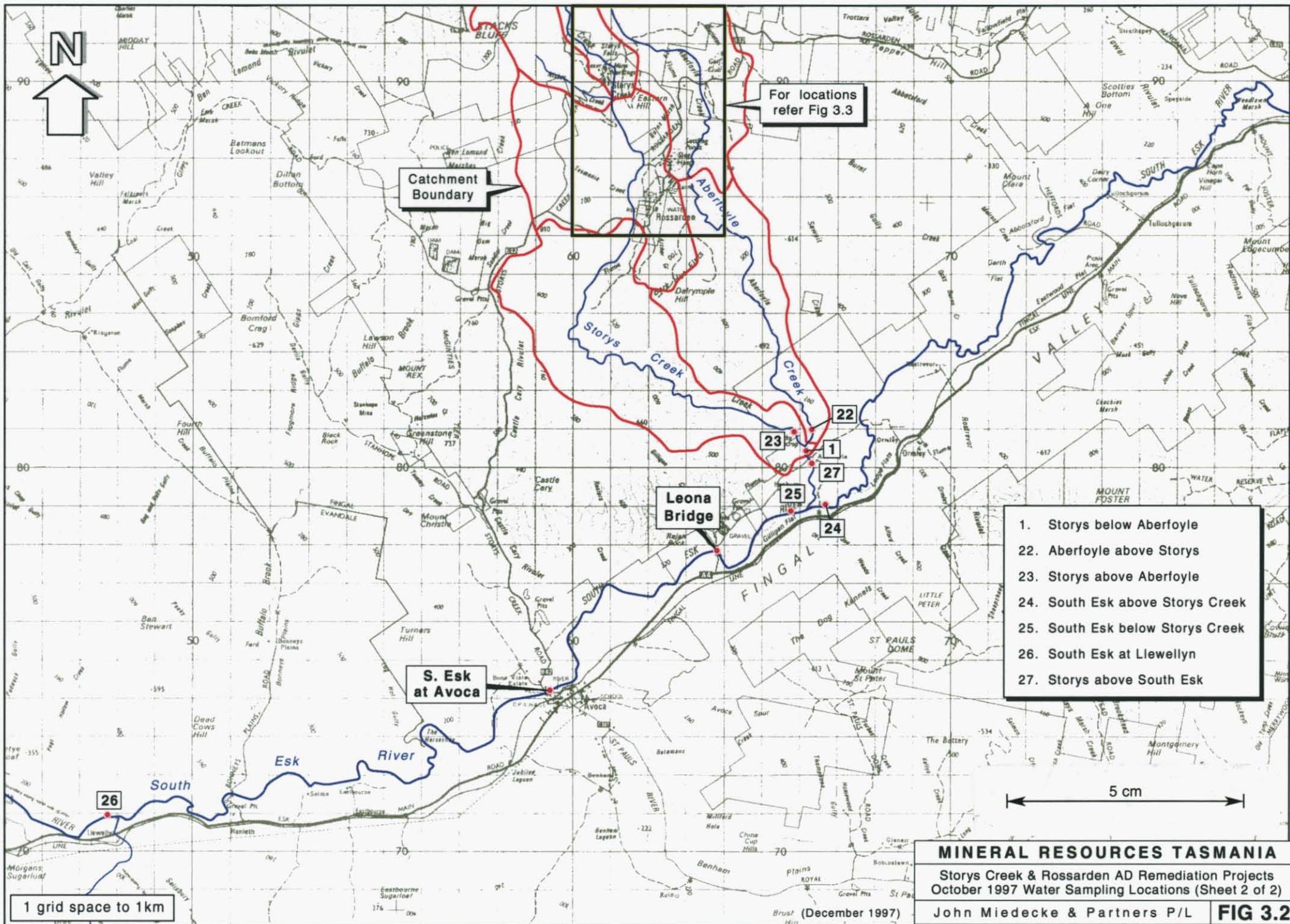
- Storys Creek and;
- Aberfoyle Creek.

The catchments combine to join the South Esk River which eventually flows to the Tamar River at Launceston.

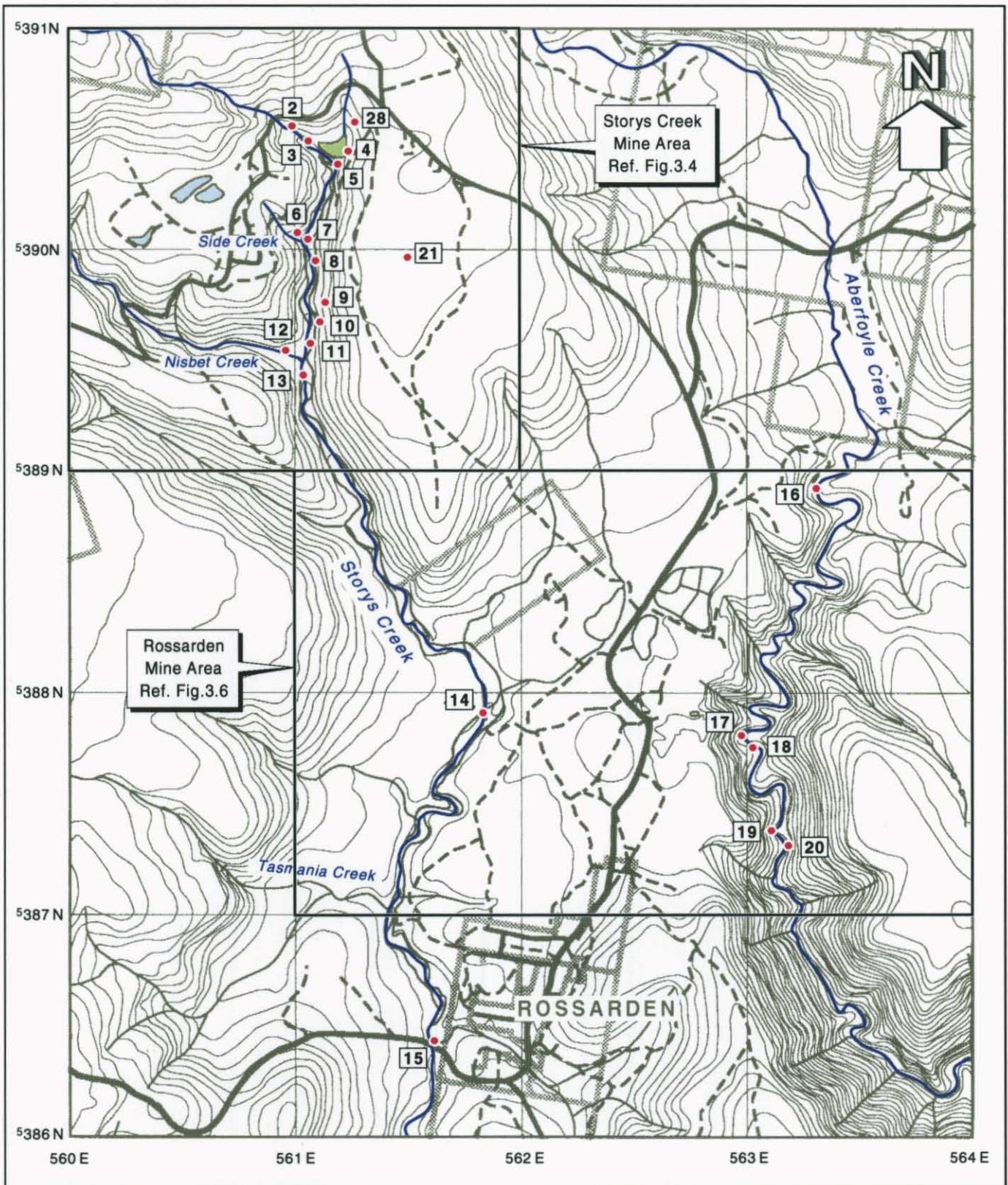
Figures 3.2 and 3.2 show the catchments.

Figure 3.1: Concept Drainage Model.





- 1. Storys below Aberfoyle
- 22. Aberfoyle above Storys
- 23. Storys above Aberfoyle
- 24. South Esk above Storys Creek
- 25. South Esk below Storys Creek
- 26. South Esk at Llewellyn
- 27. Storys above South Esk



- | | |
|---------------------------------------|---|
| 2. Storys above mine | 13. Storys below Nisbet Creek |
| 3. Inflow to Storys near old workings | 14. Storys below mine managers residence |
| 4. Tailings Dam outflow | 15. Storys at Rossarden Bridge |
| 5. Storys below Tailings Dam | 16. Aberfoyle Creek above workings |
| 6. Side Creek - wetlands inflow | 17. No.2 Adit |
| 7. Side Creek - wetlands outflow | 18. Aberfoyle below No.2 Adit |
| 8. Storys below Side | 19. No.4 Adit |
| 9. Eastern Hill - wetlands inflow | 20. Aberfoyle below No.4 Adit |
| 10. Eastern Hill - wetlands outflow | 21. Eastern Hill Tailings Dam - pond only |
| 11. Storys below Eastern Hill | 28. Diversion Channel above Tailings Dam |
| 12. Nisbet Creek | |

1 grid space to 1km

5 cm

3.3 Water Quality and Pollutant Indicators

3.3.1 Water Quality

The historical water quality data was limited in the elements analysed, the detection limits and lacked supporting flow data. The data has been collected by a variety of groups and individuals with little consistency in:

- Sampling sites;
- Sampling frequency;
- Analytes; and
- Detection limits and analysis precision.

The data collected to date allows only a cursory assessment of patterns, loads and priority contaminants in the system. None of the data collected allows a viable assessment of:

- Trends or changes in water quality with time, particularly over 10 - 30 year periods (except in the Storys Creek);
- Trends in water quality in space, particularly in relation to changes downstream of Storys Creek in the South Esk River;
- Relationships between analyte concentrations or loads and floods;
- Seasonal patterns in analyte concentrations or loads;
- Relative balances of total and filterable/bio-available metals.

The above comments relate to analytes associated with the Storys Creek - Aberfoyle Creek catchments. Data on water quality associated with the South Esk River is even less suitable for assessment of changes in time or space due to impacts such as land clearing, grazing and irrigation, riparian impacts, channel erosion and Story Creek inputs.

There are some indications that there have been improvements in water quality over time. Comparison of Norris's water quality data with the recent DELM (1996-97) data suggests that water quality may have changed slightly since 1975-76, although both data sets have low sample numbers making further comparison and/or correction for flow conditions unwarranted. A review of the water quality data in Storys Creek, pre-1990 and post-1990 appears to indicate a reduction in pollutant loads (see later discussion).

3.3.2 Pollutant Indicators

From the results of the few complete analyses, the data confirms that aluminium, cadmium, iron, copper, manganese and zinc are the main soluble metals and sulphate is the dominant anion. Calcium and magnesium are also major cations with magnesium generally occurring at higher concentrations than calcium. Sodium and chlorine are generally low, but fluorine is elevated.

The concentration of other elements of potential environmental concern such as Pb, As and Hg are generally below detection or at very low concentrations.

The data confirms that the primary indicators of acid drainage and sulphide oxidation at Storys Creek are pH, sulphate, iron, aluminium, zinc, cadmium and copper. Manganese is a secondary indicator.

The Aberfoyle Creek waters are neutral, with mine drainage contributing metals, but at

TABLE 3.1: WATER QUALITY DATA: STORIES CREEK, ABERFOYLE CREEK AND SOUTH ESK RIVER
 COMPILATION OF HISTORICAL DATA - MEDIANS (mg/L)

STATION	DESCRIPTION	SOURCE	COLLECTION PERIOD		Number Samples	pH		TDS mg/L	TSS mg/L	FLOW l/sec	Al	Cd	Cu	Fe all mg/L	Mn	SO4	Zn	
			from	to		lab/field												
10	SC above mine	a	Apr-82	May-90	7	5.9	L		32					0.10	2.0	0.10		
10	SC above mine	c	-	Dec-84	1†	8	L	44					0.10	0.10	1.0	0.10		
11	SC above PPT dam	a	May-81	Dec-87	8	7.1	L		1				0.0005†	0.005†	11	0.086†		
11	SC above seep from ppt	b	Nov-84	Oct-95	11	7.1	L			15.00			0.001	0.002	0.02	0.01	5.0	0.04
12	SC at PPT dam Q/F	a	Jul-75	Feb-77	10	6.6	F	1105										
	seepage from ppt dam	b	Dec-84	Oct-95	21	5.8				0.50			0.425	0.560	7.88	2.90	167.5	12.50
	PPT dam seepage	c	-	Dec-84	1†	6.3	L	380						0.10	3.60	185.0	18.00	
13	SC below PPT dam	a	May-81	Sep-90	9				3.35				0.530		10.8†		10.22	
13	SC below PPT dam	b	Nov-84	Oct-95	13	6.6	L			15.25			0.016	0.029	0.13	0.06	9.5	0.53
13	SC below PPT dam	c	-	Dec-84	1†	6.6	L	51			0.20		0.20	0.20	8.4	0.70		
14	SC mine water	a	Jul-75	Feb-77	10	6.8	F	1380										
	SC at ford opp. tails	c	-	Dec-84	1†	4.8	L	110					2.00	5.00	54.0	5.30		
15	SC above Side	a	-	Sep-90	1†								0.060				3.20	
22	Side above SC	a	May-82	May-90	14													
22	Side Ck	b	Nov-94	Oct-95	5	3.3	L			1.50			0.310	0.485	5.10	2.05	156.0	9.10
22	Side Ck	c	-	Dec-84	1†	2.8	L	1130			12.50			39.00	11.00	670.0	50.00	
16	SC at Side conf	a	-	Sep-90	1†								0.360				10.00	
17	SC below Side	a	Dec-84	Sep-90	13													
17	SC below Side	b	Dec-84	Oct-95	18	4.9	L			17.00			0.110	0.278	0.90	0.55	47.0	3.45
17	SC below Side	c	-	Dec-84	1†	4	L	180			3.70			5.20	1.50	110.0	23.00	
	Eastern Hill Adit	b	Nov-94	Feb-95	3	4.2				0.50			0.310	0.003	131.00	18.60	1460.0	18.60
	SC below East Hill	b	-	Jun-95	1†	nr				20.00			0.070	0.178	0.91	0.98		2.35
	SC above Nisbet	c	-	Dec-84	1†	3.8	L	340						3.10	3.30	200.0	16.00	
	Nisbet Ck	c	-	Dec-84	1†	7.7	L	72					0.10	0.10	2.0	0.10		
	SC below Nisbet	c	-	Dec-84	1†	4.4	L	210					3.50	2.00	120.0	10.00		
	SC at Ross pump	c	-	Dec-84	1†	4.5	L	185			2.80		1.80	1.50	95.0	7.50		
18	SC at Ross bridge	a	May-81	May-90	17	4.6	L	150	2.55				0.029		1.20	81.0	8.10	
18	SC at Ross bridge	b	Apr-82	Jan-96	29	4.8	L	113					0.060	0.230	0.75	0.51	53.0	2.38
18	SC at Rossarden	c	-	Dec-84	1†	4.6	L	160					1.40	1.20	93.0	7.50		
20	SC above AC	a	Apr-82	May-90	29	5.9	F	115	1.0	25.20			0.085		0.40	52.2	4.10	
	SC at Freemans	c	-	Dec-84	1†	4.6	L	130			2.10			0.10	9.00	63.0	6.70	
21	SC below AC	a	Apr-82	Nov-91	21	6.25	F	130	5.6	78.00			0.050		0.30	62.5	1.50	
	AC at Mangana Rd	c	-	Dec-84	1†	6.5	L	34					0.1	0.10	1.0	0.10		
31	AC above mine	a	Nov-84	Dec-87	6	6.7†	L		3.3†				0.001			1.0	0.02	
32	AC mine water	a	Jul-75	Feb-77	8	6.8	L	1005										
33	AC at tails Q/F	a	Jul-75	Feb-77	9	6.5	L	290										
	AC at spur	c	-	Dec-84	1†	6.5	L	73					4.50	0.20	25.0	0.60		
34	AC below Fraeman	a	Jul-75	Nov-91	10	6.9	L	155										
35	AC above SC	a	Apr-82	May-90	36	6.1	F	175	1	31.00			0.010		0.10	85.0	0.55	
35	AC above conf	c	-	Dec-84	1†	6.9	L	390			0.15			0.10	0.10	210.0	0.50	
	AC below conf	c	-	Dec-84	1†	6.8	L	290			0.20			0.10	0.40	160.0	2.80	
40	SESK above SC	a	Mar-86	Dec-87	5	5.9†	L		7.4†				0.001			7.5	0.26	
41	SESK below SC	a	Mar-86	Dec-87	5	5.9†	L		6.6†				0.010			10.0	0.47	
42	SESK at Aber bridge	a	Apr-86	May-94	12	6.8	L	67					0.010		0.10	5.0	0.10	
42	SESK at Aber bridge	c	-	Dec-84	1†	6.8	L	48						0.20	1.0	1.0	0.10	
	SESK at Avoca	c	-	Dec-84	1†	7	L	63					0.20	0.10	6.0	0.20		

† Data based on single event sampling
 a Helen Locher
 b DELM
 c Hugh Wellington

Table 3.2: Storys and Aberfoyle Creek Water Quality-October 1997.
(mg/L)

LOCATION refer Hydro report PARAMETER (mg/l)	ANZECC		ANZECC	ANZECC	Irrigation	2	3	4	5	6	8	9	10	11	12	13
	Drinking Toxicant	Non Toxic.	Aqu Life EQOs	Livestock		Storys above mine 975998	inflow 975999	PPT Dam outflow 976000	Storys below PPT Dam 976001	Side Creek 976002	Storys below Side 976003	Eastern Hill inflow 976004	Eastern Hill outflow 976005	Eastern Hill 976006	Storys below Eastern Hill 976007	Nisbet Creek 976008
SAMPLE DATE						2-Oct	3-Oct	2-Oct	2-Oct	2-Oct	2-Oct	2-Oct	2-Oct	2-Oct	2-Oct	2-Oct
FLOW L/sec						41	0.2	1	42	0.3	40	2.3	1.8		37	98
pH L		6.5-8.5	6.5-9		4.5-9.0	5.8	6.1	3.4	5.7	3.7	5.1	5.0	3.4	4.9	5.7	5.4
pH F						7.6	7.2	3.6	6.2	3.7	5.3	6.1	3.5	4.9	6.6	5.9
Acidity (CaCO3)						2	<1	227	5	35	20	69	76	25	<1	6
Alkalinity (CaCO3)						11	20	<1	4	<1	1	3	<1	<1	13	2
Cond µS/cm L			1500		0-500	23	42	908	64	254	141	665	786	197	35	109
Cond F						24	42	826	67	291	145	718	778	201	39	115
TDS		1000		3000	0-800 ok	26	44	692	54	149	99	502	516	155	24	85
NFR (suspended solids)						<1	<1	59	11	<1	5	60	36	5	<1	7
DOC mg/L						1.4	1.0	1.8	0.5	2.2	0.8	0.5	0.7	0.4	0.8	0.4
Hardness (CaCO3)		500				7	14	197	17	53	37	247	255	56	11	32
Ca T				1000		2.0	3.0	44.0	4.0	12.0	9.0	55.0	57.0	14.0	2.0	8.0
Cl						1.6	2.3	17.0	1.8	3.4	1.8	3.8	3.9	2.0	2.0	2.0
F				2	1	<0.02	0.02	12.00	0.56	5.30	1.40	6.10	6.00	1.40	0.02	0.77
K T						0.1	0.2	0.9	0.2	0.9	0.3	1.0	1.0	0.3	0.1	0.2
Mg T				600		0.7	2.0	21.0	2.0	6.0	3.0	26.0	27.0	5.0	1.0	3.0
Na T		300				2.0	2.0	4.0	2.0	3.0	2.0	6.0	6.0	3.0	2.0	2.0
SO4		400		1000		0.54	0.72	498.00	22.00	94.00	60.00	361.00	355.00	91.00	2.00	40.00
Metals																
Al T		0.2	<0.005 (PH <6.5)	5	5	0.1	0.1	10.0	0.7	3.0	2.0	2.0	2.0	2.0	0.1	1.0
Al F			<0.1 (PH >6.5)			<0.1	0.1	9.0	0.1	3.0	1.0	2.0	2.0	2.0	0.1	0.4
As T	0.05			0.5	0.1	<0.001	<0.001	0.006	<0.001	<0.001	<0.001	0.019	0.004	<0.001	<0.001	<0.001
As F			0.05			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001
Cd T	0.005			0.01	0.01	<0.001	0.001	2.550	0.083	0.143	0.158	0.123	0.123	0.158	<0.001	0.080
Cd F			0.0002-0.002			<0.001	0.010	2.450	0.077	0.139	0.154	0.121	0.121	0.155	<0.001	0.077
Cr T	0.05			1	1	<0.001	<0.001	0.005	<0.001	<0.001	<0.001	0.002	0.002	<0.001	<0.001	<0.001
Cr F			0.01			<0.001	<0.001	0.003	<0.001	<0.001	<0.001	0.002	0.002	<0.001	<0.001	<0.001
Cu T		1		0.5	0.2	<0.001	0.003	5.620	0.194	0.174	0.464	0.003	0.003	0.487	0.001	0.259
Cu F			0.002-0.005			0.001	0.002	5.420	0.086	0.169	0.438	0.005	0.002	0.468	0.001	0.223
Fe T		0.3			1	<0.1	<0.1	30.0	3.0	0.2	3.0	48.0	24.0	4.0	<0.1	1.0
Fe F			1			<0.1	<0.1	8.0	<0.1	0.1	2.0	13.0	9.0	3.0	<0.1	0.3
Hg T	0.001			0.002	0.002	<0.0001	<0.0001	0.003	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Hg F			0.0001			<0.0001	<0.0001	*	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Mn T		0.2			2	<0.1	<0.1	6.0	0.2	0.9	0.6	6.0	6.0	1.0	<0.1	0.6
Mn F						<0.1	<0.1	6.0	0.2	0.9	0.6	0.0	6.0	1.0	<0.1	0.5
Ni T	0.1			1	0.2	<0.001	0.001	0.087	0.005	0.022	0.012	0.081	0.082	0.018	<0.001	0.009
Ni F			0.015-0.15			<0.001	<0.001	0.076	<0.001	0.014	0.004	0.071	0.075	0.015	<0.001	<0.001
Pb T	0.05			0.1	0.2	0.001	0.001	0.110	0.006	0.003	0.006	0.003	0.002	0.012	<0.001	0.008
Pb F			0.001-0.005			<0.001	0.001	0.102	0.001	0.002	0.004	<0.001	0.001	0.010	<0.001	0.002
Sb T						<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sb F						<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sn T						<0.010	<0.010	0.134	0.013	<0.010	<0.010	0.243	0.115	0.012	<0.010	<0.010
Sn F						<0.010	<0.010	0.041	<0.010	<0.010	<0.010	0.059	0.033	0.014	<0.010	0.011
Zn T		5		20	2	<0.001	0.052	61.800	2.430	4.140	4.540	7.420	7.310	4.920	0.015	2.500
Zn F			0.005-0.05			0.004	0.051	58.400	2.300	4.070	4.460	7.280	7.230	4.790	0.020	2.434

EQOs in BOLD

L Lab
F Field
T Total
F Filtered

Table 3.2: Storys and Aberfoyle Creek Water Quality-October 1997.
(mg/L)

LOCATION	14	15	16	17	18	19	20	21	22	23	1	27	24	25	26	28
refer Hydro report	Storys	Storys at	Aberfoyle Creek	No 2	Aberfoyle	No 4	Aberfoyle	Eastern Hill	Aberfoyle	Storys above	Storys below	Storys above	South Esk	South Esk	South Esk	Channel
PARAMETER (mg/l)	below pumphouse	Rossarden	above workings	Adit	below No 2	Adit	below No 4	Tailings Dam	above Storys	Aberfoyle	Aberfoyle	South Esk	above Storys	below Storys	at Lewellyn	above PPT Dam
	976009	976010	976011	976012	976013	976014	976015	976016	976017	976018	975997	976022	976019	976020	976021	976023
SAMPLE DATE	3-Oct	3-Oct	3-Oct	2-Oct	2-Oct	2-Oct	2-Oct	3-Oct	3-Oct	2-Oct						
FLOW L/sec	153	216	89	0.25	117	6.5	144		174	220	394	470	10230	10701	12540	0.12
pH L	5.3	5.7	6.3	6.0	6.1	6.9	6.7	3.6	6.7	5.6	6.0	6.4	6.5	6.4	6.4	4.8
pH F	5.8	5.9	7.6	5.9	6.6	7.0	7.0	3.7	7.0	6.0	6.9	6.9	7.2	7.2	7.3	5.0
Acidity (CaCO3)	8	5	<1	18	<1	21	<1	40	<1	6	<1	<1	<1	<1	<1	35
Alkalinity (CaCO3)	1	1	18	5	15	360	59	<1	43	1	13	16	17	17	18	<1
Cond µS/cm L	98	82	40	1100	70	1130	237	227	193	71	107	119	74	76	81	285
Cond F	100	84	41	1018	71	1165	242	243	197	72	109	122	76	78	83	290
TDS	63	61	37	930	40	668	153	97	126	47	80	87	48	56	59	246
NFR (suspended solids)	6	3	<1	2	1	50	6	<1	<1	<1	<1	<1	2	2	1	11
DOC mg/L	1.2	2.4	2.3	2.0	1.5	2.3	1.4	0.4	2.0	2.0	2.3	1.7	2.4	2.3	2.6	1.4
Hardness (CaCO3)	27	13	13	573	22	594	99	20	79	17	35	42	17	18	20	85
Ca T	6.0	5.0	3.0	123.0	5.0	127.0	21.0	5.0	17.0	4.0	8.0	9.0	3.0	3.0	4.0	17.0
Cl	2.3	3.0	2.5	3.2	2.8	5.1	3.2	0.8	3.8	3.7	3.7	3.7	11.0	10.0	11.0	3.5
F	0.56	0.40	0.02	3.90	0.17	6.30	1.00	4.10	0.78	0.29	0.47	0.48	<0.02	0.03	0.03	0.59
K T	0.3	0.4	0.2	4.0	0.3	3.0	0.7	0.5	0.7	0.5	0.6	0.6	0.6	0.6	0.6	0.8
Mg T	3.0	2.0	1.0	64.0	3.0	67.0	11.0	2.0	9.0	2.0	4.0	5.0	2.0	2.0	3.0	10.0
Na T	3.0	3.0	3.0	3.0	3.0	11.0	4.0	0.6	4.0	4.0	4.0	4.0	7.0	7.0	8.0	3.0
SO4	36.00	26.00	1.40	604.00	15.00	362.00	61.00	73.00	48.00	19.00	27.00	30.00	1.80	2.80	2.70	132.00
Metals																
Al T	0.9	0.6	0.1	1.0	0.4	0.9	0.4	2.0	0.2	0.4	0.4	0.3	0.3	0.3	0.4	3.0
Al F	0.4	0.3	0.1	0.6	0.1	0.4	0.1	2.0	0.1	0.2	0.1	0.1	0.2	0.2	0.2	2.0
As T	<0.001	<0.001	0.002	0.013	0.002	0.069	0.010	0.002	0.003	0.001	<0.001	0.001	0.001	0.001	0.001	0.001
As F	<0.001	<0.001	<0.001	0.002	0.002	0.002	0.005	0.003	0.002	0.002	<0.001	0.001	0.001	0.001	0.001	0.001
Cd T	0.079	0.060	<0.001	0.423	0.012	0.047	0.018	0.446	0.014	0.048	0.038	0.033	<0.001	0.001	0.001	0.339
Cd F	0.075	0.060	<0.001	0.406	0.011	0.030	0.013	0.428	0.012	0.046	0.034	0.030	<0.001	0.001	0.001	0.328
Cr T	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cr F	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cu T	0.262	0.193	0.001	0.545	0.083	0.228	0.086	0.997	0.028	0.097	0.067	0.058	0.001	0.004	0.005	0.014
Cu F	0.238	0.172	0.001	0.304	0.035	0.010	0.013	0.954	0.013	0.080	0.044	0.029	0.002	0.004	0.004	0.014
Fe T	0.8	0.4	0.2	0.4	0.2	19.0	3.0	0.7	0.5	0.1	0.3	0.3	0.3	0.3	0.3	<0.1
Fe F	0.4	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	0.7	<0.1	<0.1	<0.1	<0.1	0.1	0.1	0.1	<0.1
Hg T	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Hg F	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Mn T	0.4	0.3	<0.1	2.0	0.2	10.0	1.0	1.0	0.4	0.2	0.3	0.2	<0.1	<0.1	<0.1	3.0
Mn F	0.4	0.3	<0.1	2.0	0.2	10.0	1.0	1.0	0.4	0.2	0.3	0.2	<0.1	<0.1	<0.1	3.0
Ni T	0.007	0.005	<0.001	0.078	0.004	0.075	0.014	0.016	0.007	0.004	0.004	0.005	0.002	0.001	0.001	0.053
Ni F	<0.001	<0.001	<0.001	0.066	<0.001	0.058	0.004	0.006	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.050
Pb T	0.050	0.002	<0.001	0.021	<0.001	0.003	0.002	0.062	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Pb F	0.002	<0.001	<0.001	0.007	<0.001	0.001	<0.001	0.059	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.001
Sb T	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sb F	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sn T	0.026	<0.010	<0.010	0.015	<0.010	0.082	<0.010	<0.010	0.015	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sn F	0.011	<0.010	<0.010	<0.010	<0.010	0.012	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Zn T	2.330	1.810	0.001	14.200	0.500	4.330	0.966	12.400	0.549	1.420	1.120	0.991	0.003	0.040	0.032	17.000
Zn F	2.280	1.770	0.008	13.600	0.460	2.960	0.706	12.000	0.457	1.380	1.030	0.896	0.007	0.034	0.035	17.700

an alkaline pH, with residual alkalinity. This is an important buffering source for the acid Storys Creek waters prior to the South Esk River junction.

The acidity in drainage waters is due mainly to iron, aluminium, manganese and zinc.

The overall message from the existing water quality data is:

- Storys Creek above Aberfoyle Creek and Aberfoyle Creek upstream of Storys Creek are significantly contaminated with zinc, cadmium, copper and aluminium in both total and dissolved (i.e. filterable at 0.45 micron) forms;
- Storys Creek has contributed and continues to contribute environmentally significant loads and concentrations of zinc, cadmium and aluminium to the South Esk River, with occasional high concentrations of copper.
- Most of the above metals are in filterable form, but the degree to which these metals are truly in dissolved form and hence toxic to aquatic life is unknown.
- Significant loads of iron and aluminium, in flocculated hydroxide forms, are present within Aberfoyle and lower Storys Creeks, and these are deposited both within the Creek channels and in the South Esk River.
- Total concentrations of metals decrease downstream in the South Esk River from the Storys Creek junction.
- Inputs from Storys Creek have been responsible for metal contaminated sediments deposited within and outside the South Esk River channel, the environmental significance of which is unknown.

Table 3.1 shows the summary of all the historical data. Appendix A contains the water quality data report and the complete data base is in an Excel workbook format.

A 'snap shot' water quality and flow sampling was carried out in October 1997 at 25 sites within the study area to confirm water quality and flow data. This is generally consistent with the data presented in Locher (1993) and by more recent data collected by DELM and DPIF.

Table 3.2 shows the October sampling results.

Based on this water quality sampling, zinc, cadmium and copper exceed the Environmental Quality Objectives (EQOs - see section for discussion) for aquatic life for these metals in Aberfoyle Creek and Storys Creek. In the South Esk, only copper slightly exceeds the EQOs (cadmium detection limits are not low enough for comparison). Cu is also elevated above the confluence.

For other uses - livestock, irrigation and drinking water - only cadmium exceeds the ANZECC criteria in Storys Creek - Aberfoyle Creek.

3.4 Pollutant Loads and Source Evaluation

The monitoring data has been analysed to provide median values for the data. At many locations there is no flow data and the means of measuring uncertain. The HEC have established expected mean flows for the various catchments.

Acidity has not been directly measured in many cases and could not be calculated from the dissolved metal concentrations and pH, because of the lack of data. The acidity data is critical for evaluating the alkalinity requirement for treatment of acid drainage sources.

Therefore the October sampling results were used to calculate load estimates for zinc, cadmium, copper, iron, sulphate, acidity and alkalinity. These are discussed below for each catchment. The load values are only a once-off, but the comparison with previous data gives some confidence in the calculations. These provide the data to evaluate the pollutant sources and their significance.

3.4.1 Storys Creek Catchment

The Storys Creek catchment comprises the main acid drainage sources. These are the diffuse sources from tailings and waste materials on the edge (such as the jig tailings) and within the creek itself, Precipitate Dam leachates, Side Creek Adit discharges, Eastern Hill Adit discharges.

The creek has a long history of disturbance and transport of mine waste materials, being disturbed by past alluvial mining, massive flooding (1929 flood was a 1:10,000 year event) and tailings and mine water discharges.

From aerial photography and site inspections, the majority of waste materials are deposited in the stream bed between the mine and Rossarden township. After the township, the stream gradient increases, and it would appear that most of the waste materials have been distributed down the catchment. The water quality data also supports this, as the major metal inputs occur prior to Rossarden.

Table 3.2 shows the water quality values from the October sampling, for each monitoring site along Storys Creek to the South Esk River. These sites are shown on Figure 3.4 which is an enlarged scale of the Storys Creek section from Figure 3.3.

The estimated acidity, zinc, cadmium, copper, and sulphate loads within Storys Creek are shown on Table 3.3. Loads are shown for measured flows.

The data shows that the major metal loads are from the materials deposited in the creek (with the majority of the loads occurring prior to Rossarden), and that the point source loads - such as the Precipitate Dam and the drainage from the Storys Creek mine workings and Eastern Hill Adit are not the major source. It is noted that the visible drainage from the Side Creek adits, is much smaller than expected. This is attributed to subsurface drainage to the creek baseflow, and is reflected in the increased loads in Storys Creek below Side Creek.

Figure 3.5 shows the estimated loads in Storys Creek as the % of the loads at Rossarden.

A review of the Precipitate Dam water quality data indicates that the pH has declined from 5.3 to 7 in 1985 to approximately 5.7 in 1997. Iron concentrations (and therefore acidity) have increased significantly as have Zn, Cd, Cu and all metals. There is insufficient data (principally flow data) to quantify the effects of the capping carried out in 1994, but it is noted that Bill Bourke (DELM) believes that seepage rates have declined (from personal observations). This may account for the increased metal and acidity concentrations, but it is considered likely that loads may be similar, if not higher due to the acidification of the materials. It is noted that the water levels in the dam responds to seasonal influences and that there has been no declining trends. This demonstrates that the capping has been largely ineffective in reducing infiltration, but may have had beneficial effects on surface runoff quality.

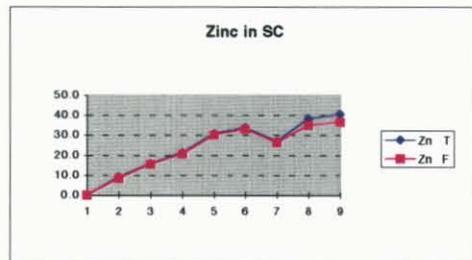
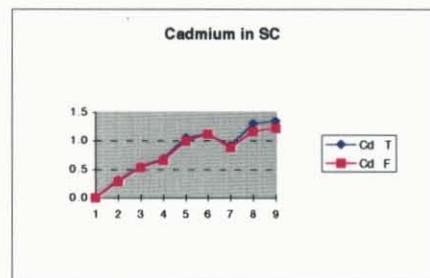
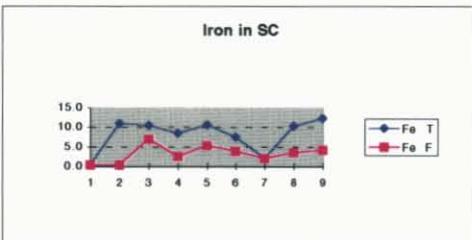
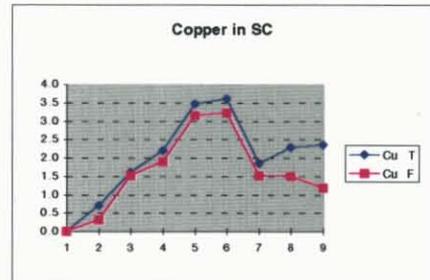
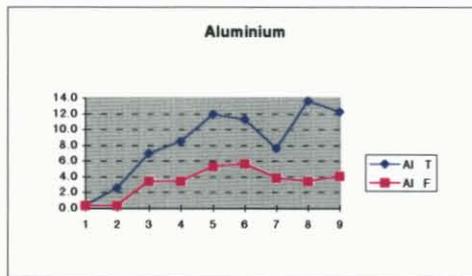
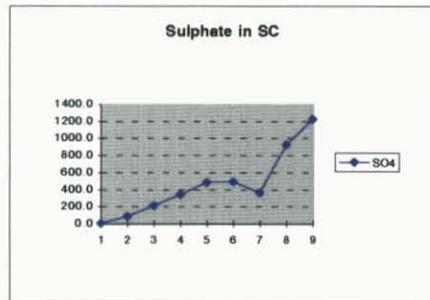
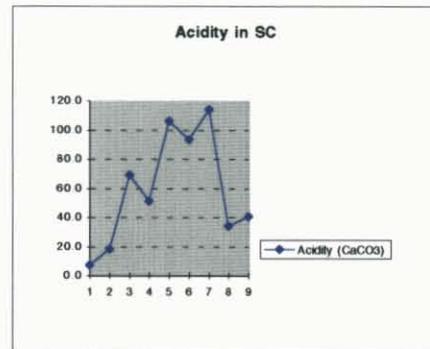
There appears to be a trend in improved water quality in Side Creek, from the initial sampling in 1982 to the present. This possibly is partly due to a reduction in the overall oxidation rate within the old workings over time as the more reactive sulphides are oxidised. The constructed wetlands are having no beneficial effects on water quality, due to the acidity of the waters.

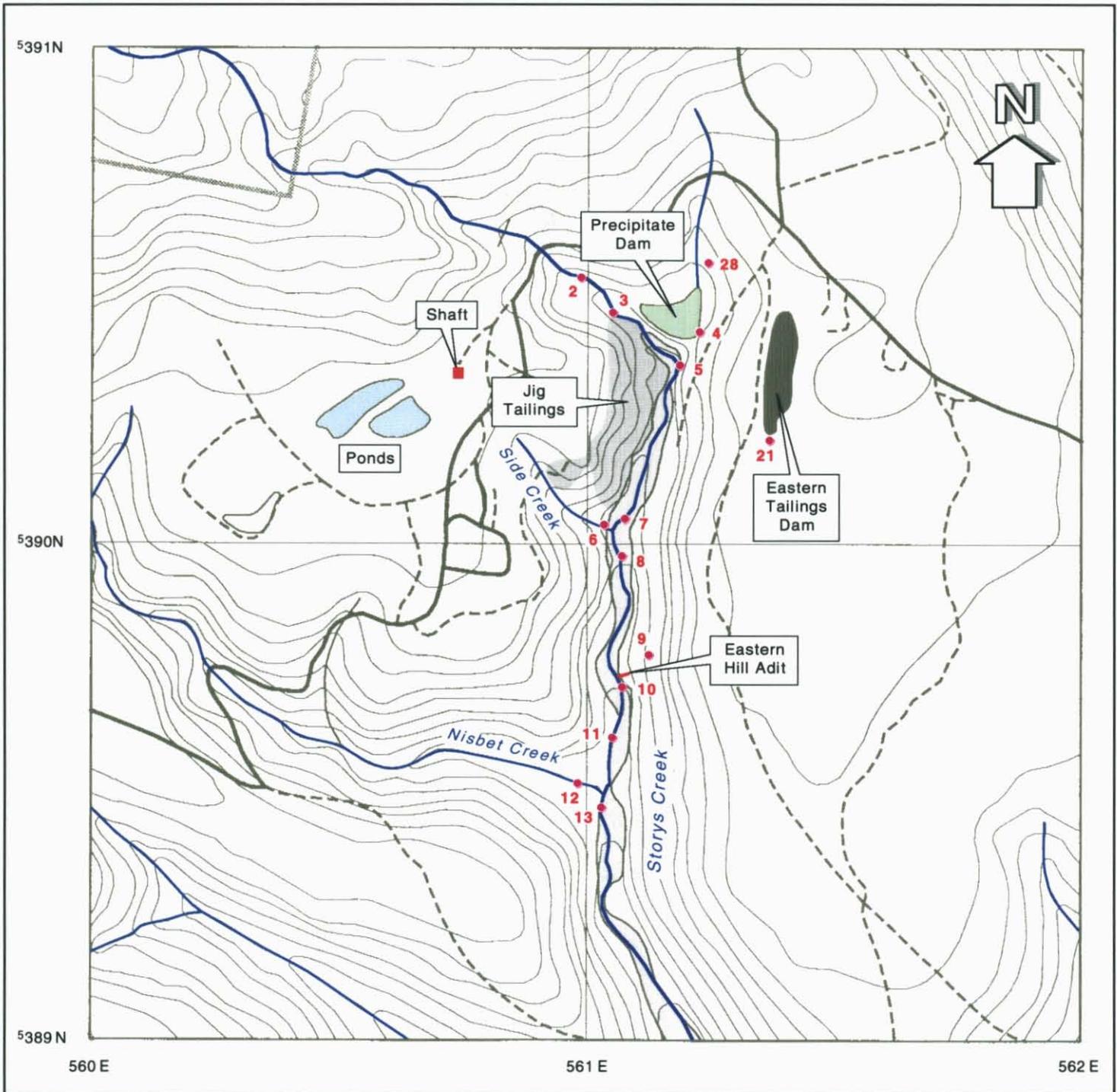
The Eastern Hill Adit contributes metal loads, again the wetlands are having no beneficial effects on water quality.

An oxidised (brown colour) and unoxidised (grey colour) sample of creek-bank deposited tailings was collected from Storys Creek below the mine managers residence (Site 14, Figure 3.1). The samples were analysed for pH, electrical conductivity and acidity (on a 1 part sample to 2 parts deionised water); and total sulphur, acid neutralising capacity (ANC) and the net acid generation (NAG) test. The test results are presented in Table 3.4.

Table 3.3 Acid Drainage and Metals Loads in Storys Creek
1097 data

LOCATION	1	2	3	4	5	6	7	8	9
refer Hydro report	SC ab M	SC b TD	SC b Side	SC b NC	SC b res	SC at Ros	SC a AC	SC b AC	SC a SE
PARAMETER	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
SAMPLE DATE									
FLOW L/sec	41	42	40	98	153	216	220	394	470
pH L	5.8	5.7	5.1	5.4	5.3	5.7	5.6	6.0	6.4
pH F	7.6	6.2	5.3	5.9	5.8	5.9	6.0	6.9	6.9
Acidity (CaCO3)	7.1	18.1	69.1	50.8	105.8	93.3	114.0	34.0	40.6
Alkalinity (CaCO3)	39.0	14.5	3.5	16.9	13.2	18.7	19.0	442.5	649.7
NFR (suspended solids)	3.5	39.9	17.3	59.3	79.3	56.0	19.0	34.0	40.6
Hardness (CaCO3)	24.8	61.7	127.9	271.0	356.9	242.6	323.1	1191.5	1705.5
SO4	1.9	79.8	207.4	338.7	475.9	485.2	361.2	919.1	1218.2
Metals									
Al T	0.4	2.5	6.9	8.5	11.9	11.2	7.6	13.6	12.2
Al F	0.4	0.4	3.5	3.4	5.3	5.6	3.8	3.4	4.1
Cd T	0.0	0.3	0.5	0.7	1.0	1.1	0.9	1.3	1.3
Cd F	0.0	0.3	0.5	0.7	1.0	1.1	0.9	1.2	1.2
Cr T	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cr F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cu T	0.0	0.7	1.6	2.2	3.5	3.6	1.8	2.3	2.4
Cu F	0.0	0.3	1.5	1.9	3.1	3.2	1.5	1.5	1.2
Fe T	0.4	10.9	10.4	8.5	10.6	7.5	1.9	10.2	12.2
Fe F	0.4	0.4	6.9	2.5	5.3	3.7	1.9	3.4	4.1
Hg T	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hg F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mn T	0.4	0.7	2.1	5.1	5.3	5.6	3.8	10.2	8.1
Mn F	0.4	0.7	2.1	4.2	5.3	5.6	3.8	10.2	8.1
Ni T	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2
Ni F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pb T	0.0	0.0	0.0	0.1	0.7	0.0	0.0	0.0	0.0
Pb F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sb T	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2
Sb F	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2
Sn T	0.0	0.0	0.0	0.1	0.3	0.2	0.2	0.3	0.4
Sn F	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4
Zn T	0.0	8.8	15.7	21.2	30.8	33.8	27.0	38.1	40.2
Zn F	0.0	8.3	15.4	20.6	30.1	33.0	26.2	35.1	36.4





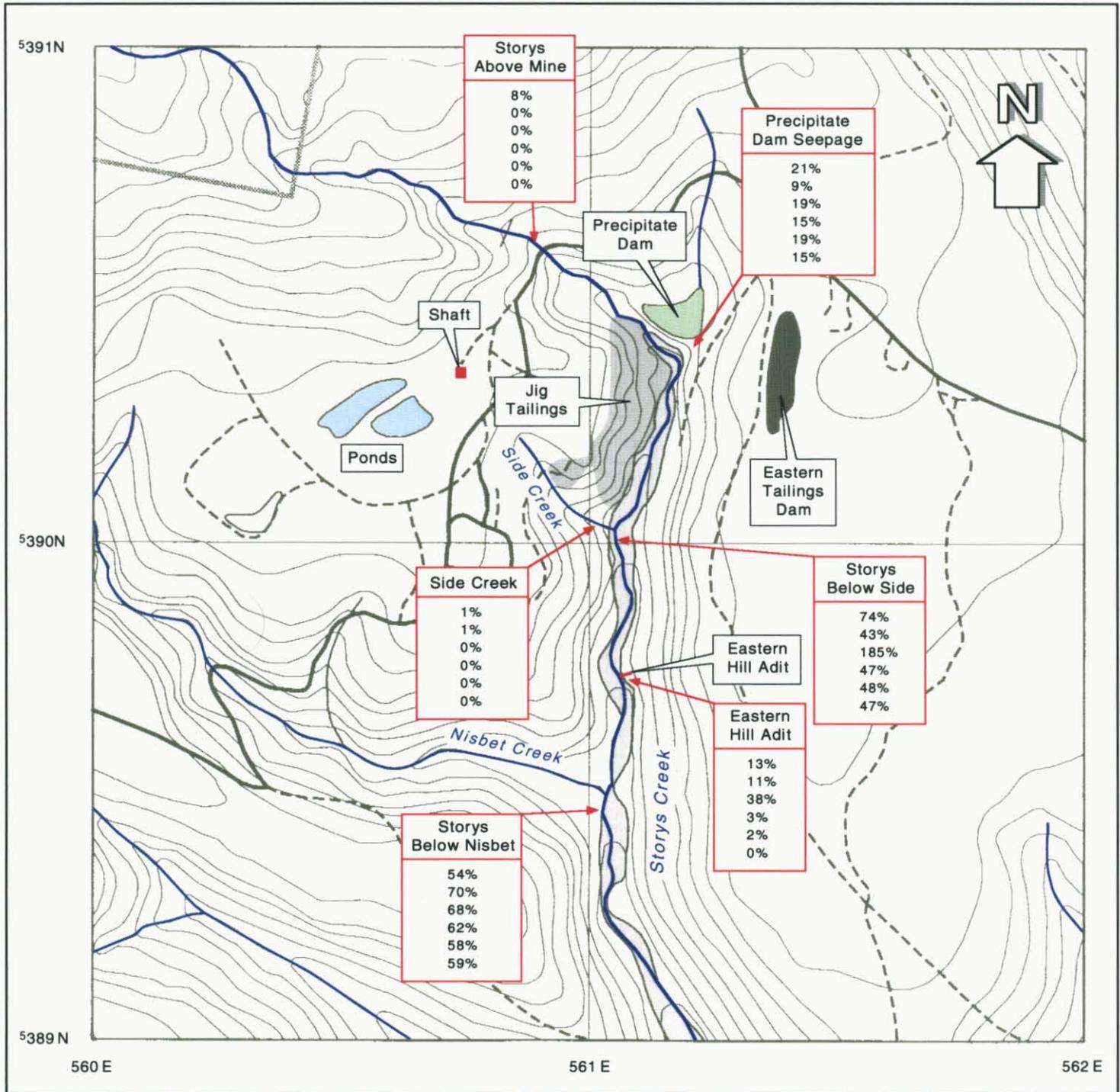
1 grid space to 1km

● 8 October water sampling site

5 cm

MINERAL RESOURCES TASMANIA
 Storys Creek & Rossarden AD Remediation Projects
 Storys Creek Mine Area
 John Miedecke & Partners P/L **FIG 3.4**

(December 1997)



1 grid space to 1km

Storys Below Rossarden	Legend
100%	Acidity
100%	SO ₄
100%	Fe
100%	Zn
100%	Cd
100%	Cu

5 cm

MINERAL RESOURCES TASMANIA
 Storys Creek & Rossarden AD Remediation Projects
 Storys Creek -Sources & Loads
 (% of loads in Storys Creek at Rossarden)
 John Miedecke & Partners P/L **FIG 3.5**

(December 1997)

Table 3.4: Acid Forming Characteristics of Storys Creek Tailings (Creek-bank deposit)

Sample	pH 1:2	EC 1:2 dS/m	Acidity 1:2 mgCaCO ₃ /L	Sulphur %S	ANC	NAPP	NAGpH
Oxidised	5.2	0.237	218	0.08	2	3	5.7
Unoxidised	5.9	0.113	27	0.04	1	-5	5.6

ANC, NAPP in kgH₂SO₄/t

Table 3.4 shows that the tailings have only a low S content (less than 0.1% S) but also have negligible ANC. The NAG pH values are greater than 4 which indicates that the samples are non-acid forming. However, since the tailings are essentially devoid of ANC, the pH of material represented by these samples would be expected decrease to about 4 to 5.5 as it oxidises (as indicated by the oxidised sample). Because of these low pH conditions, metal solubility can be relatively high and the large area of creek-bank deposited tailings is therefore a major ongoing potential source of soluble metals in the stream.

A review of water quality at Rossarden indicates that there is an improving trend. Table 3.5 shows that virtually all water quality parameters are indicating a reduction in concentrations, many improving by up to 50%.

This is partly attributed to a reduction in the overall oxidation rate as physically stable oxidation profiles develop over time in the creek-bank deposited tailings. Oxygen then has to diffuse to greater depths, reducing the oxygen flux to the grey unoxidised tailings. Re-exposure of the grey underlying tailings could, however, result in a reversal of this decreasing trend.

There is a similar pattern for the Storys Creek above Aberfoyle Creek Station (although with reduced data, where there is also an observed trend of improved water quality. Cd, Zn, Cu have reduced by greater than 50%. (See Table 3.6).

In all cases sulphate and acidity loads are low and amenable to passive treatment and insitu neutralisation to remove metals from solution.

3.4.2 Aberfoyle Creek

The catchment is shown on Figure 3.6 and extends from the monitoring site 16 at the head of the catchment to monitoring site 22 near the confluence with Storys Creek. The creek receives drainage from the No 1 Adit (also known as 2 Adit), from No 2 Adit on 4 Level (also referred to as No 4 Adit) and from drainage from tailings dams located in the catchment. Water quality is deleteriously affected below No 1 Adit, with water quality exceeding aquatic life guidelines.

Table 3.6 gives the median concentrations and estimated loads for acidity, alkalinity, zinc iron, copper and sulphate within the catchment. Figure 3.7 shows the % of loads.

The data indicates that the major sources of metals, sulphate and alkalinity are the mine drainage, in particular the No 4 Adit drainage, with a significant input from No 2 adit drainage and probably diffuse tailings leachates.

Table 3.5
Storys Creek Water Quality Trends

Storys Creek below Rossarden Bridge

	Date from	to	pH	TDS mg/L	SO4 mg/L	F mg/L	Cd mg/L	Cu mg/L	Zn mg/L	Fe mg/L	Mn mg/L
Median	Apr-82	May-90	5.4	100	50.5	0.9	0.109	0.7	3.105		0.6
No samples	15										
Median	Apr-95	Oct-97	5.9	61	26	0.4	0.063	0.202	2.2	0.71	0.459
No samples	13										

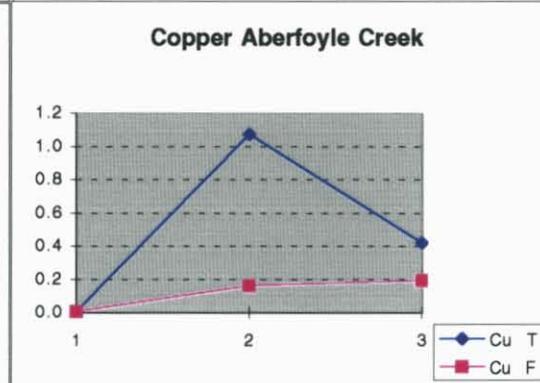
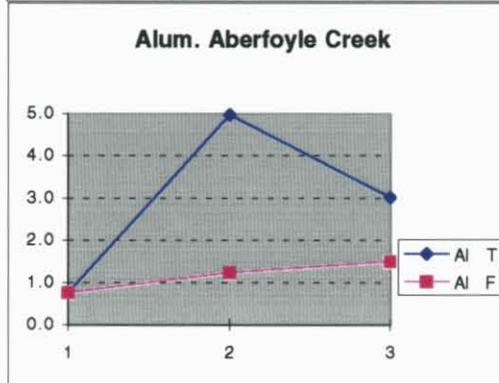
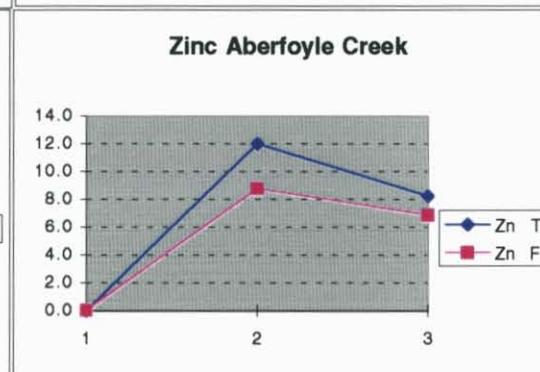
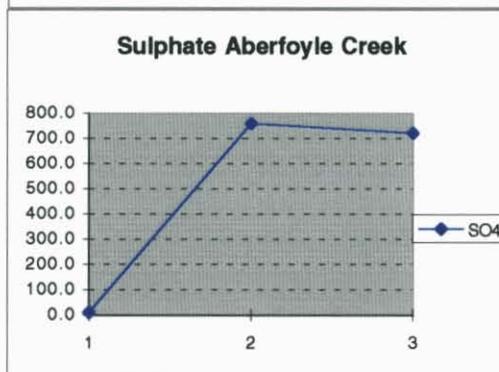
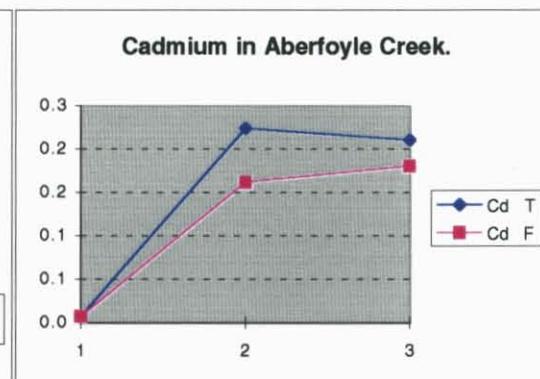
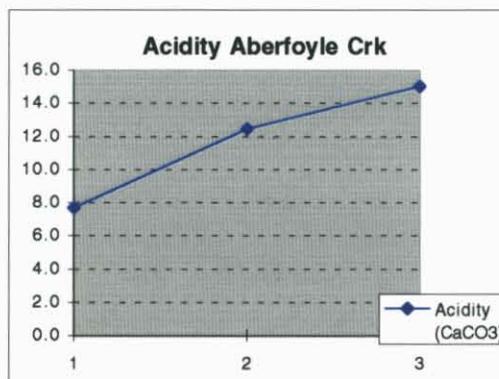
believed to be total metals.

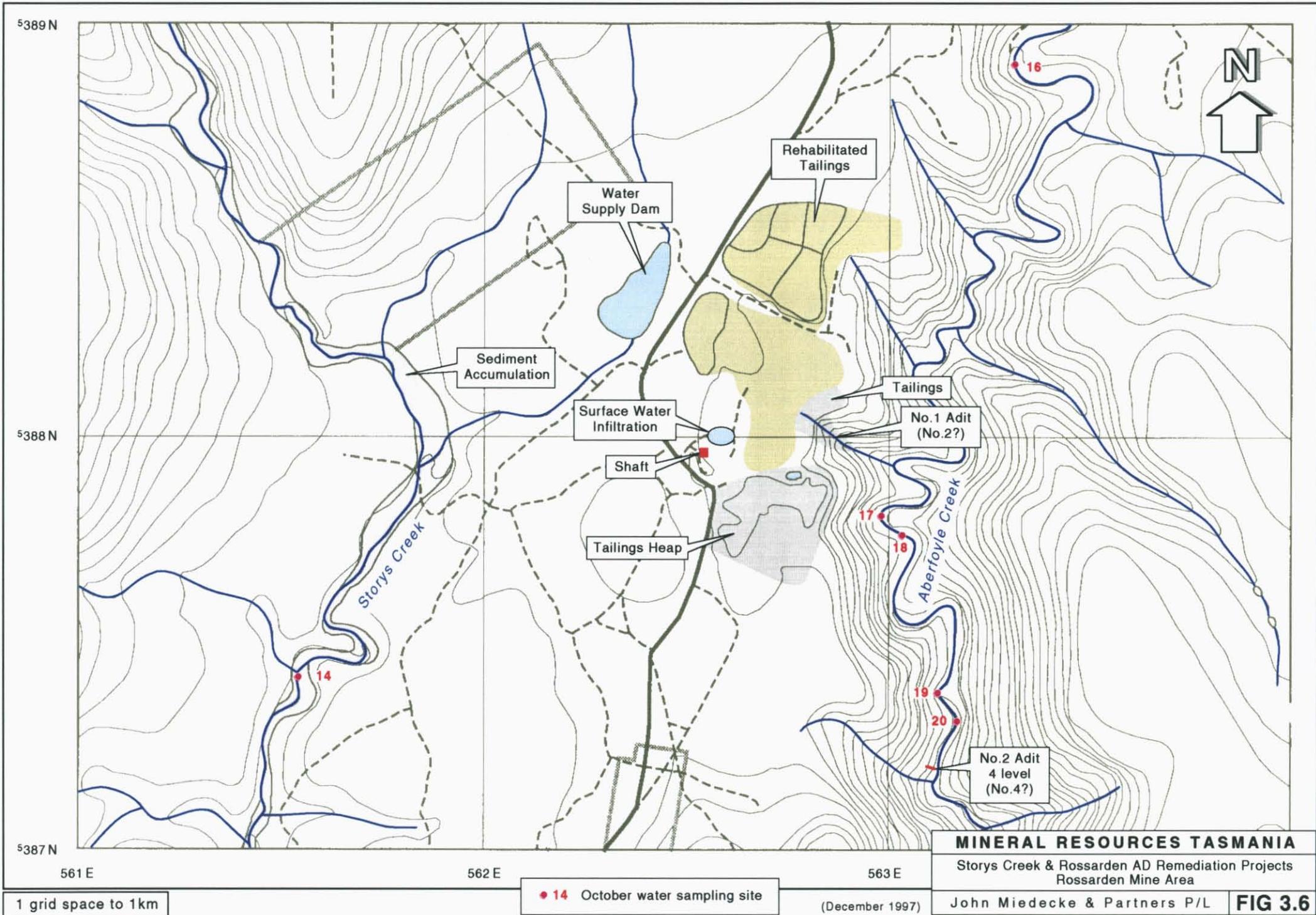
Storys Creek above Aberfoyle Creek

	Date from	to	Field pH	Filt. Res./ TDS	Sulphate SO4	F	Filt. Cd	Total Cu	Filt. Zn	Fe	Filt. Mn
Median	Apr-82	May-90	5.9	115	52.2	0.895	0.085	0.2975	4.1		0.4
No samples			11	29	29	28	8	14	15		15
Median	15/11/96	2/10/97	6	47	19	0.29	0.048	0.0935	1.43	0.28	
No samples			1	1	1	1	4	4	4	3	

Table 3.6 AD and Metal Loads in Aberfoyle Creek
1097 data

LOCATION refer Hydro report	1 AC a work kg/day	2 b 4 adit kg/day	3 AC a SC kg/day
PARAMETER			
SAMPLE DATE			
FLOW L/sec	89	144	174
pH L	6.3	6.9	6.7
pH F	7.6	7.0	7.0
Acidity (CaCO3)	7.7	12.4	15.0
Alkalinity (CaCO3)	138.4	734.1	646.4
NFR (suspended solids)	7.7	74.6	15.0
Hardness (CaCO3)	100.0	1231.7	1187.7
SO4	10.8	758.9	721.6
Metals			
Al T	0.8	5.0	3.0
Al F	0.8	1.2	1.5
Cd T	0.0	0.2	0.2
Cd F	0.0	0.2	0.2
Cr T	0.0	0.0	0.0
Cr F	0.0	0.0	0.0
Cu T	0.0	1.1	0.4
Cu F	0.0	0.2	0.2
Fe T	1.5	37.3	7.5
Fe F	0.8	1.2	1.5
Hg T	0.0	0.0	0.0
Hg F	0.0	0.0	0.0
Mn T	0.8	12.4	6.0
Mn F	0.8	12.4	6.0
Ni T	0.0	0.2	0.1
Ni F	0.0	0.0	0.0
Pb T	0.0	0.0	0.0
Pb F	0.0	0.0	0.0
Sb T	0.0	0.1	0.1
Sb F	0.0	0.1	0.1
Sn T	0.1	0.1	0.2
Sn F	0.1	0.1	0.2
Zn T	0.0	12.0	8.3
Zn F	0.1	8.8	6.9





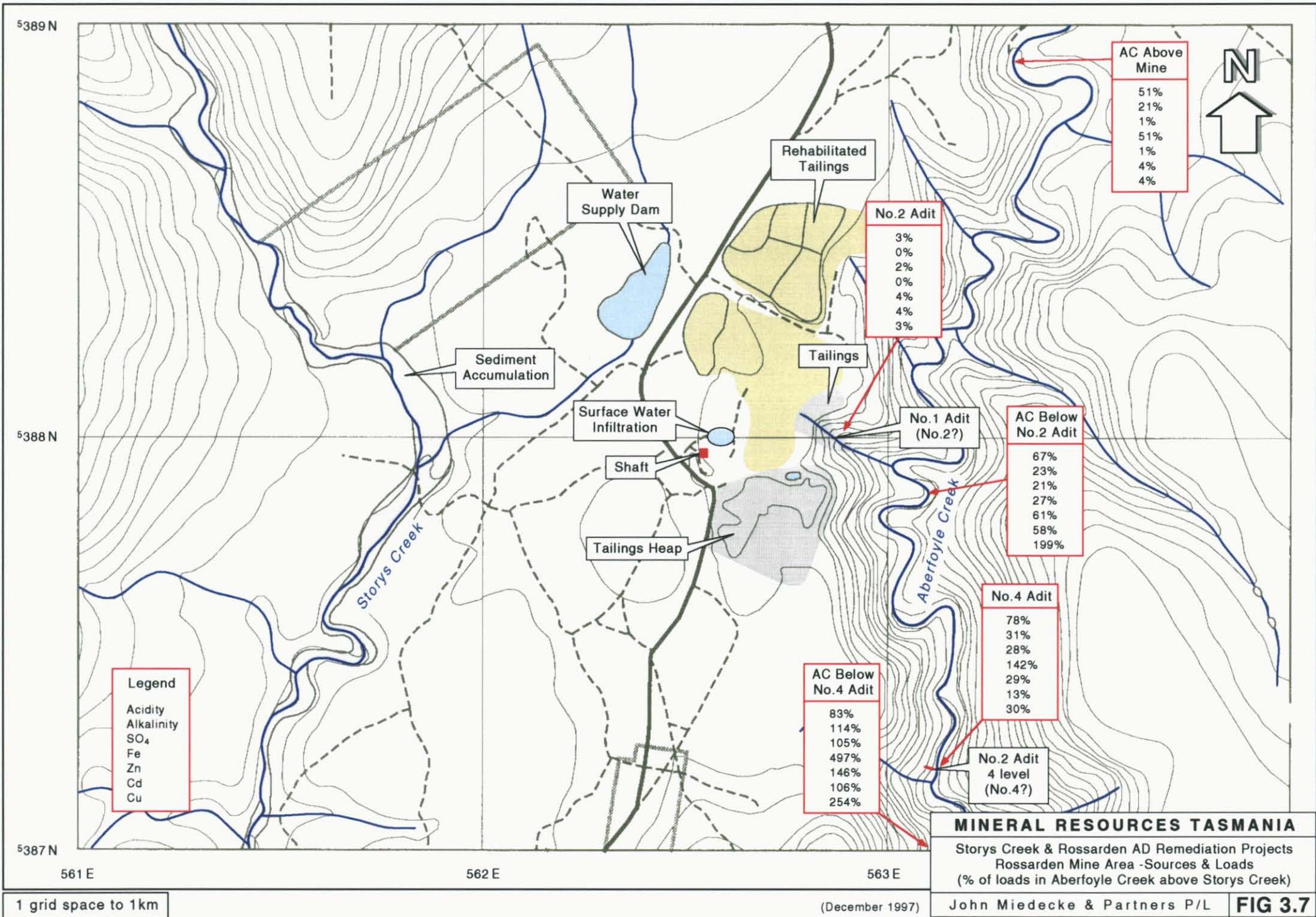
1 grid space to 1km

• 14 October water sampling site

(December 1997)

John Miedecke & Partners P/L

FIG 3.6



MINERAL RESOURCES TASMANIA
 Storys Creek & Rossarden AD Remediation Projects
 Rossarden Mine Area - Sources & Loads
 (% of loads in Aberfoyle Creek above Storys Creek)
 John Miedecke & Partners P/L **FIG 3.7**

(December 1997)

1 grid space to 1km

The creek alkalinity load is significant, with No 4 Adit contributing significant alkalinity.

3.4.3 Pollutant Load Summary

Table 3.7 and Figure 3.8 summarises the acidity, alkalinity, sulphate, iron, zinc, cadmium and copper load data for each catchment and the study area.

The data confirms that Storys Creek is the major pollutant source and contributes over 70% of the total Zn, Cd and Cu loads from the catchment, and most of the acidity. Aberfoyle Creek contributes lower loads of metals, but is a significant source of alkalinity, which buffers the Storys Creek acid drainage.

However, pollutant loads are relatively low (Zn 40 kg/day, Cd 1.3 kg/day), when compared to other areas of historical acid drainage - such as Mount Lyell (copper 2,500 kg/day). Sulphate and acidity loads are low.

The October sampling data indicates that the river deposited tailings contribute about 280 kgSO₄/day, while the mine site contributes approximately 200 kgSO₄/day. It is estimated that the area of deposited tailings is about 17ha, and therefore the sulphate release rate is about 16 kgSO₄/day. This indicates only a very low oxidation rate which is equivalent to the practical design target for closure of reactive sulphide waste rock and tailings at other sites. Since the oxidation rate is low, significant benefit would be achieved by applying crushed limestone at normal agricultural rates to the deposited tailings.

The South Esk is a significant contributor of sulphate, acidity and alkalinity, iron, copper and cadmium. Zinc is the major pollutant.

Within Storys Creek the major source of metals are not point sources, such as the Precipitate Dam, Side Creek Adits or Eastern Hill Adit, but the more diffuse sources within the creek itself - tailings waste rock etc. Most of the loads are above Rossarden, and therefore contribute most of the loads from the study area.

The previous works carried out in the Storys Creek catchment - such as the capping of the Precipitate Dam and the wetlands treatment of acid drainage from Side Creek and Eastern Hill Adit, are not believed to have significantly ameliorated the acid drainage. The use of aerobic wetlands to treat AD is not an appropriate technology and the capping does not appear to have reduced oxidation processes significantly.

However, there is an overall trend in improving water quality, attributed to an overall reduction in the oxidation rate per unit area of deposited tailings. This has resulted in an improvement in water quality and reduction in loads of probably in the order of 50%.

The acidity data suggests that the introduction of systems to provide alkalinity could be highly effective in ameliorating the residual acid drainage impacts in the Storys Creek catchment. Treatment of point sources would have beneficial effects.

In the Aberfoyle Creek catchment, loads are lower and not due to acid conditions. The treatment of the No 4 Adit drainage would have beneficial effects on water quality, but the use of the passive input of alkalinity is unlikely to be effective. More diffuse sources will be difficult to ameliorate.

3.5 Control of Metal Release and Solubility

Based on the review of the water quality data and site inspections of the Storys Creek mine site, it is apparent that the mine rocks and waste materials are essentially devoid of any acid neutralising capacity. The water in Storys Creek above the mine also contains very little buffering capacity. The pH of this water is naturally neutral to slightly acidic but has a very low dissolved solids content. The SO₄ concentration is

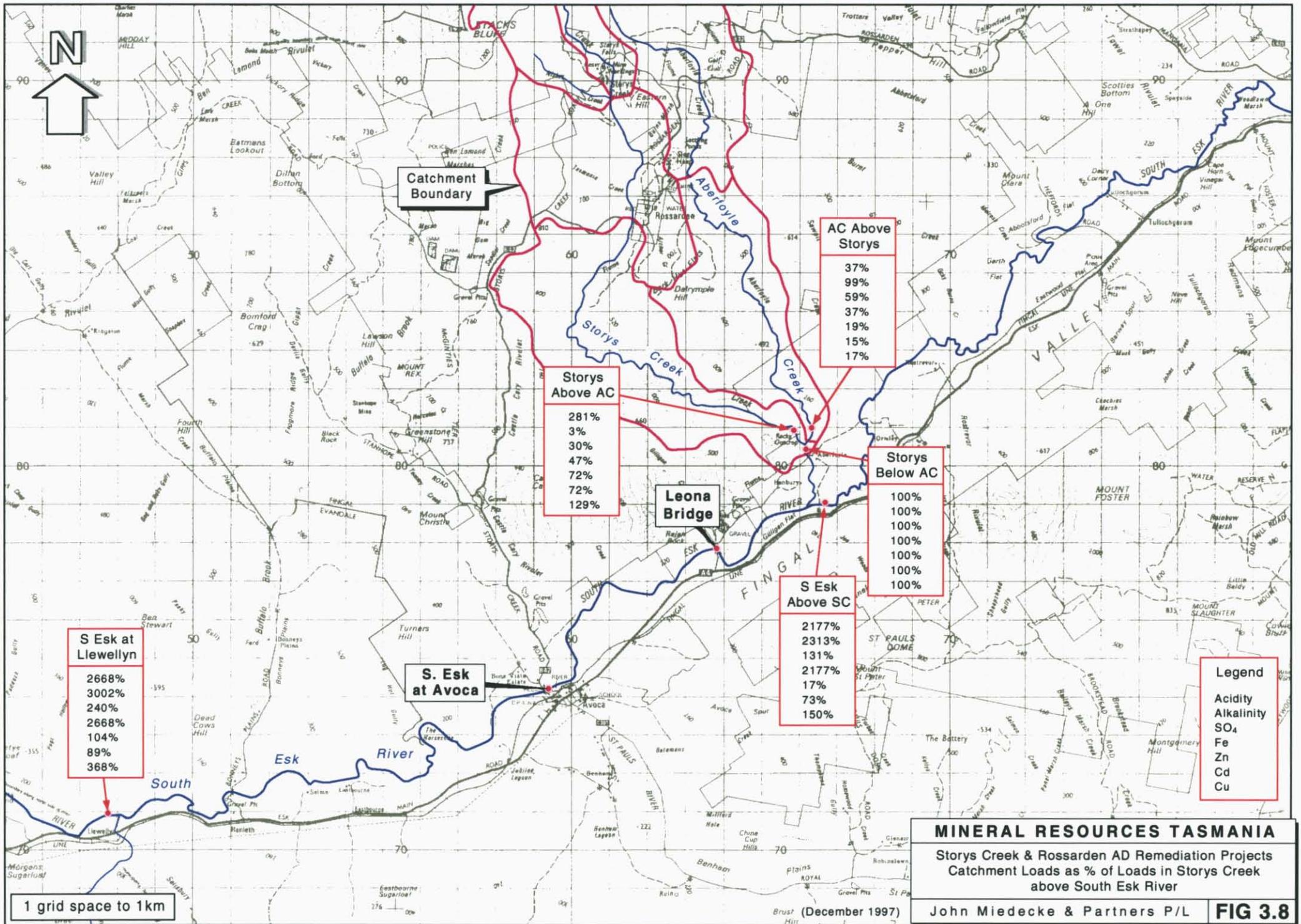


Table 3.7: Loads in Storys Creek, Aberfoyle Creek and the South Esk River as a percentage of Storys Creek above South Esk

LOCATION refer Hydro report	2 Storys Creek above mine	15 Storys Creek at Rossarden	16 Aberfoyle Creek above workings	22 Aberfoyle Creek above Storys Creek	23 Storys Creek above Aberfoyle	1 Storys Creek below Aberfoyle	24 South Esk above Storys	25 South Esk below Storys	26 South Esk at Lewellyn
PARAMETER									
SAMPLE DATE	2-Oct	3-Oct	3-Oct	3-Oct	3-Oct	3-Oct	3-Oct	3-Oct	3-Oct
Acidity (CaCO3)	17%	230%	19%	37%	281%	84%	2177%	2277%	2668%
Alkalinity (CaCO3)	6%	3%	21%	99%	3%	68%	2313%	2419%	3002%
NFR (suspended solids)	9%	138%	19%	37%	47%	84%	4353%	4554%	2668%
Hardness (CaCO3)	1%	14%	6%	70%	19%	70%	881%	976%	1271%
Ca T	2%	26%	6%	70%	21%	75%	726%	759%	1186%
Cl	4%	37%	13%	38%	47%	84%	6471%	6154%	7932%
F	0%	38%	1%	60%	28%	82%	91%	142%	167%
K T	1%	31%	6%	43%	39%	84%	2177%	2277%	2668%
Mg T	1%	18%	4%	67%	19%	67%	871%	911%	1601%
Na T	4%	34%	14%	37%	47%	84%	3809%	3984%	5336%
SO4	0%	40%	1%	59%	30%	75%	131%	213%	240%
Metals									
Al T	3%	92%	6%	25%	62%	112%	2177%	2277%	3557%
Al F	9%	138%	19%	37%	94%	84%	4353%	4554%	5336%
Cd T	0%	84%	1%	16%	68%	97%	66%	69%	81%
Cd F	0%	92%	1%	15%	72%	95%	73%	76%	89%
Cr T	9%	46%	19%	37%	47%	84%	2177%	2277%	2668%
Cr F	9%	46%	19%	37%	47%	84%	2177%	2277%	2668%
Cu T	0%	153%	0%	18%	78%	97%	38%	157%	230%
Cu F	0%	273%	1%	17%	129%	127%	150%	314%	368%
Fe T	3%	61%	13%	62%	16%	84%	2177%	2277%	2668%
Fe F	9%	92%	19%	37%	47%	84%	2177%	2277%	2668%
Hg T	9%	46%	19%	37%	47%	84%	2177%	2277%	2668%
Hg F	9%	46%	1%	37%	47%	84%	2177%	2277%	2668%
Mn T	4%	69%	9%	74%	47%	126%	1088%	1138%	1334%
Mn F	4%	69%	9%	74%	47%	126%	1088%	1138%	1334%
Ni T	2%	46%	4%	52%	37%	67%	871%	455%	534%
Ni F	9%	46%	19%	37%	47%	84%	2177%	2277%	2668%
Pb T	9%	92%	19%	37%	47%	84%	2177%	2277%	2668%
Pb F	9%	46%	19%	37%	47%	84%	2177%	2277%	2668%
Sb T	9%	46%	19%	37%	47%	84%	2177%	2277%	2668%
Sb F	9%	46%	1%	37%	47%	84%	2177%	2277%	2668%
Sn T	9%	46%	19%	56%	47%	84%	2177%	2277%	2668%
Sn F	9%	46%	19%	37%	47%	84%	2177%	2277%	2668%
Zn T	0%	84%	0%	21%	67%	95%	7%	92%	86%
Zn F	0%	91%	0%	19%	72%	96%	17%	86%	104%

about 0.5 mg/L. As a result, even a small acid input from the mine site will lower the pH sufficiently and any released metals from the site will remain mobile.

Figure 3.9 shows the pH dependent solubility of Zn, Cu and Al, respectively for water samples from Side Creek, Eastern Hill Adit, Storys Creek above Nisbet and the Precipitate Dam. These relationships were developed by increasing the pH of actual water samples taken from each location, mixing for 1 hour, filtering (0.45 μm) and then determining the element concentration in the filtered sample. These plots indicate that for Zn the pH needs to be increased to at least pH 7.5 to significantly reduce the 'dissolved' concentration (note that the 'y axis' is log scale), while for Cu and Al a pH of 7 is adequate.

Figure 3.10 is a plot of pH versus Cu, Cd and Zn concentrations for the available Story's Creek monitoring data (1984-97). This plot also shows that in Storys Creek, a pH greater than 7 is adequate for Cu and Cd but the pH needs to be at least 7.5 to effectively remove Zn, although even at pH 7 the Zn concentration and load will be significantly less than at pH 5 to 5.

Figure 3.11 shows the buffering curves resulting from the titration of acidity from the natural acid pH of these samples to pH 8.5. The results show that Storys Creek above Nisbet requires an alkalinity input equivalent to about 30 mgCaCO₃/L to raise the pH to 7 and about 35 mgCaCO₃/L to raise the pH to 7.5. Figure 3.11 also shows the alkalinity requirements to raise the pH of drainage from the Eastern Adit, Precipitate Dam and Side Creek.

This alkalinity can be provided by direct lime dosing by increasing the alkalinity inputs into the catchment by using SAPS and limestone drains. For example, at Side Creek approximately 220 mgCaCO₃/L to required to raise the pH to 7.5. Since the flow at this location is only about 0.5 L/s, the total alkalinity required is only about 9.5 kgCaCO₃/day. This alkalinity addition is well within the design capability of limestone drains and SAPS.

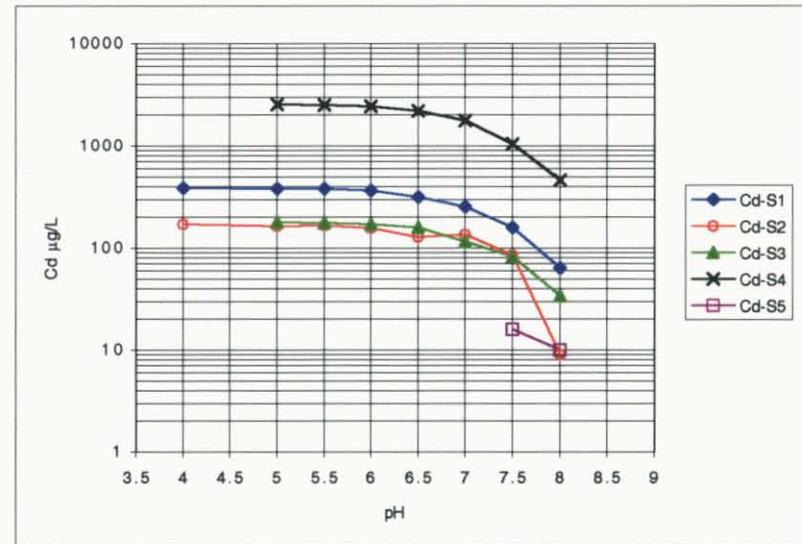
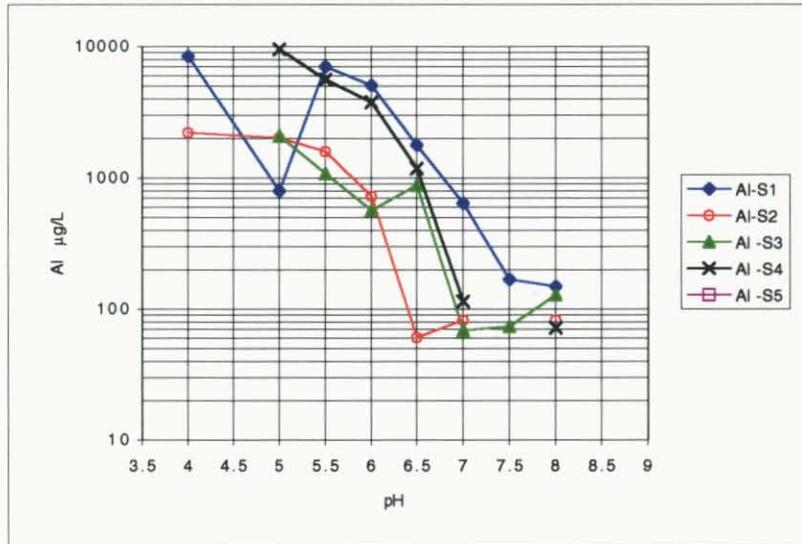
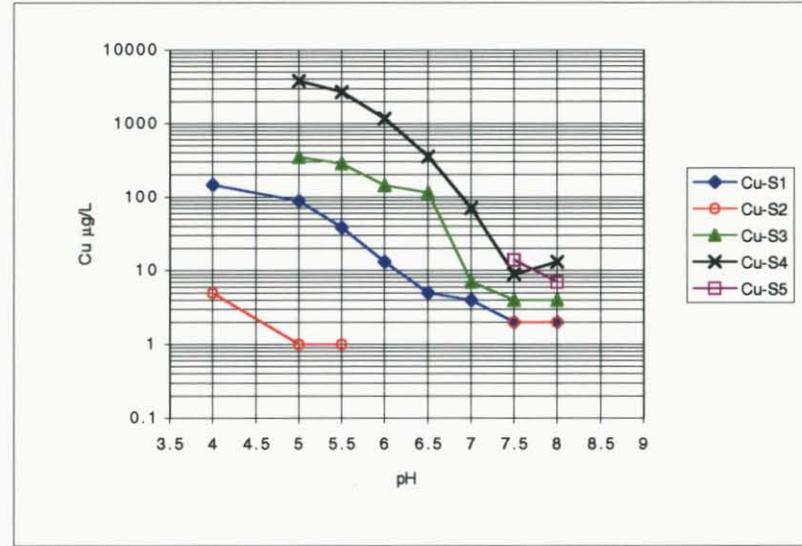
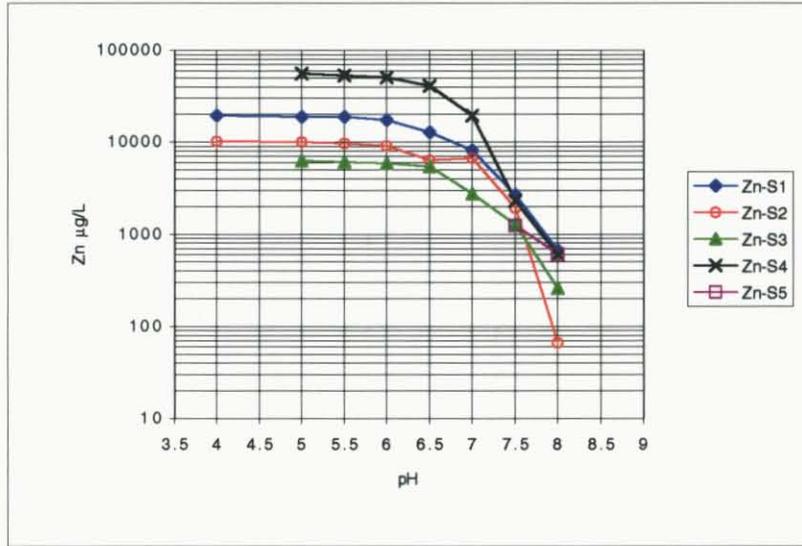
Assuming a flow of about 40 L/s in Storys Creek below Side Creek (refer to Table 3.2), the alkalinity requirement is about 120 kgCaCO₃/day to raise the pH to 7.5. This is only about 45 tonnes per year.

The discussion above focusses on the treatment of acid drainage from the Storys Creek site. As discussed previously, the load calculations indicate that the main contaminant is the creek-bank deposited tailings rather than the mine point sources. Control from these diffuse sources can be achieved by oxidation control and/or geochemical control. Oxidation control is achieved by excluding oxygen from reactive sulphides in the mine rock and mine waste. This can be achieved by inundation with water (this must be a permanent water cover) or placement of a cover which incorporates an oxygen diffusion control layer. At Storys Creek the cover option may be feasible for the tailings/precipitate dam however it is not practical or necessary for the jig tailings. Flooding of underground workings may be feasible for the Eastern Hill Adit, but is unlikely to be feasible for the mine (this is discussed later in the report). Flooding of creek-bank deposits could also be achieved by construction of check dams or paddies down the creek, but these must maintain a permanent water cover to be effective.

Geochemical control can be achieved by the addition of crushed limestone (CaCO₃) to the jig tailings and creek-bank deposited tailings. Placement of limestone in direct contact with oxidising material will provide immediate neutralisation and precipitation of any released metals at the source. Also, an increase in pH will further reduce the oxidation rate.

The results of the geochemical characterization of the tailings suggest that improving the buffering capacity of the tailings by the addition of crushed limestone (at rates of only about 1 to 2 tonnes per hectare), would significantly reduce the metal release rate from the creek-bank deposited tailings. The feasibility of permanently flooding tailings deposits down Storys Creek should also be investigated.

Figure 3.9 pH Dependent Solubilities for Al Cd, Cu and Zn



1 is Side Creek, 2 is EHill Adit, 3 is Storys below E Hill Adit, 4 is Precipitate Dam, 5 is Aberfoyle No 4 Adit

Figure 3.10 pH versus Cu, Cd and Zn for Storys Creek.

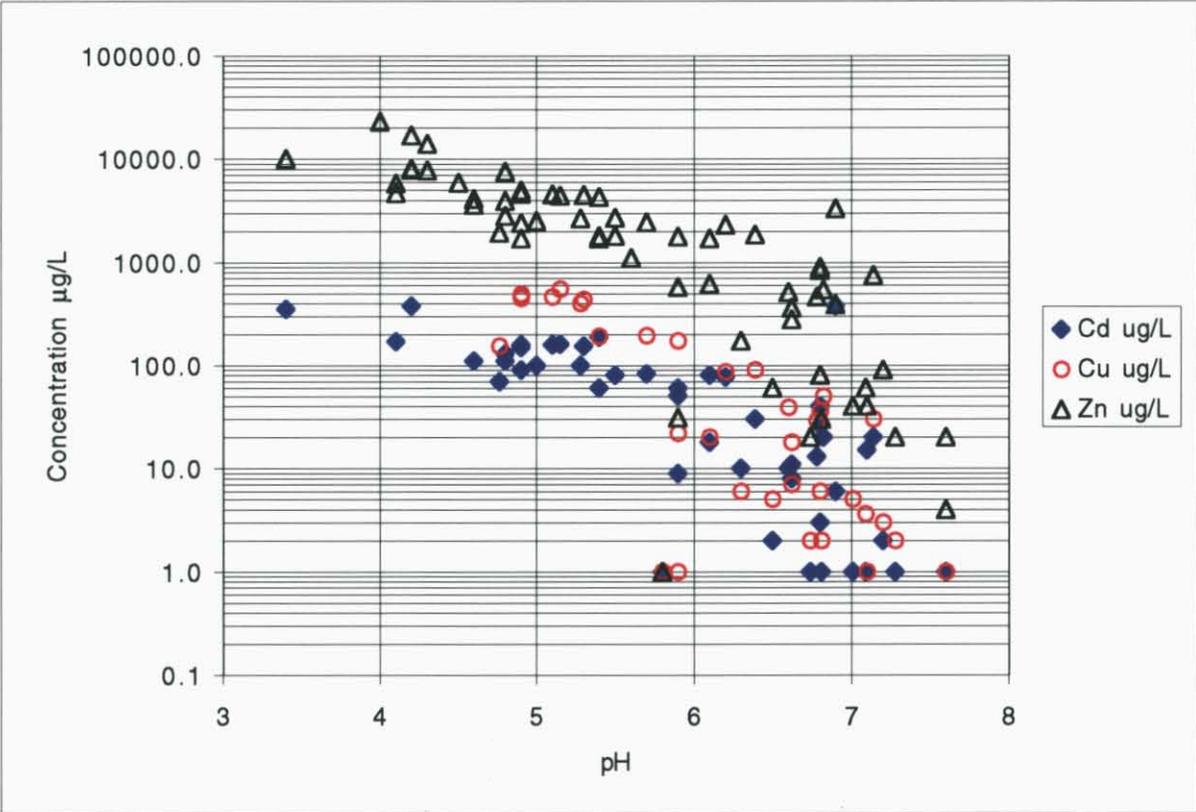
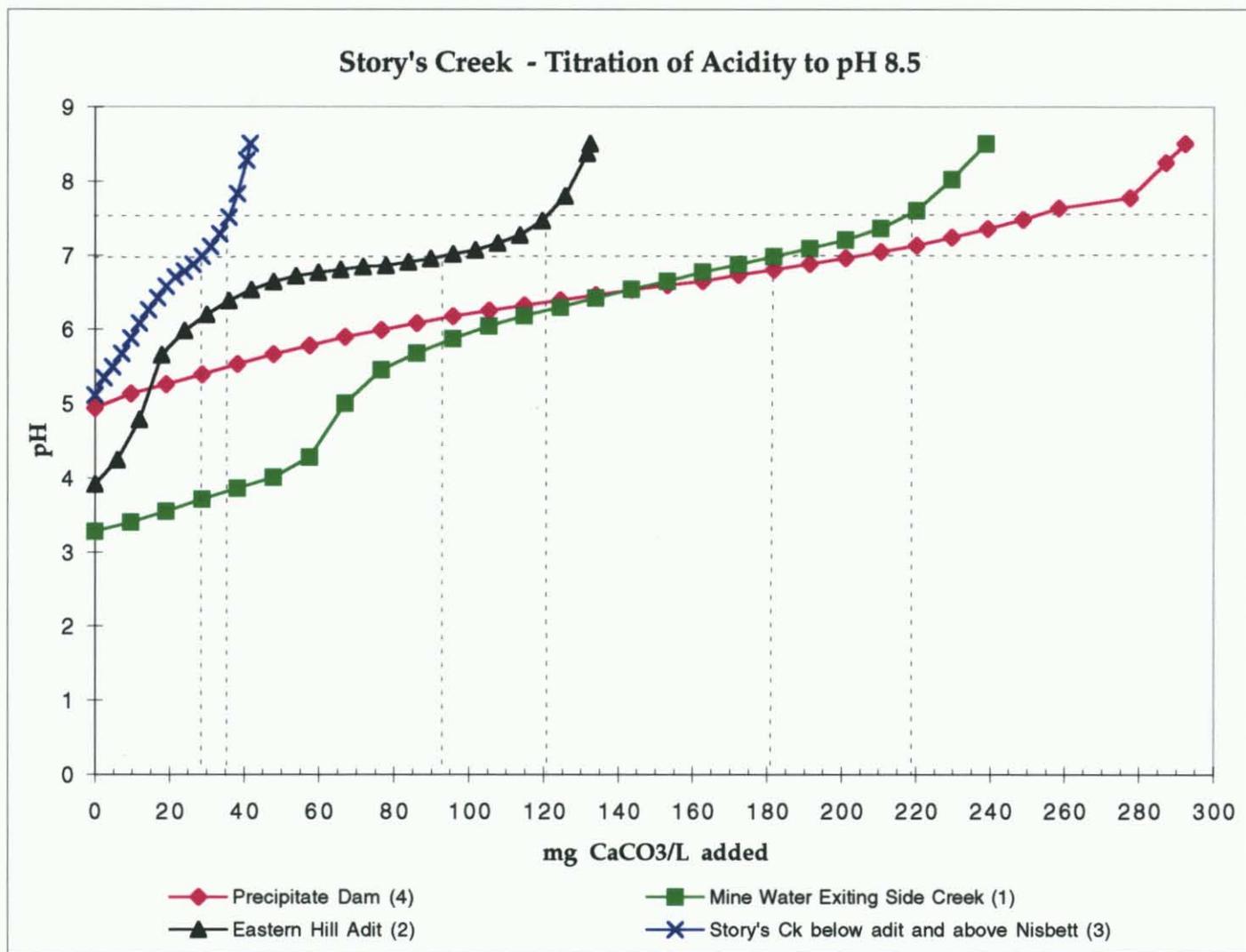


Figure 3.11: Buffering Curves.



4.0 Aquatic Fauna Assessment and Environmental Quality Objectives

4.1 Introduction

Peter Davies (Freshwater Systems) has completed a review of environmental data and developed draft Environmental Quality Objectives (EQOs) and recommendations for future monitoring. His report is attached as Appendix B. Only a summary is produced here, and references are included in Appendix B.

4.2 Sediment Chemistry Data

No recent data on sediments is available. Locher (1993) summarised the limited historical data on sediment chemistry in the South Esk River. However, much of these data were highly variable and inconsistent in the manner of collection. Overall, sediments in Storys Creek and in the South Esk downstream of Storys Creek have had a higher than background load of metals, the environmental significance of which is unclear. This needs further investigation, as efforts to improve ecological conditions through remediating water quality may be compromised by historical and/or new metal contamination of in-channel sediments. Ongoing or new sediment/substrate contamination is likely to occur with metal precipitation and/or adsorption onto hydroxide-type flocculates and deposition within the stream bed matrix.

The historical in-stream and floodplain sediment data for Storys Creek - South Esk indicates that those sediments analysed comply with the ANZECC/NHMRC definition of contaminated sites (see in Locher 1993, p 21). Levels of zinc, cadmium and copper are frequently well above the ANZECC/NHMRC (1992) levels above which detailed environmental investigation is required.

4.3 Biological Data

4.3.1 Sources

Biological data on the South Esk river system was found to have the same problems with inconsistency as for water quality, with lack of consistency in site selection and methods of data collection. Five sets of biological data are available for the South Esk River that are relevant to the Storys Creek issue. These are:

- Data collected by Thorp and Lake (1973) in 1972 on water quality and macroinvertebrates;
- Data collected by Norris for a PhD (Norris 1979) in 1975-76 (published in Norris 1980, 1981, 1982) on water quality, macroinvertebrates and fish;
- Data collected by consultants to the HEC in 1984 on macroinvertebrates (cited in Locher 1993, but not available for this study);
- Data collected by DPIF in 1995 for the South Esk Basin State of the Rivers Report (Bobbi et al. 1996) on macroinvertebrates; and
- Data collected by Inland Fisheries Commission on the trout fishery of the South Esk River (IFC, unpub. data, provided for this study).

Of these, only Norris (1979, 1980) and Bobbi et al. (1996) provide valuable

quantitative and semi quantitative data, respectively, on the biological condition of the river. Locher (1993) cites Norris's interpretation of his biological data, but detailed inspection revealed that further analysis of the data was warranted for the current report. This is described below.

4.3.2 Norris Study

The data collected by Norris consisted of eight sets of macroinvertebrate samples from each of eight sites in the South Esk River and Storys Creek collected at approximately two monthly intervals over two years, accompanied by water quality data collection at the same sites (Norris 1979).

Much of these data have been published in the scientific literature (Norris 1980, 1981, 1982). However, there are fundamental design problems with the project, the most notable being the lack of a control river system and the reliance on an upstream control set of sites against which sites downstream of Storys Creek are compared. While this design is partially adequate for assessing the impacts of Storys Creek inputs in the immediate vicinity of the junction, it is inadequate for detecting impacts further downstream.

There is a recognised decline in biological condition for many streams in agricultural areas of Tasmania and South Eastern Australia. This is largely as a result of the combination of altered flow regimes, enhanced diffuse and point source nutrient and organic inputs and enhanced sediment inputs, combined with degraded instream physical habitat and channel conditions. Such a downstream decline has been observed for the Meander River (Bobbi et al. 1996), and is apparent from a decline in macroinvertebrate diversity and major changes in community composition compared with reference conditions.

In summary, an appropriate design for the assessment of the degree of impact from Storys Creek and/or change in biological conditions in downstream reaches of the South Esk River requires either a paired catchment sampling design or multiple lower catchment control site sampling. In both cases the control condition should include at least one agricultural catchment with a river systems as similar hydrologically and geomorphologically to the South Esk River as possible. The addition of a similar, unimpacted catchment would be advantageous but one is not available.

In Norris's study, correlations were examined between biological conditions and water quality only and comparisons were made between sites far downstream in the catchment and sites upstream (some 100 - 120 km apart). This is not valid for two reasons:

- Natural changes in habitat conditions (hydrology, channel form, substrate composition) and biota downstream; and
- Incremental changes in the degree of human impacts other than Storys Creek (land clearing, riparian degradation, decreases in summer low flows from irrigation, grazing/cropping impacts, sewage inputs etc.).

On re-examination of the data, valid conclusions from the Norris study are as follows:

- That enhanced levels of zinc, cadmium, copper and lead were found downstream of Storys Creek, generally decreasing in a downstream direction;
- That there was a decrease in macroinvertebrate diversity and abundance in sites immediately downstream of Storys Creek;
- That there is a trend toward recovery evident from 30 km downstream of Storys Creek;
- That macroinvertebrate diversity and abundance were lower in sites more than 30 km downstream of Storys Creek than upstream but that this cannot be

formally linked to the Storys Creek discharge.

Norris's invertebrate data was re-analysed using both flexible UPGMA classification and multidimensional scaling (MDS) ordination using the PRIMER software package.

These analysis revealed a fundamental issue in the relationship between biological condition of the South Esk River and the impact of Storys Creek, of considerable importance in the derivation of EQOs for the River.

Norris (1982) had noted the anomaly of a slight recovery in biological condition at site 7 and an enhanced decline in biodiversity and abundance at site 8 (Evandale), some 80 km downstream of SCJ. He hypothesised that this was due to an unknown enhanced effect of the pollutants emanating from Storys Creek, but acknowledged that this was unusual being so far from the source of the impact.

The more recent analyses described above suggest an alternative explanation, that the biological communities show an identical sets of relationships to those determined purely by [Zn] and distance from Storys Creek junction.

This suggests two things:

- That there is a general downstream trend in macroinvertebrate community composition;
- That there is a disruption to that pattern due to the impact of Storys Creek, most likely due to metal contamination.

The downstream trend in macroinvertebrate community composition is accompanied by a declining trend in abundance and diversity.

Davies has concluded that the downstream trends in invertebrate community composition, diversity and abundance are due to cumulative impacts of landuse within the catchment with, *superimposed* on it, a major impact due to the input of Storys Creek water and a possible associated change in stream substrate (from armoured cobble to a less stable finer quartzitic gravels). It is also suggested that, both during Norris's study and currently (see DPIF study below), that the main zone of impact from SCR is between SCJ and Milford, some 30 km downstream. There is evidence of recovery at Clyne Vale (44 km d/s SCJ), with a further decline at Pleasant Banks (79 km d/s from Storys Creek near Evandale).

It is concluded that recovery occurs from the Storys Creek impact from around 30 km downstream and that further declines in biological condition are a result of catchment disturbance rather than SCR impacts.

4.3.3 DPIF Study

Further evidence is provided to support these ideas from the DPIF State of the Rivers Survey for the South Esk River (Bobbi et al. 1996).

Overall, the pattern in the South Esk is the same as that found by Norris (compare with Figure 1). Thus a decline in diversity is found immediately downstream of SCJ, accompanied by a decline in O/E and SIGNAL score.

The DPIF study also included an assessment of the biological condition of the Meander River. Comparison of the trends in the Meander and South Esk River are illuminating.

It appears therefore, that there are similarities in the pattern of biological condition in both rivers in a downstream direction, with the exception of a mid-reach decline in condition related to current and/or historical SC chemical and sediment pollutant inputs.

4.3.4 Fishery Data

Two data sets exist in relation to fish population survey data and fishery statistics obtained from IFC annual questionnaire data (available for the period 1985/86 to 1995/96).

Locher (1993) cites Thorp and Lake (1973) who in turn cited Tyler and Buckney (1973) that no fish were resident in the South Esk River downstream of SCJ. The only evidence provided by Tyler and Buckney is anecdotal reporting of farmers opinions and the results of an IFC electrofishing survey reportedly conducted in April 1970, the data from which is not provided in Tyler and Buckney's (1973) paper. On inspection of IFC records and annual reports, no record of this survey was found. This cannot be taken therefore as valid evidence of the absence of fish from the lower South Esk River as a result of Storys Creek impacts. Trout have also been observed to be actively feeding less than 100 m below the junction in November 1997 (J Miedecke, personal obs).

One other fish survey was conducted, by Norris and Lake (1984) while collecting fish for metal analyses. However, if one assumes that the sampling effort was essentially similar, then the data suggests that fish abundance was greater at sites downstream of Storys Creek than upstream. This is not surprising, given the greater habitat complexity in the lower river than upstream. It does suggest that several species of fish were present in the South Esk River at sites from 30 to 80 km downstream of Storys Creek, in abundances similar to or higher than those found at sites upstream of Storys Creek. The data were however, inadequate to properly assess the status of fish populations, changes between sites or the influence of the impact of Storys Creek.

A quantitative survey of fish populations is needed to establish at least a rudimentary baseline data set for assessing the effects of any changes in environmental quality from SCR remediation.

The Inland Fisheries Commission has conducted statewide postal questionnaire surveys of trout fisheries annually since 1986.

Additional questionnaire data obtained in the 1992 survey showed that some 35% of the angling effort in the South Esk River exerted in the reach from Storys Creek to Perth, while 20% was exerted upstream.

South Esk River catch per day was marginally significantly lower than for the Meander River over the 11 year period of record (paired t-test, $p = 0.02$), while harvest was the same ($p > 0.1$, paired t-test).

South Esk River catch per day data fell well within the range for other rivers in Tasmania.

Overall the South Esk River supports a recreational brown trout fishery with a sustained high visitation and harvest rate, a catch rate similar to of other Tasmanian river fisheries, with a significant portion of the fishery effort being expended between Storys Creek and Perth.

4.3.5 Summary

The overall weight of evidence suggests that the South Esk River is not heavily impacted from Storys Creek for its entire length from the junction to Perth, as has historically been believed.

The evidence indicates that:

- Storys Creek has and continues to have a major impact on water quality downstream of Storys Creek, primarily through the input of zinc and possibly through input of cadmium, metal hydroxide flocs and coarse sediment;

- The overall pattern of biological impact appears to have been sustained at least between the 1970s and 1990s, but insufficient data exists to assess the extent of any recovery or further decline;
- The biological impact of Storys Creek is significant within the reach approximately 30 km downstream of Storys Creek, but not necessarily beyond that;
- There is a significant biological degradation associated with general catchment land use (including the riparian zone), which is significant both upstream and downstream of Storys Creek and that appears to be cumulative in a downstream direction;
- The level of biological impact from catchment land use practices is similar and possibly more severe than that experienced in the Meander River;
- Fish (brown trout, redfin perch, eels, tench, pygmy perch) are resident in the river reaches downstream of Storys Creek, though possibly not immediately downstream;
- A significant recreational brown trout fishery exists in the South Esk River, with some 35-40% of the angling effort being expended in the reach between Storys Creek and Perth and with an average catch per unit effort marginally lower than for the Meander River;
- Biological integrity of the South Esk River can be restored only by a combination of management of Storys Creek impacts and improved catchment management and riparian condition.
- That EQOs for the South Esk River catchment should be established separately for the reach 30 km downstream of Storys Creek, and for the remainder of the river.

4.4 Other Effects

Insufficient data has been collected on the current and past impact of Storys Creek in relation to inputs to the South Esk River, both coarse (gravels, mine tailings etc.) and fine (metal precipitates and hydroxide flocs). Estimates made in this report suggest that the volumes of material sourced from the Storys Creek mine and creek dredging activities may be no more than 25% of the volume of material estimated to be deposited onto the South Esk River floodplain in the vicinity and downstream of Storys Creek.

There is an insufficient understanding of the fluvial geomorphology of the middle and lower South Esk River and its current status with regard to sediment sources movement and storage. The comparative impacts on river channel morphology (including bank and bed stability and erosion status) and hydrology as a result of Storys Creek related gravel/tailings inputs, effects of agricultural channel/riparian modification, and natural geomorphological process (such as mid-catchment adjustments to changes in geology) must be understood before river remediation options can be proposed.

Similarly, the data on the intensity and geographic extent of soil contamination is inadequate to assess the impact of Storys Creek on soil, vegetation, agricultural or economic values. Significant metal contamination of surface soils in the South Esk River floodplain immediately downstream (and upstream) of Storys Creek has been described (see Locher 1993). The recommendations regarding animal health and metal residue levels (particularly cadmium) do not appear to have been investigated.

4.5 Environmental Quality Objectives (EQOs)

This section describes Environmental Quality Objectives for the aquatic values of Storys/Aberfoyle Creek and South Esk River catchments, as they pertain to the possible remediation of the catchments. The recommendations are not exhaustive and are not the result of a community consultation process. Rather they are a technical series of recommended EQO targets focussed on the restoration/remediation of environmental health in the South Esk River and Storys/Aberfoyle Creeks.

They do not address issues of riparian or stream channel management, land use, management of exotic plants and animals or diffuse water quality impacts. They are also different from those EQOs recommended by Davies et al. (1996) for the South Esk River in their report on environmental flow needs for the river.

It is recommended that these be subject to review following collection and analysis of further data (see below) and be used and reviewed as part of any larger community-based process for developing EQOs for water quality and quantity for the South Esk catchment that may be initiated by DELM and/or DPIF under the State Water Quality Management Policy and the Water Reform Process.

For the purposes of this report, three catchments compartments have been identified:

- Storys Creek catchment (divided into the catchments of Aberfoyle and Storys Creeks);
- South Esk River catchment downstream of Storys Creek to 30 km downstream; and
- South Esk River from 30 km downstream of Storys Creek to Perth.

4.5.1 Overall Objectives

1 To restore the biological condition of Storys Creek (or a section thereof), Aberfoyle Creek and the South Esk River downstream of its junction with Storys Creek to a natural state, or to a level commensurate with background catchment conditions by:

- Decreasing total and filterable water concentrations of zinc, cadmium, copper and aluminium to concentrations which allow aquatic life to at least partially return toward a natural state;
- Reducing overall instream and floodplain sediment concentrations of zinc, cadmium and copper to background levels which allow aquatic life to at least partially return toward a natural state;
- Partially restoring stream substrate conditions where they are shown to be detrimental to aquatic health.

Given the scale of the Storys Creek related water quality problems, it is recommended that the above EQO should be targeted in the following order of priority:

- South Esk more than 30 km downstream of Storys Creek ;
- South Esk 0 - 30 km downstream of Storys Creek ;
- Aberfoyle Creek;
- Storys Creek upstream of Aberfoyle Creek.

2 To restore those aspects of the trout fishery impacted by Storys Creek to a condition that would be expected in an unpolluted environment.

3 To ensure that water in the South Esk River is suitable for primary and secondary contact.

4.5.2 Water Quality Objectives

Table 4.1 presents target maximum concentrations of priority pollutants in the streams mentioned above, for the achievement of the EQOs.

These are largely based on ANZECC (1992) guidelines for soft waters, taking into account the potential for limited complexation of dissolved metals by dissolved organics (measured as DOC in this report). DOC levels found in the 1997 HEC survey ranged between 1.5 and 2.5 mg/l for Aberfoyle and lower Storys Creeks and the South Esk River. This is around 20% of the levels found in West Coast streams associated with Mt Lyell (Davies et al. 1996) and the Pieman catchment (Koehnken 1993), and suggests only limited complexation capacity which may need investigation. In addition, it must be noted that most of the metal levels reported below (as totals) may not be dissolved, i.e. are either in non-filterable (> 0.45 micron) or filterable but fine flocculate forms, and hence non-toxic. Thus the use of ANZECC (1992) guidelines may be unnecessarily conservative, but they are used in the absence of other evidence.

Using ambient metal data combined with biological data from the existing survey work to develop targets for metals is not possible due to:

- The previously mentioned problem of unknown dissolved fractions;
- The presence of modified stream substrate due to historical tailings etc. inputs from Storys Creek causing potential impacts on biota independent of pollutant impacts; and
- The lack of a comprehensive current water quality and biological data set.

4.5.3 Sediment Quality Objectives

Recommended targets for sediment quality should comply with background levels of total and extractable cadmium, zinc and copper. Background levels should be defined after a comprehensive sampling program for sediments at 3 to 5 sites in the South Esk upstream of Storys Creek and in another similar river basin eg. the Meander River.

Compliance with the targets should be assessed based on a statistical comparison with those background sample data. Care should be taken to select the metal extraction method for consistency with internationally published approaches to assessing bioavailability (see MLRRDP project on Macquarie Harbour sediments).

4.5.4 Biological Health

Remediation targets for aquatic biota have been developed in a different manner than for water quality. With biological data it is possible to develop targets:

- Using historical data due to its quality and demonstrated continued relevance; and
- Taking background levels of impact into account, due to the existing downstream gradient in macroinvertebrate community composition which is believed to be due to catchment landuse impacts.

With water quality, it is believed that the only major source of metal toxicants such as zinc and cadmium is Storys Creek, whether currently through water quality or historically through deposited sediments. With aquatic biota, however, background conditions are believed to be already degraded due to poor land use and riparian management practices. Targets for remediation of Storys Creek should therefore not unrealistically be set for a pristine or reference condition but rather take this background

impact into account. If targets were being set for catchment management, then they would of course aim to restore biota to a higher level, but this study is focussed on the remediation of Storys Creek impacts within the current catchment context. Targets are shown in Table 3 of Appendix B.

Table 4.1 Recommended water quality targets for Storys Creek and South Esk River, and ambient median and maximum concentrations (based on DELM 1996-97 and 1997 HEC data). ? indicates only one or three ambient values available. SCJ Storys Creek junction.

		South	South	Storys Creek Catchment		
		Esk	Esk	SC u/s	SC u/s	Aberfoyle
0 30 km d/s	> 30 km	SC u/s	SC u/s S.	SC u/s	SC u/s	Aberfoyle
SCJ	d/s SCJ	Aberfoyle	Esk River	Aberfoyle	SEsk	creek
Zinc	Maximum	50	50	50	50	50
	Current Median, Maximum	70, 110	Unknown, Unknown	2000, 4300	1000?, Unknown	1500?, Unknown
Cadmium	Maximum	0.2	0.2	0.2	0.2	0.2
	Current Median, Maximum	2, 5	Unknown, Unknown	40, 90	33, 30	50?, Unknown
Copper	Maximum	5	5	5	5	5
	Current Median, Maximum	5, 9	Unknown, Unknown	200, 370	58, 29	90?, Unknown
Aluminium	Maximum	100	100	100	100	100
	Current Median, Maximum	300?, Unknown	Unknown, Unknown	600?, Unknown	300?, Unknown	200?, Unknown

4.5.5 Physical Quality

The presence of a highly modified stream substrate in Storys Creek and the South Esk River immediately downstream from Storys Creek, and possibly further downstream has been cited in numerous reports. This substrate is currently clearly different from the more typical Tasmanian river armoured cobble-coarse gravel substrate (Davies pers. obs.) seen in the South Esk upstream of Storys Creek. However, the extent to which this substrate change is due to natural geomorphological changes (eg. the mid-catchment transition through granodiorites) or the inputs resulting from the Storys Creek mine requires quantification. Targets for physical remediation (eg. removal of

tailings deposits and stream channel modification) cannot be set until a detailed fluvial geomorphologic survey is conducted.

There is no doubt however, that improved riparian and stream channel management is required in the South Esk River and catchment tributaries, and that this should be targeted through the new state ICM process.

4.6 Probable Effects of Neutralisation

Neutralisation of mine waters within the Storys Creek catchment is aimed at reducing the dissolved metal concentrations and loads discharged into the South Esk River. A consequence of this will be the increase in loads of precipitated metals either as fine colloids/suspensions, flocs or deposited films. While it is unlikely that the resulting concentrations of suspended material will represent a physical disturbance to biota, it is uncertain what the resulting effect will be on benthic habitat suitability for macroinvertebrates and epilithic algae. In Storys Creek it is likely, as happens at present, that the deposition of flocculated hydroxide materials will penetrate the bed matrix, filling interstices and occluding suitable habitat within the bed. In South Esk, the relative load of the precipitated material will be significantly lower and the potential for this to happen will be greatly reduced.

Biological recovery in the South Esk river downstream of Storys Creek is likely to occur if:

- the precipitated metal hydroxides are not toxic in themselves - this is highly likely, with the exception of adsorbed or precipitated cadmium which may be taken up by filter feeders;
- the load of precipitated materials is low enough not to cause significant occlusion of bed matrices;
- the residual toxicity of existing in-stream sediments is low (this has not been determined).

5.0 General Screening of Remedial Technologies

5.1 Introduction

The project required a review of the Mt Lyell Research and Remediation Demonstration Project findings, as these were considered to be applicable to the current project. This has been conducted and has included an assessment of the applicability of the remediation options suitable for the Storys Creek/Rossarden site.

The Mount Lyell Remediation Research and Demonstration Program (MLRRDP) was established as a joint program in 1995 by the Tasmanian and Federal Governments to develop a strategy for remediating the environmental effects of past mining at Mount Lyell, in western Tasmania. The authorities co-coordinating the program comprise the Tasmanian Department of Environment and Land Management, Environmental Management Division, and the Commonwealth Environment Protection Authority, Office of the Supervising Scientist and Environmental Research Institute of the Supervising Scientist.

The program is comprised of a number of projects to investigate the extent and mechanisms of the environmental impacts which have resulted from mining activities at Mount Lyell over the past century. These mining activities in the Mount Lyell region have resulted in impacts to the natural environment within and about the mining leases, the rivers downstream from the lease area and Macquarie Harbour, mostly from acid air emissions and acid drainages from the lease site. Impacts have resulted on the general landscape of the Queenstown area, the physical environment, changes to hydrology and water quality, and the deposition of tailings and slag in the Queen and King rivers and downstream to Macquarie Harbour.

The MLRRDP included three related projects dealing with the management of the quantity and quality of effluent from the lease site (acid drainage). The projects are:

- Project 1 A review and presentation of historical literature and data for the characterization of sources of effluent from the lease site;
- Project 2 Identification of the potential options for managing effluent water from the lease and recommendations for construction and operation of demonstration/evaluation trials; and
- Project 3 Construction and evaluation of test cases.

Project 2 findings were published in 1995 (John Miedecke and Partners Pty Ltd et al 1996). This report and findings were reviewed and the applicability is considered in the following section.

Project 3 - the construction and operation of test cases is current and is being supervised by DELM. Data on the monitoring of the SAPS trials and the capping and covering of Magazine Creek dump has been requested from DELM, but had not been received at the time of this report completion.

5.2 Review and Applicability

5.2.1 Study Findings

The Project 2 findings can be summarised below;

- The former Mount Lyell Mining and Railway Company Limited (MLMRCL) lease is large and the problems associated with the mine drainage, waste rock dumps and river tailings are typical of a number of old mine sites in Australia

and internationally;

- By far the greatest loads are from the Haulage Creek catchment which receives the surface discharge of the mine dewatering, adit drainage from old workings and drainage from major waste rock dumps. Approximately 2.5 tonnes of copper per day is released into the Queen River from the Queen River catchment;
- The remediation of the Mount Lyell lease to totally eliminate ongoing acid drainage and release of copper from the site is an unrealistic objective, but it is feasible to put in place strategies that will result in a progressive reduction in the contaminant load from the site;
- A number of remediation technologies was reviewed, this included overseas best practice;
- The review of acid drainage remediation technology revealed that to meet water quality objectives for downstream, because of the high loads, the only feasible means of reducing the acid mine drainage loads is by a conventional neutralisation water treatment plant. This will require substantial capital investment and ongoing operating costs;
- A Solvent Extraction/Electrowinning (SX/EW) plant design could be constructed to recover copper from the high concentration streams in the Haulage Creek catchment, as a revenue measure.
- The balance of the lease site has acid drainages with much lower loads and flows and other options have been identified which could remediate these sources. These included the reduction in loads by flooding and covering AD sources, the passive treatment of adit drainages by successive alkalinity producing systems, and alkalinity addition to receiving waters by anoxic limestone drains and limestone addition.
- Trials were recommended for these technologies.

5.2.2 Applicability

5.2.2.1 Introduction

There are significant differences between the Mount Lyell and the Storys Creek/Rossarden mine sites. The main source of contamination at Mount Lyell was copper with high concentrations (>100mg/l) high acidity and sulphate loads. In Storys Creek, the main contaminants are Zn and Cd, with concentrations several orders of magnitude less.

Similarly, the acid load from Storys Creek is also significantly lower. The sulphate loads in Storys Creek are 207 kg SO₄/day, compared with Haulage Creek where the loads are approximately 112, 000 kg SO₄/day. Therefore, there is at least 3 orders of magnitude difference in sulphate generation rate (sulphide oxidation rate) between Story Creek and Mount Lyell.

The magnitude of the problem is therefore much smaller and more amenable to low cost more passive treatment systems. Therefore, the passive treatment systems investigated as part of the MLRDDP program have direct application.

5.2.2.1 Metal Recovery

The metal concentrations in mine drainage and in Storys Creek, are generally less than 5mg/L (ppm). The MLRRDP study findings indicate that metal recovery would only be viable at concentrations (of Cu) which exceeded at least 100ppm. Zinc is of much lower value than Cu and therefore, the recovery of metals is not an applicable technology.

5.2.2.2 Conventional Neutralisation and Precipitation

This is proven technology able to cope with the high loads and flows. It could be constructed to treat point sources collected from the Precipitation Dam etc .

However, because identified point sources are not the major pollution source, this approach will not be effective, as treatment of the entire creek flow would not be practical.

5.2.2.3 Covering of Sources to Reduce AD Loads

Because of the steep topography and diffuse nature of the AD sources, this has limited applicability. Capping of the Precipitate Dam is a possible option, as is geochemical control by reducing oxidation.

5.2.2.4 Flooding of Old Workings and Flow Diversion

Flooding of the Storys Creek, Eastern Adit and Aberfoyle Mine workings is potentially an applicable technology and was considered.

Diversion of surface flows from areas with potential leakage paths into mine workings has also been considered.

5.2.2.5 Flooding of Creek- bank Deposited Tailings

Flooding of the Storys Creek bank tailings would be effective if a permanent water cover could be achieved. Due to the topography, a series of dams would need to be constructed down the creek and require design to cope with floods and high flows.

The capital and operating costs are unlikely to be cost effective versus the limestone capping.

5.2.2.6 Passive Treatment of Adit Discharges and Low Flows

Point sources such as adit discharges and tailings dam seepages are potentially treatable by passive treatments.

Anoxic Limestone Drains (ALDs) and Successive Alkalinity Producing Systems (SAPS) are potentially applicable. ALDs are of restricted ability as they cannot treat waters with elevated Al or ferrous Fe. SAPS trials have been constructed on AD at Mount Lyell.

Aerobic wetlands are applicable to non-acid sources.

5.2.2.6 Alkalinity Generation and Insitu Neutralisation

Alkalinity generation into the receiving waters to buffer AD and precipitate metals within the stream system and/or wetlands is an applicable technology. This could take the form of direct limestone (sands or crushed rock) application, relying on stream movements to distribute the limestone, to direct lime/crushed limestone addition to acid drainage producing sources.

6.0 Remediation Technologies and Selection of Site Specific Trials

6.1 Introduction

The Storys Creek Mine area has been identified as a source of acid drainage. The main sources loads have been identified as tailings and waste rock materials in the floor of the creek and in creek bank overbank deposits. Pollutant loads including acidity are generally low and are amenable to alkalinity addition to buffer acid drainage, raise pH, remove metals from solution and precipitate metals in the creek bed as colloids and precipitates.

Other less significant point sources have been identified as;

- Precipitate Dam seepage;
- Side Creek Adit drainage (including Story mine workings);
- Eastern Hill Adit

The Aberfoyle Mine area has non-acid mine drainage, with low but still significant metal concentrations. The topography and main source of pollution via an adit in close proximity to Aberfoyle Creek limits possible remediation options.

6.2 Load Reduction

An alternative strategy to treatment of acid drainage is to control the release of metals from the mine rock and waste and hence reduce the concentration in the drainage. This can be achieved by oxidation control and/or geochemical control. Oxidation control is achieved by excluding oxygen from reactive sulphides in the mine rock and mine waste. This can be achieved by inundation with water (this must be a permanent water cover) or placement of a cover which incorporates an oxygen diffusion control layer.

Geochemical control can be achieved by the addition of crushed limestone (CaCO_3) to the jig tailings and creek-bank deposited tailings. Placement of limestone in direct contact with oxidising material will provide immediate neutralisation and precipitation of any released metals at the source. Also, an increase in pH will further reduce the oxidation rate.

6.2.1 Flooding of Old Workings and Drainage Diversions

6.2.1.1 Storys Creek Mine Workings

The Storys workings are extensive and have a number of open adits, shafts and stopes. It is also suspected that workings may have exposed cavities which are now below the existing creek floor. These are believed to be allowing acid drainage via leakage to creek under the creek sediments.

As such, the plugging and flooding of the old workings is not considered practical.

6.2.1.2 Eastern Hill Adit

The Eastern Hill Adit is believed to be have been driven as an exploration adit to a depth of approximately 70 -100 metres. With no extensive underground workings, it should be feasible to flood the Adit at a relatively low cost. This is estimated at

\$10,000 - \$20,000.

6.2.1.3 Aberfoyle Mine Workings

These workings are extensive and have at least two adits which exit to Aberfoyle Creek. No 2 Adit on 4 level is a drainage adit, and significant flows occurs direct to Aberfoyle Creek.

No 1 Adit also known as No 2, is also located close to Aberfoyle creek and is believed to be covered with tailings and scree.

It is considered practical to plug No 2 Adit (4 Level adit) however, drainage is then likely to occur from No 1 adit. If this adit was blocked there still remains the possibility of failure and the mass releases to Aberfoyle Creek.

As drainage is non-acid, the benefits of floodings the old workings are uncertain. The transfer of drainage to No 1 Adit will not permit any additional areas for downstream treatment.

Therefore, the plugging and flooding of the old workings is considered of dubious benefit, would be expensive - because of access, with a risk of failure.

A surface pipeline could be constructed from No 2 level and 4 level adits, a distance of some 6km downstream by helicopter access to an area where a wetland could be constructed. This is estimated to cost some \$ 525,00, plus annual operating (maintenance costs) of estimated \$10,000. The pipeline would be subject to vandalism and damage from fire.

The diversion by pumping and treatment at another location is considered more practical and preferable. The capital cost of a duplicate pump set up in the main shaft, pumping to a surface wetland and draining to the Storys Creek catchment is estimated at some \$50,000, with annual operating costs of \$ 35,000.

6.2.2 Covering of Waste Rock Dumps (Oxidation Control)

The placement of a cover which incorporates an oxygen diffusion control layer can control oxidation and control the release of metals from the mine rock and waste and hence reduce the concentration in the drainage. At Storys Creek the cover option may be feasible for the tailings/precipitate dam, however it is not practical or necessary for the jig tailings.

The Precipitate Dam has been capped but this has proved ineffective as water levels are still high, with continued oxidation.

It would be possible to cover the dam with a new design, however this likely to cost more than removal and storage elsewhere at a more suitable location away from the creek.

The tailings dams at Aberfoyle Rossarden have recently been covered and revegetated, but the cover design is not sufficient to reduce infiltration, or oxidation. However, most of the tailings are believed to be non acid generating and the loads are likely to be small.

6.2.3 Geochemical Control

Geochemical control can be achieved by the addition of crushed limestone (CaCO_3) to the jig tailings and creek-bank deposited tailings in Storys Creek. Placement of limestone in direct contact with oxidising material will provide immediate neutralisation and precipitation of any released metals at the source. The increase in pH will further reduce the oxidation rate.

6.2.4 Removal of AD sources

This is potentially applicable only to all exposed acid generating materials - such as waste/dumps and tailings, including river bank deposits. These could be removed and stored in a constructed impoundment where oxidation could be restricted and drainage controlled.

The Precipitate Dam is a logical candidate as this is an obvious point source and more importantly, in the current location there is a risk of catastrophic failure during flood/high flows with significant downstream impacts.

While the Jig Tailings and creek deposits could possibly be removed or flooded, the alternative of geochemical control by limestone addition is considered more feasible.

6.2.5 Surface Water Diversion

There is a demonstrated leakage to Storys Creek mine working from surface waters located near the existing ponds and this is probably contributing to the volume of acid drainage.

It would be possible to divert waters from entering the workings of Storys Creek, by diverting and capping the back of the shaft area. The control of this drainage should be considered only after use for alkaline recharge is considered further.

It will also be possible to divert waters from Rossarden workings, by diverting and capping the infiltration area. This is believed to be near an open fault and requires further investigation.

6.3 Load Treatment

6.3.1 Passive Treatment of Acid Drainage

The passive treatment of point sources by aerobic wetlands, anoxic limestone drains (ALDs) and SAPS is applicable.

6.3.1.1 Aerobic Wetlands

Aerobic wetlands will not be successful in treating acid drainage sources - such as Storys Creek, but they are expected to be successful in treating the alkaline Rossarden 4 Adit drainage.

Adit drainage would be pumped from the workings to a surface dam and treated by wetlands, or piped downslope to a suitable treatment area. Capital and operating costs of a 10 L/sec pump, for 130 metres would be in the order of \$30,000 plus \$12,000 per year power costs. Some alkalinity addition may be required to raise the pH sufficiently to remove Zn and Cd. However, most would be expected to co-precipitate or adsorb onto iron floc that will naturally form as the mine water oxidised in the wetland.

6.3.1.2 Anoxic Limestone Drains

In an ALD, alkalinity is produced when the acidic water contacts the limestone in an anoxic, closed environment. They are now widely used in the United States for inducing alkalinity into mine drainages, mainly coal mines and their design parameters and operating requirements are becoming well understood.

However, not all water is suitable for pretreatment with ALDs. The primary chemical

factors believed to limit the utility of ALDs are the presence of ferric iron (Fe^{3+}), aluminium (Al) and dissolved oxygen (DO).

The ALD must be sealed so that inputs of atmospheric oxygen are minimised and the accumulation of CO_2 within the ALD is maximised. This is usually accomplished by burying the ALD under several feet of clay. Plastic is commonly placed between the limestone and clay as an additional gas barrier and designed so that the limestone is inundated with water at all times.

The mass of limestone required to neutralize a certain discharge for a specified period can be readily calculated. From Mount Lyell studies, approximately 14 hours of contact time between mine water and limestone in an ALD is necessary to achieve a maximum concentration of alkalinity.

ALDs are not expected to be applicable at Storys Creek, because of Al and Fe concentrations. It may be possible to use ALDs for alkalinity additions.

6.3.1.3 Successive Alkalinity Producing Systems (SAPS)

Successive alkalinity producing systems (SAPS) which combine ALD technology with sulphate reduction mechanisms; promoting a vertical flow through organic substrates, into limestone beds, and ultimately discharging the pore waters were developed in the Eastern United States. SAPS are constructed ponds with a base of limestone, overlain by a layer of compost then a depth of free water.

SAPS have been demonstrated at the MLRDP programs to have been successful in treating acid drainage, but with some mechanical problem with blocking in the trials. They are suitable for the Storys Creek acid drainage sources.

6.3.1.4 Alkalinity Addition

Alkalinity addition is a viable technology because of the low acid loads and dispersed pollution sources. This could be applied in Storys Creek above the workings, and at select points within the creek.

Water flowing over limestone creates alkalinity when the acidic water contacts the limestone. They are subject to armouring and passivation when exposed to acid drainage, but recent studies indicate that even in this condition they still produce alkalinity.

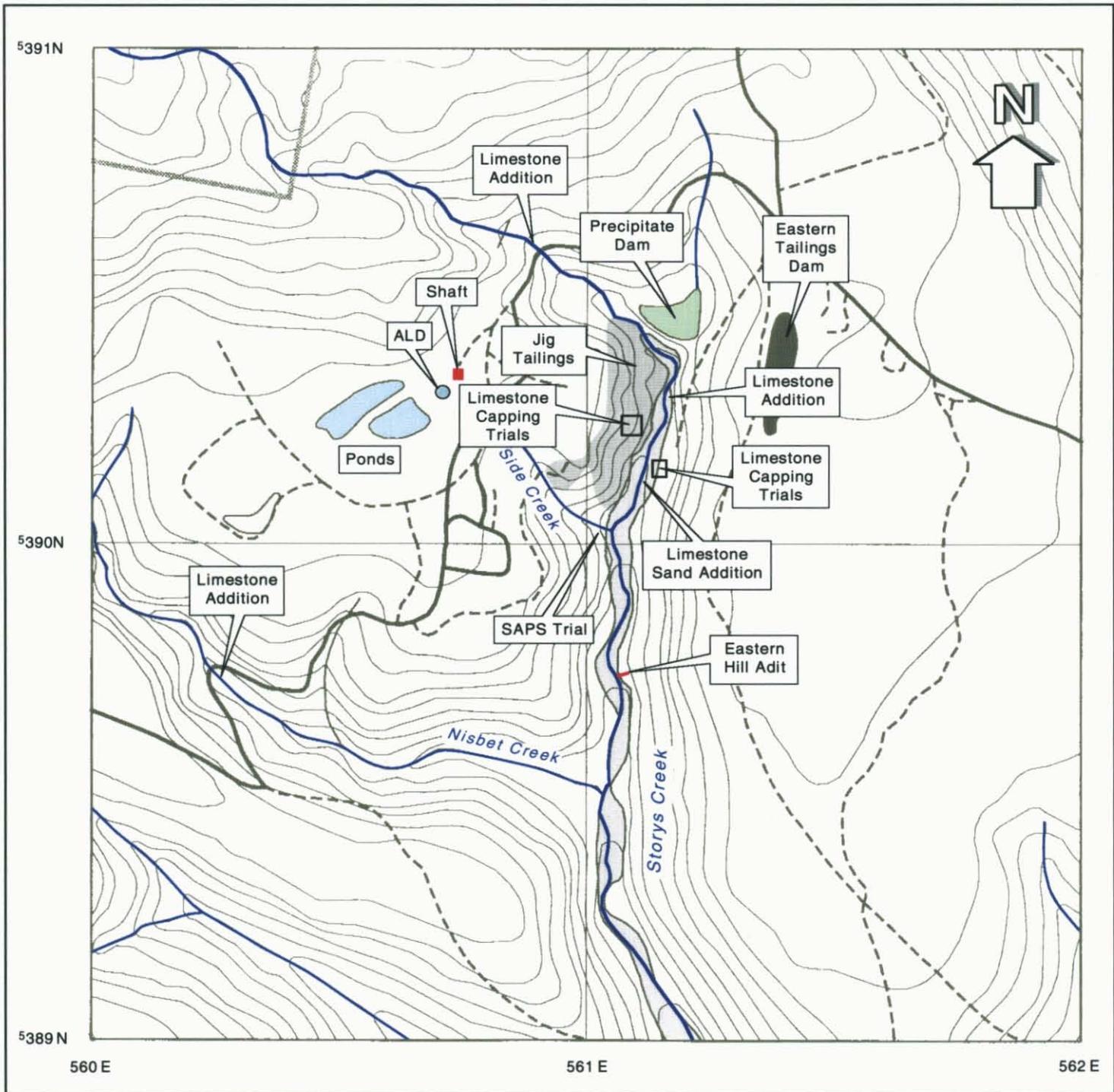
Limestone in the form of sands which are mobilised and dispersed under high flow conditions have also been successfully applied. The rates of alkalinity generated in an atmospheric environment are not large, but open drain systems and limestone sands are cheap, easily applied and suitable to steep topography. They are therefore potentially applicable on the site.

The effectiveness of sand addition has been proven in eastern USA and in particular in West Virginia. Work published by Zurbruch (Zurbruch, 1996) (Proceeding of the Seventeenth Annual West Virginia Surface Mine Drainage Task Force Symposium, 1996) documents the results achieved to date. He reported on the addition of limestone sands to lightly buffered streams in West Virginia. This work has been carried out since 1988, when sand sized particles were first noted not to be coated significantly with AD precipitates.

A five year program has now been completed to optimize the instream limestone sand treatment and the West Virginia Department of Natural Resources are now using instream limestone sand as a management technique for streams and in tributaries of lakes being affected by acid deposition. The technique has raised in-stream pH to over 7 (from below 5) and trout have now recolonised the streams. More recently trials have been carried out in acid mine drainage itself and this has also proven effective.

An alternative could be a water driven lime dosing plant which would be periodically filled by a contractor.

The use of ALDs to add alkalinity to the surface waters infiltrating into the Storys Creek



1 grid space to 1km

5 cm

MINERAL RESOURCES TASMANIA	
Storys Creek & Rossarden AD Remediation Projects Storys Creek Mine Area Trials	
John Miedecke & Partners P/L	FIG 6.1

(December 1997)

mine workings to raise the pH and precipitate metals within the workings may also be feasible. If they are proven to add significant alkalinity, they could be applicable at other clean water sources in the catchment.

6.4 Possible Trials

It is recommended that the following trials (and investigations) be conducted to evaluate the feasibility of remediation options (refer Figure 6.1).

The poor water quality data base will require site specific monitoring to establish effectiveness of the trials. This is discussed in Section 6.5.

6.4.1 Storys Creek

6.4.1.1 Alkalinity Addition

This would consist of alkalinity addition to clean and contaminated waters via the addition of limestone rock and sands. This would be in Storys Creek above the mine and near the Jig Tailings. Approximately 100 tonnes of limestone sands would be placed in the creek and water quality monitored above and below to establish the effectiveness the alkalinity addition. Limestone rock would be placed in the creek above the workings. Estimated costs are approximately \$12,000.

6.4.1.2 Limestone to Jig Tailings

Crushed agricultural grade limestone could be added to an area of the Jig tailings. Leachate from the trial area would be monitored by a lysimeter collector, as would an untreated area. Estimated costs are approximately \$12,000.

6.4.1.3 Limestone to Stream Bank Deposits

Crushed agricultural grade limestone could be added to an area of the river bank tailings, either near Storys Creek or near Rossarden, raising the buffering capacity of the creek-bank tailings.

After discussion with the steering committee, a smaller scale trial is proposed. The trial design is enclosed in Appendix C.

Following a demonstration of success, a larger scale trial would involve application of crushed limestone (grading to be confirmed but typically minus 5 to 10 mm with all-in-fines or agricultural grade) and monitoring pore water and runoff chemistry through time. Samples would be taken of surface materials and profiles.

6.4.1.3 ALD in Area Above Storys Mine

This would consist of an excavation, filled with 50 tonnes of limestone (100 mm) and capped with plastic and soil. Surface water at a rate of 1/3 litre would be directed into it to recharge the mine workings.

A smaller scale trial is recommended to assess alkalinity generation rates.

Periodic sampling from a lysimeter within the ALD would determine alkalinity generation rates.

6.4.1.4 SAPS

It would be possible to construct SAPS at the adit outflow of Side Creek. This would only be one or 2 series because of topography, but would raise pH, reduce acidity and precipitate Al and Fe and reduce acidity.

SAPS could also be built at Eastern Hill adit using existing wetlands.

6.4.2 Rossarden

Trials at Rossarden are recommended on the No 4 Adit outflow, however, access to the adit is difficult.

Trials could be conducted using a small wetland, however because of topography it is not recommended that trials be conducted at the outflow. A trial would involve pumping from one of the shafts, the construction of a small wetland and the installation of fauna trial, as recommended by Peter Davies.

Speciation of the drainage to determine Al and Fe is also recommended, as it is possible that some of the Zn which is reported as in solution is a fine colloid.

Studies to identify and minimise surface infiltration to the workings are required. This would aim at minimising the flows and therefore cost of pumping and treatment.

6.5 Further Monitoring and Investigations

6.5.1 Introduction

Additional environmental data is required for two primary purposes:

- Clarifying existing relationships between water quality, biological health, hydrology and sediment quality to refine remediation targets (and EQOs);
- Establishing a database against which the future success of remediation or other events in achieving the EQOs can be assessed.

An integrated assessment of chemical, biological conditions is required for the Storys Creek and South Esk catchments with sampling conducted at the same sites over a 12 month period.

6.5.2 Water Quality

The historical water quality data was limited in the elements analysed, the detection limits and lacked supporting flow data. As such the data allows only a cursory assessment of patterns, loads and priority contaminants in the system. There trends in water quality over time, relationships with flood events and seasonal variations are uncertain.

Therefore, benefits and changes in water quality due to the implementation of remediation works will be difficult to determine, because of these deficiencies, particularly in the South Esk River.

A monitoring program should be implemented which will allow;

- Direct measurements of the efficacy of reduction of metal loads/concentrations in Storys Creek and to the South Esk River;
- Measurement of the efficacy of reduced metal loads/concentrations in restoring environmental (biological and water quality) values in the Storys Creek and South Esk catchments.

Thus a monitoring program for the remediation should have two sequential stages, with primary water quality assessment in the Storys Creek catchment, followed by secondary environmental assessment in both Storys Creek and South Esk catchments, as follows:

- 1 Routine monitoring of water quality within and at the downstream end of

the Storys-Aberfoyle Creek drainage. This should consist of three permanent stations at each of Storys Creek upstream of Rossarden, and Aberfoyle Creek, and Aberfoyle Creek upstream of Storys Creek. Each station should continuously record conductivity, pH and stage. In addition, routine collection of water samples for pH, sulphate, total zinc, iron, cadmium and copper analyses should be conducted. Where possible, relationships between ion concentrations and conductivity should be developed to estimate continuous concentration records.

When conditions are judged to have changed significantly, then :

- 2 Periodic monitoring (e.g. five yearly) of water and sediment quality and biota in the Storys Creek and South Esk catchments. This should replicate the baseline data program outlined above.

An accurate assessment of variation in both total and dissolved metal concentrations in the South Esk is required at several locations: Henbury (upstream of Storys Creek), Avoca, Milford and Evandale. Data sets which adequately describe variation in metal concentration with season and flood stage are required. Fortnightly sampling for total and dissolved zinc, cadmium, copper and aluminium is required, along with total organic carbon, pH, conductivity and sulphate. Flow recording at Llewellyn and Perth should be maintained, and a gauging station established in Storys Creek downstream of the Aberfoyle Creek junction. A detailed evaluation of the proportion of dissolved metals in a subset of the above samples is also required.

A proposed monitoring program conducted by the HEC is enclosed in Appendix D.

6.5.3 Sediment Quality

Previous data on riverine sediments is inadequate and subject to within-site inconsistency in sediment composition and location. Fine sediment samples should be collected using bed traps in mid-stream riffles at Henbury, Avoca, Milford and Evandale on five occasions over 12 months. The dried sediment should be analysed for organic content, total zinc, cadmium, copper, aluminium, lead and size fractions.

As indicated previously, levels of zinc, cadmium and copper are frequently well above the ANZECC/NHMRC levels above which detailed environmental investigation is required. Such an investigation should be conducted, to:

- develop a more comprehensive database of total and extracted metals from instream and floodplain sediments at a number of sites and several sediment size fractions;
- assess the bioavailability of the metals to aquatic organisms;
- identify any sites that may need active clean-up.

6.5.4 Biological Health

6.5.4.1 Invertebrates

Current data on invertebrates is insufficient. A combined quantitative-qualitative survey of invertebrates should be conducted at all South Esk sites originally sampled by Norris as well as sites in upper and lower Storys and Aberfoyle Creeks. Sampling should be conducted using the MRHI AUSRIVAS sampling protocol with both live pick and preserved sub-sampled residue processing (this does not require additional field sampling resources). Sampling to be conducted twice once in spring and in autumn. This will enable assessment of each site using the standard AUSRIVAS predictive model framework, deriving O/E indices and bands, as well as providing quantitative data for comparison with Norris database and to establish a current database for future

comparisons. Some environmental variables should also be measured at each site to assess the relationship between invertebrate community composition, diversity and abundance and landuse/riparian factors.

In addition, where pilot experiments are conducted to assess the feasibility of water quality remediation on-site (eg by neutralization, SAPS etc.), there is potential for using the outflows, at appropriate dilutions, as source wastewaters to test toxicity to macroinvertebrates in simple artificial streams. Such experiments are being proposed for assessing water quality remediation targets for Mt Lyell (under the MLRRDP). They also allow the testing the impact of the resulting composite effluent i.e. including the mixture of dissolved metals as well as flocculated material on aquatic invertebrates.

6.5.4.2 Fish

Fish data is highly inadequate. A quantitative survey of fish populations at the invertebrate sampling sites should be conducted once in January-March. Sampling should also be done semi-quantitatively at the same time (this will not require additional resources) to allow rapid electrofishing assessment to be used in the future to reduce the resources required. A number of habitat variables should be measured to enable data to be compared with HAFA (Habitat Attribute Fish Abundance) models developed for Tasmanian riverine trout populations. Deviations from HAFA trout biomass predictions can be used as an index of human impact on trout biomass.

6.5.4.3 Monitoring Program

A proposed monitoring program conducted by Freshwater Systems is enclosed in Appendix E.

6.5.5 Data Analysis

The entire baseline data set should be analysed for:

- Median and percentile metal concentrations at all stations;
- Median sediment metal concentrations at all stations;
- Total metal loads entering the South Esk at Storys Creek;
- Total metal loads at the three locations downstream of Storys Creek;
- relationships between metal concentrations, metal speciation (total/dissolved) and flow stage;
- relationships between water and sediment metal concentrations, catchment based environmental variables and biological condition measured as invertebrate AUSRIVAS O/E scores, number of taxa, abundance and dissimilarity, and as fish biomass and abundance and deviation from HAFA predictions.

The above analyses should be used to derive target EQO water and sediment metal concentrations for Storys and Aberfoyle Creeks and for the South Esk River at Avoca, Milford, and Evandale.

A standard database containing all information should be established, and formally used as a basis for evaluation of remediation success.

REFERENCES

Bobbi et al. 1996. South Esk Basin, State of Rivers Report. DPI, 1996.

John Miedecke and Partners, 1997. Storys Creek/Rossarden Acid Drainage Remediation Study - Stage 1 Interim Report. September 1997.

Locher (1993). Rossarden/Storeys Creek Overview of Environmental Monitoring Data. Department of Environment and Land Management 1993

Zurbruch, 1996. Proceeding of the Seventeenth Annual West Virginia Surface Mine Drainage Task Force Symposium, 1996.

Note: other references listed in Appendix B

APPENDIX A WATER QUALITY DATA REPORT

STORYS CREEK WATER QUALITY DATA BASE

A data base is available which contains the basic data used in the study. An Excel Workbook contains the following spreadsheets:

- the medians for the data obtained from Helen Locher, DELM and Wellington,
- Helen Locher data for Storys Creek
- Helen Locher data for Aberfoyle Creek
- Helen Locher data for Side Creek
- Helen Locher data for South Esk
- DELM data 1984-1995
- DELM data 1996-1997
- Hugh Wellington 1994 data
- HEC 1997 data
- HEC HYDROL data 1982-1989
- DPIF South Esk data

This data base will be available from Mineral Resources or John Miedecke and Partners.

The primary data obtained is from three sources. The first set is from Helen Locher, which was used in her 1992 report. A second data set was sourced from DELM, and the third set was collected by Hugh Wellington.

The data from Helen Locher is extensive, and included sites in Storys Creek, Side Creek, Aberfoyle Creek and the South Esk River. The number of samples for each station varies, but is usually between five and ten. The period of collection also varies from station to station. Generally it covers the period between 1982 and 1990, however, some stations were sampled regularly between 1975 and 1977. The parameters tested for included pH (sometimes field sometimes lab), TDS, TSS, Cd, Cu, Fe, Mn, SO₄ and Zn. Generally these were filtered, occasionally, totals were reported. For each station, it was found that there was no "standard set" of parameters analysed - on some occasions parameters were reported, and on others they were not. Two of the stations yielded extensive data sets, one in Storys Creek (Stn 20) and one in Aberfoyle Creek (Stn35).

The DELM data set appears to have been collected to observe the effects of works carried out around the Precipitation Dam in 1994. The data for each station was split into "before works" and "after works", with means calculated for before and after. The data was labelled according to the location of the sample, and so these were compared to the stations for the Locher data, and the corresponding station number applied. Data was collected in Storys Creek and Side Creek, over a period from 1984 to 1995. The parameters sampled were similar to that found in the Locher data set. Some flow data is included in this set.

The third data set is a "snapshot" of the Storys, Side, Nisbet and Aberfoyle Creeks and the South Esk River. This one-off sample was taken in December 1984 by Hugh Wellington and analysed the water samples for pH, Zn, Fe, F, Mn, Al, Ca, Mg, Na, SO₄, and TDS. We are unsure whether it is lab or field pH, or if the other constituents are totals or filtered.

Each of the data sets was organised to achieve some consistency. Medians were calculated for each station for the Locher and DELM data. A table was then created showing the median data arranged by station. The result was a table showing each station, the source of the data (a, b and c for Locher, DELM and Wellington respectively), the collection period, and the medians for selected parameters (pH, TDS, TSS, Al, Cl, Cu, Fe, Mn, SO₄, and Zn). This table was then used as a working table to examine the data closer and to refine the data sets.

The data was analysed to determine exactly what was being presented. Was the pH a lab or field measurement? Were the constituents filtered or totals? What was the number of samples for each station, and for each set?

On closer examination of the data we found that some of the data in the Locher data set appeared to be sourced from the DELM data set. This was discovered because of an irregularity observed in the Locher set. One particular sample date had been pasted into the Locher set from the DELM set, without the units being converted (the DELM set was reported as µg/L, the Locher set is in mg/L). We then found that there was a considerable amount of duplication between the Locher set and the DELM set. Stations 11, 13, 17 and 18 contain data which is common to both sets. So far though, both sets remain complete, the reason being that even though there is duplication, not all of the parameters are present in both sets. By deleting the duplicated sample dates from one data set, we may lose information for the parameters that are not duplicated.

The presence of this duplication did however answer some questions, particularly about the DELM data set. We were able to tell if lab or field pH was being reported, and if totals or filtered results were reported.

A new table was created from the medians of each sampling station. This table included information about the number of samples taken at each station, if the pH value is lab or field, any relevant flow data, a Cd column was added, and a column was added showing if the constituents are totals or filtered. A column with any comments about a station is also included, particularly to show which stations have data duplicated in the DELM and Locher data sets.

Acidity calculations have not been done because in no instance is there a station which has a complete set of parameters required to calculate acidity. Al, Cl and Cu have been reported very infrequently, and these columns will need to be completed with estimates in order to calculate acidity.

Additional data has been obtained from the HEC and DPIF which is included in the data base.

APPENDIX B FRESHWATER SYSTEMS REPORT

Storys Creek/Rossarden Mines - Environmental Data, EQO's and Monitoring Program

*Peter Davies, Freshwater Systems,
82 Waimea Avenue Sandy Bay Tas 7005*

Introduction

This section describes the state of water quality, biological and other environmental data associated with the impacts of Storys Creek-Rossarden Mines (SCR) on the South Esk catchment. These data were summarised and reviewed in a comprehensive report by Locher (1993). The content of that report is regarded as being largely accurate and does not warrant detailed repetition. This section therefore provides:

1. an overview of pre-1993 environmental data and new data collected up to late 1997;
2. an analysis of water quality and biological data for the South Esk River;
3. an assessment of data needs to address specific issues;
4. a list of interim Environmental Quality Objectives (EQO's) for the South Esk and Storys Creek catchments as they pertain to the SCR issue;
5. a monitoring program design for the assessment of recovery in environmental condition in the South Esk and Storys Creek systems with remediation.

Existing Environmental Data

Environmental data associated with the SCR issue has been collected in relation to:

- Surface water quality;
- Sediment chemistry and quantity;
- Aquatic biota and fisheries;
- Soil chemistry.

Water quality

Existing water quality data on both Storys Creek and South Esk catchments is limited in its utility. Data has been collected by a variety of groups and individuals with little consistency in:

- Sampling sites
- Sampling frequency'

- Analytes
- Detection limits and analysis precision

The subsequent discussion will only describe sets of water quality data deemed large, reliable and representative enough to at least qualitatively describe water quality in the South Esk and Storys Creek drainages as it pertains to the SCR issue.

Water quality data collected prior to 1993 has been summarised by Locher (1993), and there is little point in repeating details presented in that comprehensive report. Results of the 1997 HEC survey conducted as part of this study are reported elsewhere. Comparison of Norris's water quality data with the recent DELM (1996-97) data suggests that water quality may have changed slightly since 1975-76, although both data sets have low sample numbers making further comparison and/or correction for flow conditions unwarranted.

There are two main water quality datasets of use in determining current water quality in the South Esk and Storys Creek systems, those reported by DELM (unpub. data for 1996-97) and those cited in this report. A single collection of samples at a range of sites was also performed by DPIF in March 1995 (Bobbi et al. 1996). The DELM data consists of nine samples collected over 12 months in 1996-97 in Storys Creek at Rossarden and in the South Esk at Avoca, as well as three samples collected in Aberfoyle Creek downstream of adit 4. These data are considered reliable in terms of precision and accuracy and are the only data with sufficient (though minimally) data to estimate interim median and maximum values. The median DELM values are consistent with those recorded at the same sites in the present HEC survey and in the 1995 DPIF survey (Bobbi et al. 1996).

The data collected to date allows only a cursory assessment of patterns, loads and priority contaminants in the system. None of the data collected allows a viable assessment of:

- Trends or changes in water quality with time, particularly over 10 – 30 year periods;
- Trends in water quality in space, particularly in relation to changes downstream of SCJ in the South Esk River;
- Relationships between analyte concentrations or loads and floods;
- Seasonal patterns in analyte concentrations or loads;
- Relative balances of total and filterable/bioavailable metals.

The above comments relate to analytes associated with the SCR issue. Data on water quality associated with non-SCR issues is even less suitable for assessment of changes in time or space due to impacts such as land clearing, grazing and irrigation, riparian impacts, channel erosion and STP inputs.

The overall message from the existing water quality data is:

1. SC above Aberfoyle Creek and Aberfoyle Creek upstream of Storys Creek are significantly contaminated with zinc, cadmium, copper and aluminium in both total and dissolved (i.e. filterable at 0.45 micron) forms;
2. SC has contributed and continues to contribute environmentally significant loads and concentrations of zinc, cadmium and aluminium to the South Esk River, with occasional high concentrations of copper.
3. Most of the above metals is in filterable form, but the degree to which these metals are truly in dissolved form and hence toxic to aquatic life is unknown.
4. Significant loads of iron and aluminium, in flocculated hydroxide forms, are present within Aberfoyle and lower Storys Creeks, and these are deposited both within the Creek channels and in the South Esk River.
5. Total concentrations of metals decrease downstream in the South Esk River from SCJ.
6. Inputs from SC have been responsible for metal contaminated sediments deposited within and outside the South Esk River channel, the environmental significance of which is unknown.

Sediment Chemistry data

No recent data on sediments is available. Locher (1993) summarised the limited historical data on sediment chemistry in the South Esk River. However, much of these data were highly variable and inconsistent in the manner of collection. Overall, sediments in Storys Creek and in the South Esk downstream of SCJ have had a higher than background load of metals, the environmental significance of which is unclear. This needs further investigation, as efforts to improve ecological conditions through remediating water quality may be compromised by historical and/or new metal contamination of in-channel sediments. Ongoing or new sediment/substrate contamination is likely to occur with metal precipitation and/or adsorption onto hydroxide-type flocculates and deposition within the stream bed matrix.

The historical instream and floodplain sediment data for Storys Creek – South Esk indicates that those sediments analysed comply with the ANZECC/NHMRC (1992) definition of contaminated sites (see in Locher 1993 p 21). Levels of zinc, cadmium and copper are

frequently well above the ANZECC/NHMRC (1992) levels above which detailed environmental investigation is required.

Biological Data

Biological data on the South Esk river system was found to have the same problems with inconsistency as for water quality, with lack of consistency in site selection and methods of data collection. Five sets of biological data are available for the South Esk River that are relevant to the Storys Creek issue. These are:

1. Data collected by Thorp and Lake (1973) in 1972 on water quality and macroinvertebrates.
2. Data collected by Norris for a PhD (Norris 1979) in 1975 – 76 (published in Norris 1980, 1981, 1982) on water quality, macroinvertebrates and fish;
3. Data collected by consultants to the HEC in 1984 on macroinvertebrates (cited in Locher 1993, but not available for this study);
4. Data collected by DPIF in 1995 for the South Esk Basin State of the Rivers Report (Bobbi et al. 1996) on macroinvertebrates;
5. Data collected by Inland Fisheries Commission on the trout fishery of the South Esk River (IFC, unpub. data, provided for this study).

Of these, only Norris (1979, 1980) and Bobbi et al. (1996) provide valuable quantitative and semi quantitative data, respectively, on the biological condition of the river. Locher (1993) cites Norris' interpretation of his biological data, but detailed inspection revealed that further analysis of the data was warranted for the current report. This is described below.

Norris study

The data collected by Norris consisted of eight sets of macroinvertebrate samples from each of eight sites in the South Esk River and Storys Creek collected at approximately two monthly intervals over two years, accompanied by water quality data collection at the same sites (Norris 1979). Plots of the changes observed in mean abundance and total number of taxa with distance from SCJ are shown in Figure 1. While there are few problems with the consistency and representativeness of these data, no details are provided on the substrates from which they were collected, nor are quantitative data available on the condition of the stream channel at each location.

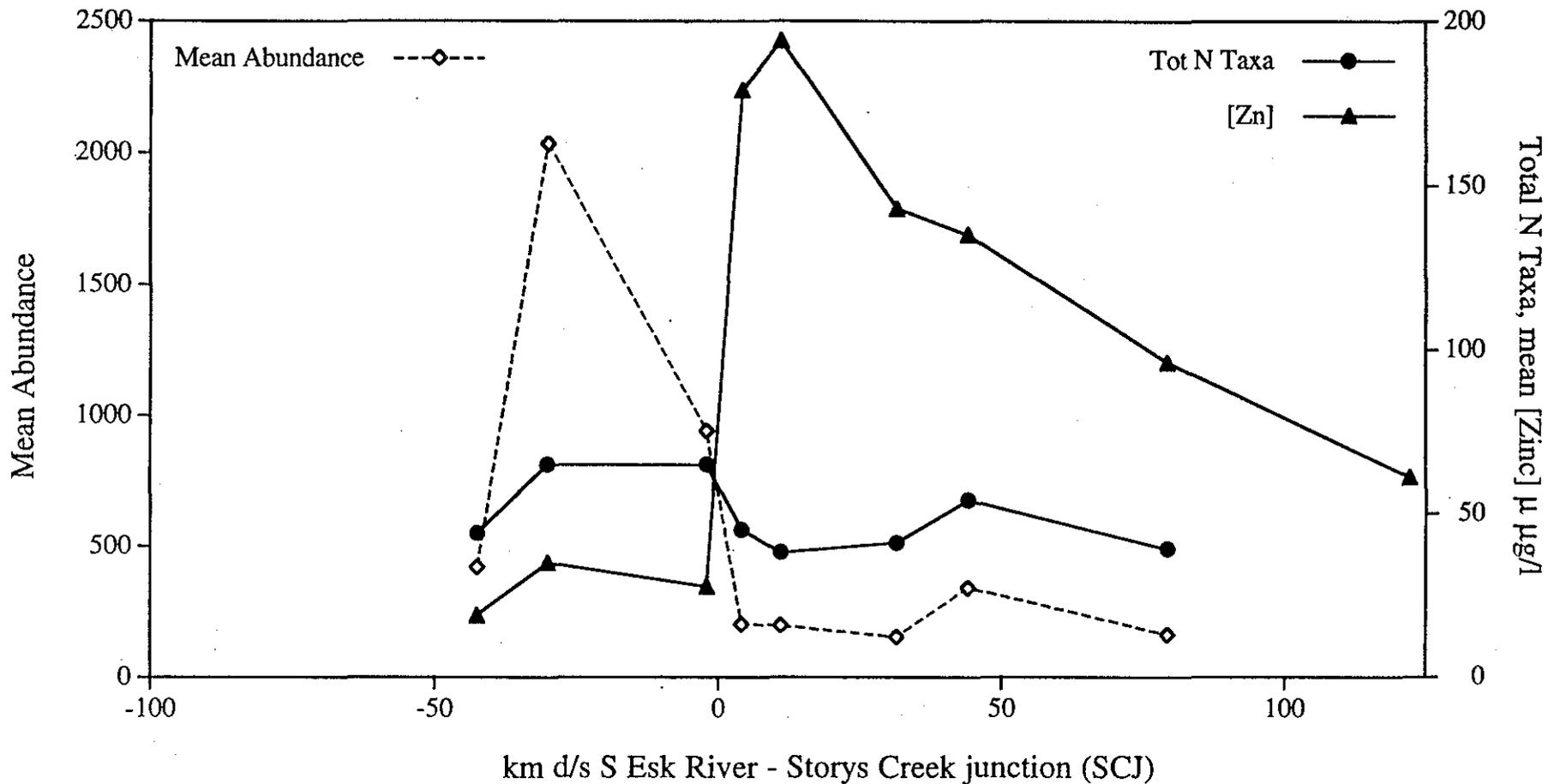


Figure 1. Plot of mean water zinc concentration, total number of tax (species) and mean abundance (n/0.6m²) against distance from Storys Creek junction (SCJ) at eight South Esk River sites quantitatively sampled in 1975-76 by Norris (1979).

Much of these data have been published in the scientific literature (Norris 1980, 1981, 1982). However, there are fundamental design problems with the project, the most notable being the lack of a control river system and the reliance on an upstream control set of sites against which sites downstream of Storys Creek are compared. While this design is partially adequate for assessing the impacts of Storys Creek inputs in the immediate vicinity of the junction, it is inadequate for detecting impacts further downstream.

There is a recognised decline in biological condition for many streams in agricultural areas of Tasmania and South Eastern Australia. This is largely as a result of the combination of altered flow regimes, enhanced diffuse and point source nutrient and organic inputs and enhanced sediment inputs, combined with degraded instream physical habitat and channel conditions. Such a downstream decline has been observed for the Meander River (Bobbi et al. 1996), and is apparent from a decline in macroinvertebrate diversity and major changes in community composition compared with reference conditions.

In summary, an appropriate design for the assessment of the degree of impact from Storys Creek and /or change in biological condition in downstream reaches of the South Esk River requires either a paired catchment sampling design or multiple lower catchment control site sampling. In both cases the control condition should include at least one agricultural catchment with a river systems as similar hydrologically and geomorphologically to the South Esk River as possible. The addition of a similar, unimpacted catchment would be advantageous but one is not available.

In Norris' study, correlations were examined between biological condition and water quality only and comparisons were made between sites far downstream in the catchment and sites upstream (some 100 - 120 km apart). This is not valid for two reasons:

- Natural changes in habitat conditions (hydrology, channel form, substrate composition) and biota downstream; and
- Incremental changes in the degree of human impacts other than Storys Creek (land clearing, riparian degradation, decreases in summer low flows from irrigation, grazing/cropping impacts, sewage inputs etc.).

On re-examination of the data, valid conclusions from the Norris study are as follows:

- That enhanced levels of zinc, cadmium, copper and lead were found downstream of Storys Creek, generally decreasing in a downstream direction;

- That there was a decrease in macroinvertebrate diversity and abundance in sites immediately downstream of Storys Creek;
- That there is a trend toward recovery evident from 30 km downstream of SCJ;
- That macroinvertebrate diversity and abundance were lower in sites more than 30 km downstream of SCJ than upstream but that this cannot be formally linked to the Storys Creek discharge.

It was felt that the results of Norris' study were still highly relevant to the current situation (as borne out by the recent DPIF data, see below) and warranted further analysis. Norris' invertebrate data was re-analysed using both flexible UPGMA classification and multidimensional scaling (MDS) ordination using the PRIMER software package (Carr 1996). The data from all eight sampling events from each of the eight study sites was summed and $\log(x+1)$ transformed. A Bray-Curtis Similarity matrix was derived and used as the basis for performing the UPGMA clustering, to derive a dendrogram indicating relationships between the eight sites (Figure 2). In addition, MDS was performed, using 20 random starts, and resulted in a two-dimensional ordination of low stress (0.04), illustrated in Figure 3. In addition, PCA ordination was performed on mean Zn concentrations and distance from SCJ for the eight sites, again in PRIMER, and resulted in the PCA plot shown in Figure 4.

These analysis revealed a fundamental issue in the relationship between biological condition of the South Esk River and the impact of SCR, of considerable importance ion the derivation of EQO's for the River. Norris (1982) had noted the anomaly of a slight recovery in biological condition at site 7 and an enhanced decline in biodiversity and abundance at site 8 (Evandale), some 80 km downstream of SCJ. He hypothesised that this was due to an unknown enhanced effect of the pollutants emanating from SC, but acknowledged that this was unusual being so far from the source of impact. The analyses described above suggest an alternative explanation. The MDS shows a clear downstream gradient in stream sites from 1 to 8 across the ordination shown in Figure 3, with a shift sideways for sites 4 – 6 (those immediately downstream of SCJ). Principle Component Correlation (PCC in the PATN statistics package, Belbin 1993) analysis showed that the plane of site distribution defined by 1-3 and 5 – 8 was highly correlated with distance from SCJ, while the vector in the direction of sites 3 – 5 was highly correlated with mean Zn concentration (Figure 3). This pattern was almost exactly duplicated in the PCA (Figure 4) with only two environmental variables, [Zn] and distance from SCJ, with an almost

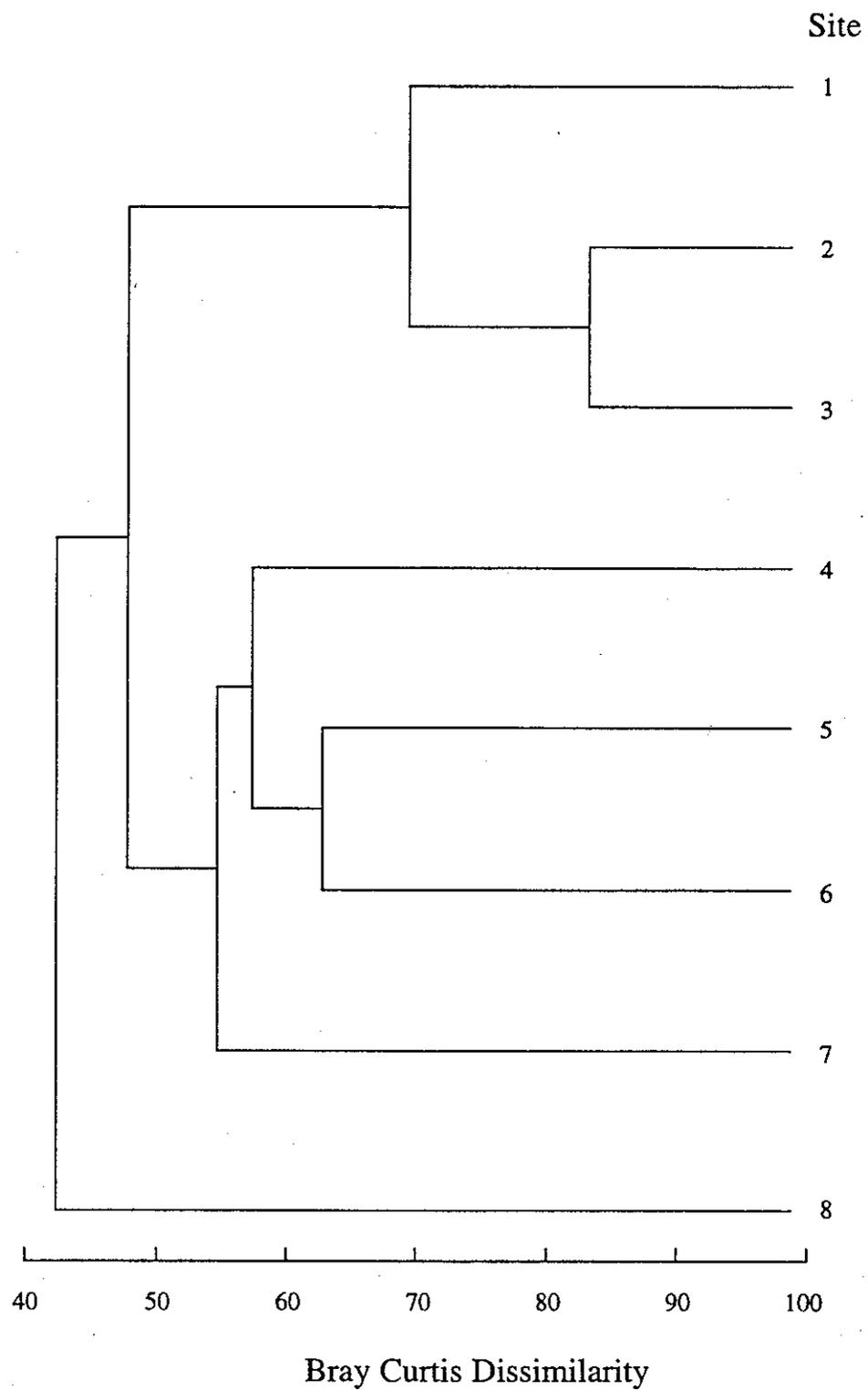


Figure 2. Classification (by flexible UPGMA, in PRIMER) of macroinvertebrate communities from eight sampling sites in the South Esk River (data from Norris 1982, see this report for details).

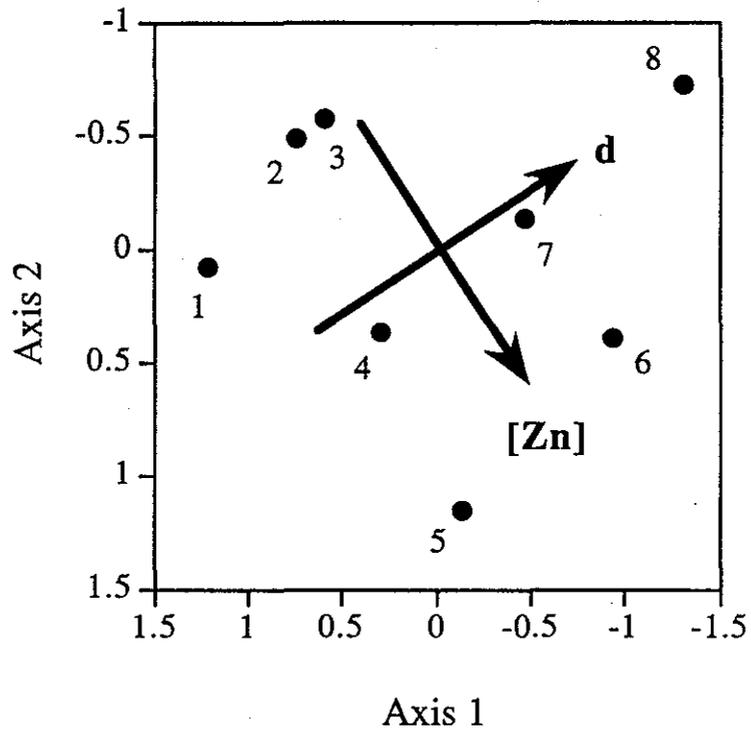
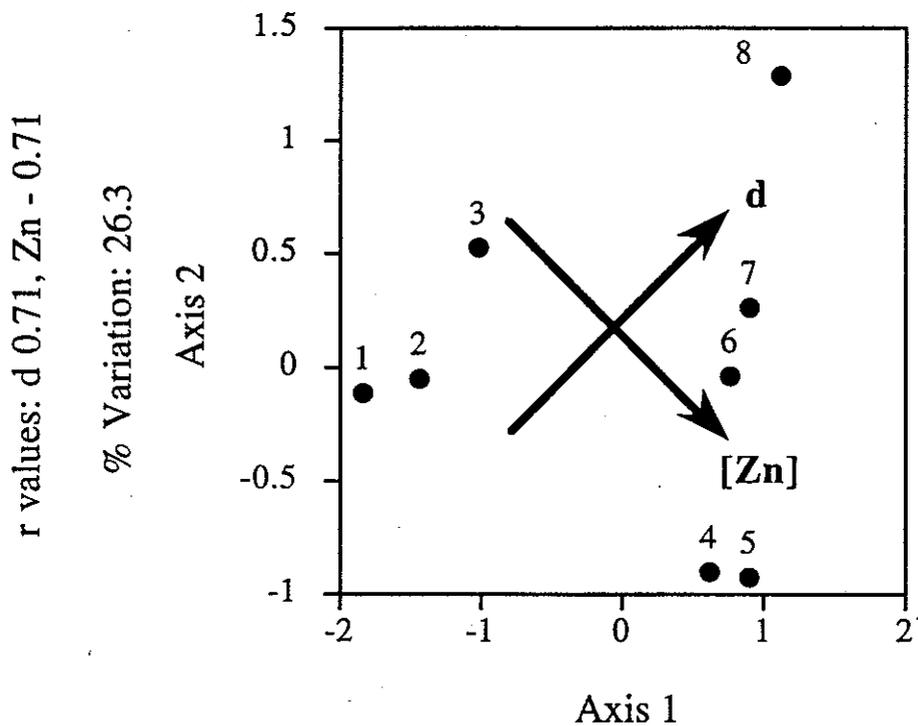


Figure 3. Plot of multidimensional scaling (MDS) ordination of South Esk sampling site macroinvertebrate community similarities (data from Norris 1979, re-analysed). Vectors for d and [Zn] derived from Principal Component Correlation analysis are shown.

Site numbers are as follows: 1 Malahide, 2 Tulochgorum, 3 Henbury, 4 2km d/s Storys, 5 Avoca, 6 Milford, 7 Clyne Vale, 8 Pleasant Banks (u/s Evandale).



r values: d 0.71, Zn 0.71

% Variation: 73.7

Figure 4. Plot of Principal Components Analysis (PCA) of South Esk sampling sites with mean [Zn] and distance d from Storys Creek Junction as variables (from Norris 1979). Vectors for d and [Zn] are shown, along with partial correlation coefficients and % variation explained by each axis.

Site numbers are as follows: 1 Malahide, 2 Tulochgorum, 3 Henbury, 4 2km d/s Storys, 5 Avoca, 6 Milford, 7 Clyne Vale, 8 Pleasant Banks (u/s Evandale).

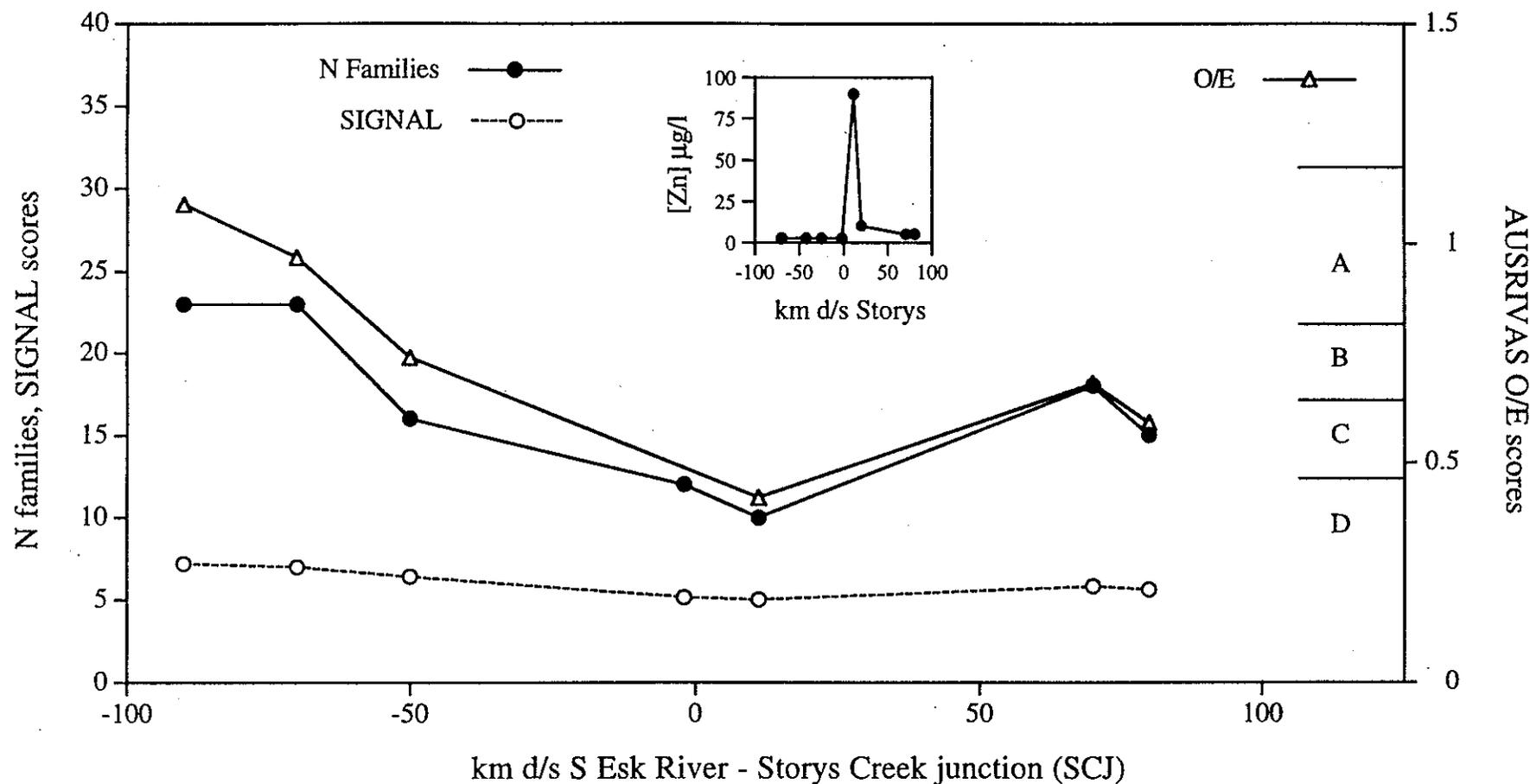


Figure 5. Plot of number of taxa (families), SIGNAL scores and AUSRIVAS O/E outputs against distance from Storys Creek junction (SCJ) at seven South Esk River sites sampled in 1995 using the AUSRIVAS rapid assessment protocol by DPIF (Bobbi et al. 1996). Total zinc concentrations from spot samples taken in March 1995 are shown in inset. O/E scores should be compared with AUSRIVAS bands shown at right (A = unimpacted, B = probable impact, C = impacted, D = severe impact).

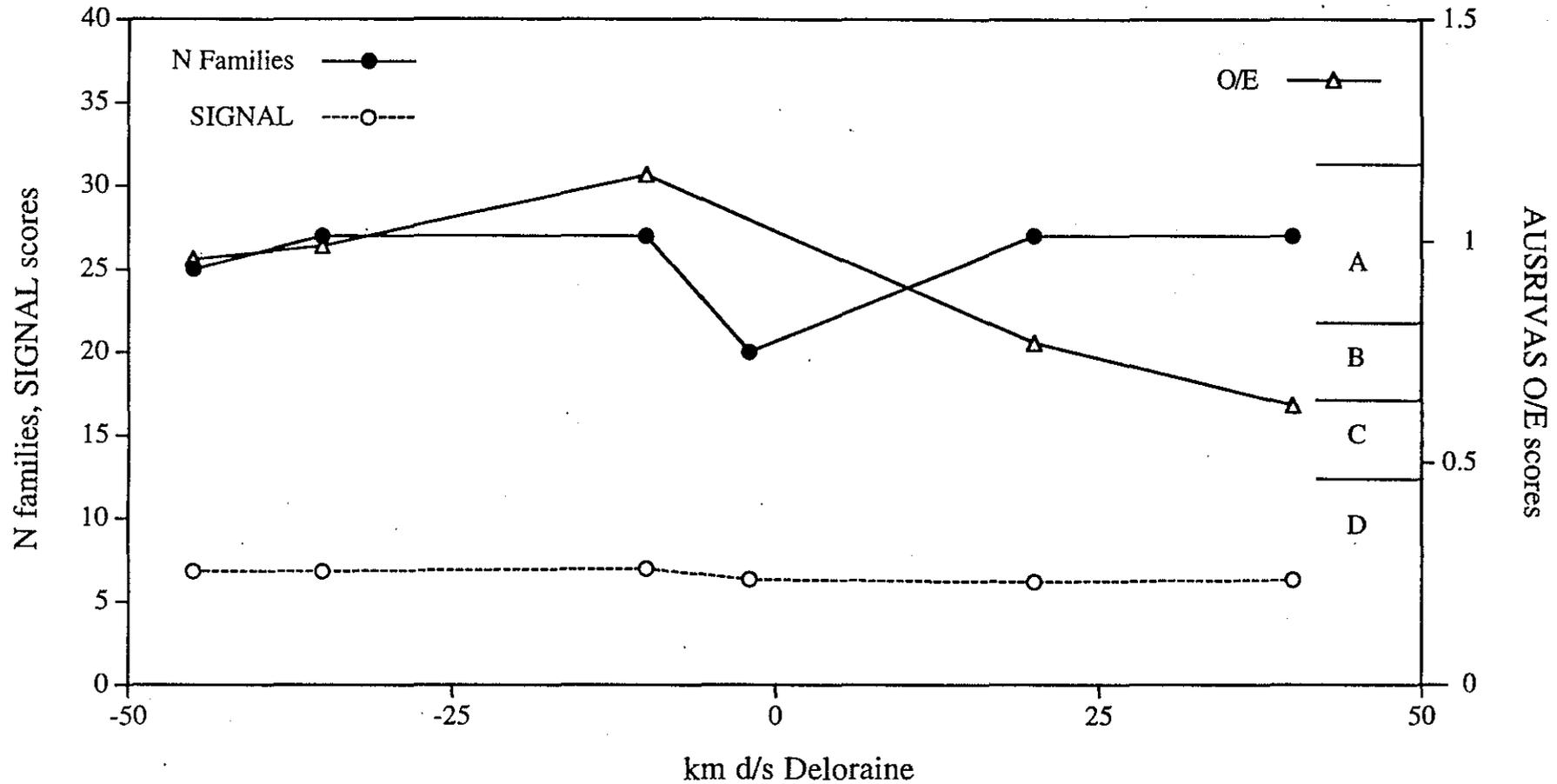


Figure 6. Plot of number of taxa (families), SIGNAL scores and AUSRIVAS O/E outputs against distance from Deloraine at seven Meander River sites sampled in 1995 using the AUSRIVAS rapid assessment protocol by DPIF (Bobbi et al. 1996). O/E scores should be compared with AUSRIVAS bands shown at right (A = unimpacted, B = probable impact, C = impacted, D = severe impact).

identical pattern of site distributions in the ordination plot. The PCA axes were highly correlated as shown in Figure 4, with the eigenvectors for [Zn] and distance from SCJ shown in the plot. Overall, the site ordinations derived independently from biological and physico-chemical data, the latter described by only two simple variables, show remarkably similar patterns.

Thus, the biological communities show an identical sets of relationships to those determined purely by [Zn] and distance from SCJ. This suggests two things:

- That there is a general downstream trend in macroinvertebrate community composition;
- That there is a disruption to that pattern due to the impact of SC, most likely due to metal contamination.

The downstream trend in macroinvertebrate community composition is accompanied by a declining trend in abundance and diversity. The Norris data supports a decline (by paired t-test, paired by sampling date) in invertebrate abundance for sites 4 and 5 but, due to wide variability in abundances at sites 1 – 3, there is no or at best a marginally ($p = 0.04$) significant overall difference in abundance and diversity between sites 6-8 and sites 1-3.

We conclude that the downstream trends in invertebrate community composition, diversity and abundance are due to cumulative impacts of landuse within the catchment with, *superimposed* on it, a major impact due to the input of SC water and a possible associated change in stream substrate (from armoured cobble to a less stable finer quartzitic gravels). It is also suggested that, both during Norris' study and currently (see DPIF study below), that the main zone of impact from SCR is between SCJ and Milford, some 30 km downstream. There is evidence of recovery at Clyne Vale (44 km d/s SCJ), with a further decline at Pleasant Banks (79 km d/s SCJ near Evandale).

We conclude that recovery occurs from the SCR impact from around 30 km downstream and that further declines in biological condition are a result of catchment disturbance rather than SCR impacts.

DPIF Study

Further evidence is provided to support these ideas from the DPIF State of the Rivers Survey for the South Esk River (Bobbi et al. 1996). Macroinvertebrate sampling was conducted at 7 sites from Mathinna to Perth in the South Esk River, unfortunately with no

sites between Avoca and Evandale. Unlike the Norris study, this was done using the semi-quantitative AUSRIVAS sampling and assessment methodology (Schofield and Davies 1996). This approach gives reliable data on diversity at family level (not species level as in the Norris study), but not on abundance. However, it also provides a standardised index of departure from an unpolluted condition, by providing a prediction of the macroinvertebrate community under unpolluted ('reference') conditions. A comparison of the number of taxa observed at the site is made with the number predicted, to give an O/E (observed to expected) ratio. This ratio is divided into bands which are used to classify a site in terms of the degree of impact from A (unpolluted or reference condition with a high number of expected taxa) to D (highly impacted or polluted and with a low number of expected taxa).

Plots of diversity (number of families), O/E and SIGNAL scores are shown for the South Esk and the Meander Rivers at distances relative to SCJ and Deloraine respectively (Figure 5 and 6). Concentrations of zinc are also plotted for the South Esk (data from the DPIF survey in 1996). Overall, the pattern in the South Esk is the same as that found by Norris (compare with Figure 1). Thus a decline in diversity is found immediately downstream of SCJ, accompanied by a decline in O/E and SIGNAL score.

There are some additional key elements, however. Firstly, a major decline in diversity, O/E and SIGNAL was found at a site upstream of SCJ, attributed to the poor condition of the river channel (stock access, eroding banks etc.), with diversity and SIGNAL values not significantly different from those found at a site immediately downstream of SCJ (Avoca). Secondly, the two sites sample at 80 and 90 km downstream of SCJ (Evandale and Perth) had SIGNAL, O/E and diversity values lower than those found at sites upstream of SCJ, but higher than those at Avoca. The lack of sites between Avoca and Evandale precludes any assessment of the current impact of SCR. The overall pattern is however consistent with the Norris study.

The DPIF study also included an assessment of the biological condition of the Meander River (Figure 6). Comparison of the trends in the Meander and South Esk River are illuminating. Declines in O/E and SIGNAL were observed in the Meander in the vicinity of Deloraine, with no recovery downstream. The decline in O/E was similar to that observed from the upper reaches of the South Esk to Perth i.e. from ca. 7 - 8 to 6. Both catchments are highly developed in the main valley floor for grazing and cropping with similar levels of degradation of riparian zones. Suspended solids and total phosphorus levels increase

downstream in both catchments, although to a lesser extent in the South Esk than in the Meander River.

It appears therefore that there are similarities in the pattern of biological condition in both rivers in a downstream direction, with the exception of a mid-reach decline in condition related to current and/or historical SC chemical and sediment pollutant inputs.

Fishery data

Two data sets exist in relation to fish – fish population survey data and fishery statistics obtained from IFC annual questionnaire data (available for the period 1985/86 to 1995/96). Locher (1993) cites Thorpe and Lake (1973) who in turn cited Tyler and Buckney (1973) that no fish were resident in the South Esk River downstream of SCJ. The only evidence provided by Tyler and Buckney is anecdotal reporting of farmers opinions and the results of an IFC electrofishing survey reportedly conducted in April 1970, the data from which is not provided in Tyler and Buckney's (1973) paper. On inspection of IFC records and annual reports, no record of this survey was found. This cannot be taken therefore as valid evidence of the absence of fish from the lower South Esk River as a result of SCR impacts.

One other fish survey was conducted, by Norris and Lake (1984) while collecting fish for metal analyses. Two hundred meters of river at all eight original South Esk sampling sites were electrofished 'exhaustively' and the numbers and species of fish caught reported by Norris and Lake (1984). These are shown in Table 1. Davies et al. (1988) and Davies (1989) discussed and evaluated the influences on electrofishing efficiency of surveys in Tasmanian rivers. It is highly likely that the Norris and Lake survey was not quantitative nor truly exhaustive. However, if one assumes that the sampling effort was essentially similar, then the data suggests that fish abundance was greater at sites downstream of SCJ than upstream. This is not surprising, given the greater habitat complexity in the lower river than upstream. It does suggest that several species of fish were present in the South Esk River at sites from 30 to 80 km downstream of SCJ, in abundances similar to or higher than those found at sites upstream of SCJ. The data were, however, inadequate to properly assess the status of fish populations, changes between sites or the influence of the impact of SCJ. A quantitative survey of fish populations is needed to establish at least a rudimentary baseline data set for assessing the effects of any changes in environmental quality from SCR remediation.

Table 1. Details of fish caught during survey conducted in January 1976 by Norris and Lake (1984).

Site No.	Site	km d/s Storys	N specie s	Total N/ 200m	Brown trout/200 m	Redfin Perch/200 m
1	u/s Break O'Day	-42.5	1	2	2	0
2	12.5 km d/s site 1	-30	5	20	6	5
3	u/s Storys	-2	4	10	6	1
4	4.1 km d/s Storys	4.1	1	5	0	0
5	11 km d/s Storys	11	0	0	0	0
6	31.5 km d/s Storys	31.5	3	11	8	2
7	44.1 km d/s Storys	44.1	3	19	5	8
8	79.2 km d/s Storys	79.2	4	47	6	1

The Inland Fisheries Commission has conducted statewide postal questionnaire surveys of trout fisheries annually since 1986. The surveys, sent to 2000+, anglers per year obtain standard data on angler visitation, catch per day, fishing effort and harvest from a wide variety of waters across the state (Davies and Thompson 1988). Data for the South Esk and Meander Rivers from 1985/86 to 1995/96 was provided for comparative analysis in this study by Stuart Chilcott (IFC pers. Comm.). Plots of fishery statistics are shown in Figures 7 and 8. The data indicates that:

- The South Esk fishery supports some 2000 - 3000 anglers per year on average, catching some 23,000 fish per year at an average rate of 1.4 fish per day.
- The Meander River fishery, by contrast supports some 1000 - 2000 anglers per year on average, catching some 20,000 fish per year at an average rate of 1.8 fish per day
- Additional questionnaire data obtained in the 1992 survey showed that some 35% of the angling effort in the South Esk River exerted in the reach from SCJ to Perth, while 20% was exerted upstream of SCJ.
- South Esk River catch per day was marginally significantly lower than for the Meander River over the 11 year period of record (paired t-test, $p = 0.02$), while harvest was the same ($p > 0.1$, paired t-test).
- South Esk River catch per day data fell well within the range for other rivers in Tasmania.

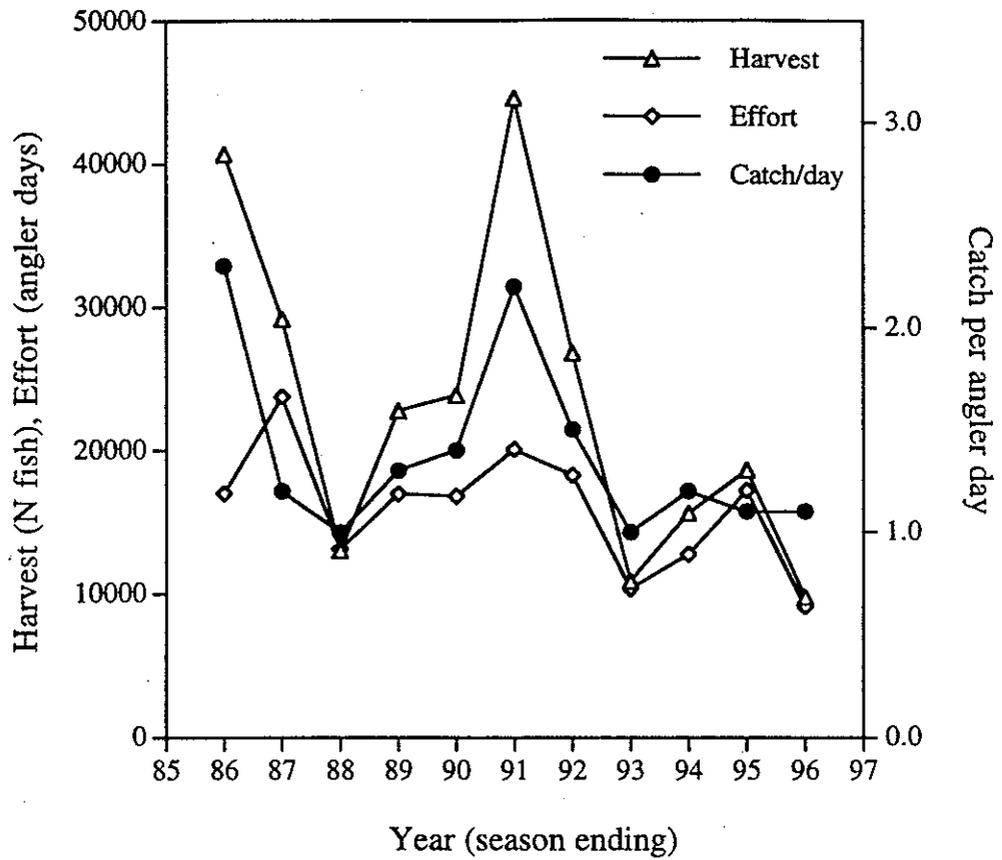


Figure 7. Plot of recreational trout fishery statistics for the South Esk River for the fishing seasons 85/86 to 95/96 (from IFC annual questionnaire records)

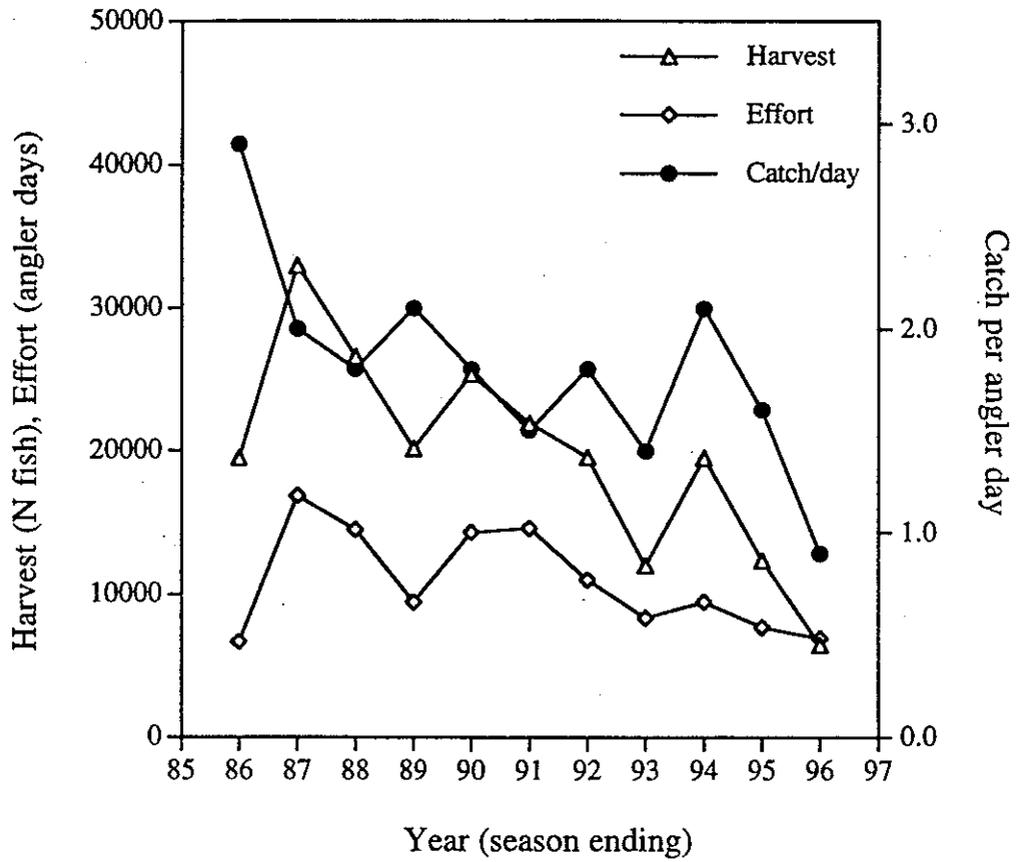


Figure 8. Plot of recreational trout fishery statistics for the Meander River for the fishing seasons 85/86 to 95/96 (from IFC annual questionnaire records)

Overall the South Esk River supports a recreational brown trout fishery with a sustained high visitation and harvest rate, a catch rate similar to of other Tasmanian river fisheries, with a significant portion of the fishery effort being expended between SCJ and Perth.

Summary

The overall weight of evidence suggests that the South Esk River is not heavily impacted from SCR for its entire length from SCJ to Perth, as has historically been believed. The evidence indicates that:

1. SCR has and continues to have a major impact on water quality downstream of SCJ, primarily through the input of zinc and possibly through input of cadmium, metal hydroxide flocs and coarse sediment;
2. The overall pattern of biological impact appears to have been sustained at least between the 1970's and 1990's, but insufficient data exists to assess the extent of any recovery or further decline;
3. The biological impact of SCR is significant within the reach approx. 30 km downstream of SCJ, but not necessarily beyond that;
4. There is a significant biological degradation associated with general catchment land use (including the riparian zone), which is significant both upstream and downstream of SCJ and that appears to be cumulative in a downstream direction;
5. The level of biological impact from catchment land use practices is similar and possibly more severe than that experienced in the Meander River;
6. Fish (brown trout, redfin perch, eels, tench, pygmy perch) are resident in the river reaches downstream of SCJ, though possibly not immediately downstream;
7. A significant recreational brown trout fishery exists in the South Esk River, with some 35-40% of the angling effort being expended in the reach between SCJ and Perth and with an average catch per unit effort marginally lower than for the Meander River;
8. Biological integrity of the South Esk River can be restored only by a combination of management of SCR impacts and improved catchment management and riparian condition.
9. That EQO's for the South Esk River catchment should be established separately for the reach 30 km downstream of SCJ, and for the remainder of the river.

Other effects

Insufficient data has been collected on the current and past impact of SC in relation to inputs to the South Esk River, both coarse (gravels, mine tailings etc.) and fine (metal

precipitates and hydroxide flocs). Estimates made in this report suggest that the volumes of material sourced from the SCR mine and creek dredging activities may be no more than 25% of the volume of material estimated to be deposited onto the South Esk River floodplain in the vicinity and downstream of SCJ. There is an insufficient understanding of the fluvial geomorphology of the middle and lower South Esk River and its current status with regard to sediment sources movement and storage. The comparative impacts on river channel morphology (including bank and bed stability and erosion status) and hydrology as a result of SCR related gravel/tailings inputs, effects of agricultural channel/riparian modification, and natural geomorphological process (such as mid-catchment adjustments to changes in geology) must be understood before river remediation options can be proposed.

Similarly, the data on the intensity and geographic extent of soil contamination is inadequate to assess the impact of SCR on soil, vegetation, agricultural or economic values. Significant metal contamination of surface soils in the South Esk River floodplain immediately downstream (and upstream) of SCJ has been described (see Locher 1993). Surprisingly, the recommendations regarding animal health and metal residue levels (particularly cadmium) do not appear to have been investigated, despite a recommendation from the then (1986) Senior Veterinary Pathologist. This issue requires further exploration, but not necessarily in the context of SCR remediation.

Environmental Quality Objectives

The following section describes Environmental Quality Objectives for the aquatic values of Storys/Aberfoyle Creek and South Esk River catchments, as they pertain to the SCR issue. The recommendations are not exhaustive and are not the result of a community consultation process. Rather they are a technical series of recommended EQO targets focussed on the restoration/remediation of environmental health in the South Esk River and Storys/Aberfoyle Creeks. They do not address issues of riparian or stream channel management, land use, management of exotic plants and animals or diffuse water quality impacts. They are also different from those EQO's recommended by Davies et al. (1996) for the South Esk River in their report on environmental flow needs for the river.

It is recommended that these be subject to review following collection and analysis of further data (see below) and be used and reviewed as part of any larger community based process for developing EQO's for water quality and quantity for the South Esk catchment that may be initiated by DELM and/or DPIF under the State Water Quality Management Policy and the Water Reform Process.

For the purposes of this report, three catchments compartments have been identified:

1. Storys Creek catchment (divided into the catchments of Aberfoyle and Storys Creeks);
2. South Esk River catchment downstream of SCJ to 30 km downstream;
3. South Esk River from 30 km downstream of SCJ to Perth.

Overall objectives

1. To restore the biological condition of Storys Creek (or a section thereof), Aberfoyle Creek and the South Esk River downstream of its junction with Storys Creek to a natural state, or to a level commensurate with background catchment conditions by:
 - decreasing total and filterable water concentrations of zinc, cadmium, copper and aluminium to concentrations which allow aquatic life to at least partially return toward a natural state;
 - reducing overall instream and floodplain sediment concentrations of zinc, cadmium and copper to background levels which allow aquatic to at least partially return toward a natural state;
 - partially restoring stream substrate conditions where they are shown to be detrimental to aquatic health.

Given the scale of the SCR related water quality problems, it is recommended that the above EQO should be targeted in the following order of priority:

South Esk more than 30km downstream of SCJ;

South Esk 0 – 30 km downstream of SCJ;

Aberfoyle Creek;

Storys Creek upstream of Aberfoyle Creek.

1. To restore those aspects of the trout fishery impacted by SCR to condition that would be expected in an unpolluted environment.
2. To ensure that water in the South Esk River is suitable for primary and secondary contact.

Water quality

The table following presents target maximum concentrations of priority pollutants associated with the SCR issue in the streams mentioned above, for the achievement of the EQO's. These are largely based on ANZECC (1992) guidelines for soft waters, taking into account the potential for limited complexation of dissolved metals by dissolved organics (measured as DOC in this report). DOC levels found in the 1997 HEC survey ranged between 1.5 and 2.5 mg/l for Aberfoyle and lower Storys Creeks and the South Esk River. This is around 20% of the levels found in West Coast streams associated with Mt Lyell (Davies et al. 1996) and the Pieman catchment (Koehnken 1993), and suggests only limited complexation capacity which may need investigation. In addition, it must be noted that most of the metal levels reported below (as totals) may not be dissolved, i.e. are either in non-filterable (> 0.45 micron) or filterable but fine flocculate forms, and hence non-toxic. Thus the use of ANZECC (1992) guidelines may be unnecessarily conservative, but they are used in the absence of other evidence.

Using ambient metal data combined with biological data from the existing survey work to develop targets for metals is not possible due to:

- The above-mentioned problem of unknown dissolved fractions;
- The presence of modified stream substrate due to historical tailings etc. inputs from SCJ causing potential impacts on biota independent of pollutant impacts;

- The lack of a comprehensive current water quality and biological data set.

Table 2. Recommended water quality targets for Storys Creek and South Esk River, and ambient median and maximum concentrations (based on DELM 1996-97 and 1997 HEC data). ? indicates only one or three ambient values available.

<i>Analyte</i>		South Esk	South Esk	Storys Creek Catchment		
		0 – 30 km d/s SCJ	> 30 km d/s SCJ	SC u/s Aberfoyle	SC u/s S. Esk River	Aberfoyle Ck.
Zinc	Maximum	50	50	50	50	50
	Current Median, Maximum	70, 110	Unknown, Unknown	2000, 4300	1000?, Unknown	1500?, Unknown
Cadmium	Maximum	0.2	0.2	0.2	0.2	0.2
	Current Median, Maximum	2, 5	Unknown, Unknown	40, 90	33, 30	50?, Unknown
Copper	Maximum	5	5	5	5	5
	Current Median, Maximum	5, 9	Unknown, Unknown	200, 370	58, 29	90?, Unknown
Aluminium	Maximum	100	100	100	100	100
	Current Median, Maximum	300?, Unknown	Unknown, Unknown	600?, Unknown	300?, Unknown	200?, Unknown

Sediment Quality

Recommended targets for sediment quality should comply with background levels of total and extractable cadmium, zinc and copper. Background levels should be defined after a comprehensive sampling program for sediments at 3 – 5 sites in the South Esk upstream of SCJ and in another similar river basin eg the Meander River. Compliance with the targets

should be assessed based on a statistical comparison with those background sample data. Care should be taken to select the metal extraction method for consistency with internationally published approaches to assessing bioavailability (see MLRRDP project on Macquarie Harbour sediments).

Biological health

Remediation targets for aquatic biota have been developed in a different manner than for water quality. With biological data it is possible to develop targets:

- using historical data (Norris 1979, 1982) due to its quality and demonstrated continued relevance; and
- taking background levels of impact into account, due to the existing downstream gradient in macroinvertebrate community composition which is believed to be due to catchment landuse impacts.

With water quality, it is believed that only major source of metal toxicants such as zinc and cadmium is SCR, whether currently through water quality or historically through deposited sediments. With aquatic biota, however, background conditions are believed to be already degraded due to poor land use and riparian management practices. Targets for remediation of SCR should therefore not unrealistically be set for a pristine or reference condition but rather take this background impact into account. If targets were being set for catchment management, then they would of course aim to restore biota to a higher level, but this study is focussed on the remediation of SCR impacts within the current catchment context.

Table 3. Recommended biological targets for Storys Creek and South Esk River, and current index values (based on data reported by Norris (1979) and Bobbi et al. (1996) data). 1 = by AUSRIVAS protocol, family level, 2 = by quantitative sampling, species level. Data insufficient indicates that new data is required to establish the target (see below).

	South Esk	South Esk	Storys Creek Catchment
--	--------------	--------------	------------------------

Sites: Biota	0 – 30 km d/s SCJ, (eg Milford)	> 30 km d/s SCJ, (eg Evandale)	SC u/s Aberfoyle	SC u/s S. Esk River	Aberfoyle Ck.
Macroinvertebrates					
Number of Taxa 1	16, or to be calculated from AUSRIVAS model	20, or to be calculated from AUSRIVAS model	To be calculated from AUSRIVAS model	To be calculated from AUSRIVAS model	To be calculated from AUSRIVAS model
Number of Taxa 2	Data insufficient	Data insufficient	Data insufficient	Data insufficient	Data insufficient
O/E, Band 1	0.6 – 0.7, B	0.6 – 0.7, B	0.5 – 0.7, B	0.5 – 0.7, B	0.5 – 0.7, B
SIGNAL 1	6	6	6	6	6
Fish					
N species	5	5	2	2	2
Abundance (trout)	Data insufficient	Data insufficient	Data insufficient	Data insufficient	Data insufficient
HABA score (trout)*	Data insufficient	Data insufficient	Data insufficient	Data insufficient	Data insufficient

* see under monitoring program, fish.

Physical quality

The presence of a highly modified stream substrate in Storys Creek and the South Esk River immediately downstream from SCJ, and possibly further downstream has been cited in numerous reports., This substrate is currently clearly different from the more typical Tasmanian river armoured cobble-coarse gravel substrate (Davies pers. obs.) seen in the South Esk upstream of SCJ. However, the extent to which this substrate change is due to natural geomorphological changes (eg the mid-catchment transition through granodiorites) or the inputs resulting from the Storys Creek mine requires quantification. Targets for physical remediation (eg removal of tailings deposits and stream channel modification) cannot be set until a detailed fluvial geomorphologic survey is conducted.

There is no doubt, however, that improved riparian and stream channel management is required in the South Esk River and catchment tributaries, and that this should be targeted through the new state ICM process.

Additional data required and Monitoring Program

Additional environmental data is required for two primary purposes:

1. Clarifying existing relationships between water quality, biological health, hydrology and sediment quality to refine remediation targets (and EQO's);
2. Establishing a database against which the future success of remediation or other events in achieving the EQO's can be assessed.

Baseline data required

An integrated assessment of chemical, biological conditions is required for the SC and South Esk catchments with sampling conducted at the same sites over a 12 month period.

Metal loads

An accurate estimate of metal loads is required as a basis for assessing net changes in metal efflux from Storys Creek. Due to the diffuse nature of metal and acid inputs throughout the SC catchment, estimation of total metal loads entering the South Esk River from SC is more relevant than separate load estimates from upper Storys or Aberfoyle Creek catchments.

Metal concentrations

An accurate assessment of variation in both total and dissolved metal concentrations in the South Esk is required at several locations: Henbury (upstream of SCJ), Avoca, Milford and Evandale. Data sets which adequately describe variation in metal concentration with season and flood stage are required. Fortnightly sampling for total and dissolved zinc, cadmium, copper and aluminium is required, along with total organic carbon, pH, conductivity and sulphate. Flow recording at Llewellyn and Perth should be maintained, and a gauging station established in Storys Creek downstream of the Aberfoyle Creek junction. A detailed evaluation of the proportion of dissolved metals in a subset of the above samples is also required.

Sediment quality

Previous data on riverine sediments is inadequate and subject to within-site inconsistency in sediment composition and location. Fine sediment samples should be collected using bed traps (see Davies and Nelson 1993) in mid-stream riffles at Henbury, Avoca, Milford and Evandale on five occasions over 12 months. The dried sediment should be analysed for organic content, total zinc, cadmium, copper, aluminium, lead and size fractions.

As indicated above, levels of zinc, cadmium and copper are frequently well above the ANZECC/NHMRC (1992) levels above which detailed environmental investigation is required. Such an investigation should be conducted, to:

- develop a more comprehensive database of total and extracted metals from instream and floodplain sediments at a number of sites and several sediment size fractions;
- assess the bioavailability of the metals to aquatic organisms;
- identify any sites that may need active clean-up.

Biological health

1. Invertebrates

Current data on invertebrates is insufficient. A combined quantitative-qualitative survey of invertebrates should be conducted at all South Esk sites originally sampled by Norris as well as sites in upper and lower Storys and Aberfoyle Creeks. Sampling should be conducted using the MRHI AUSRIVAS sampling protocol with both live pick and preserved sub-sampled residue processing (this does not require additional field sampling resources). Sampling to be conducted twice once in spring and in autumn. This will enable assessment of each site using the standard AUSRIVAS predictive model framework (Schofield and Davies 1996, Wright 1993), deriving O/E indices and bands, as well as providing quantitative data for comparison with Norris' database and to establish a current database for future comparisons. Some environmental variables should also be measured at each site to assess the relationship between invertebrate community composition, diversity and abundance and landuse/riparian factors.

These data can then be used to:

- Derive O/E scores and bands for each;
- Derive quantitative estimates of abundance and community composition for future comparison;

- Relate invertebrate characteristics with water and sediment chemistry in a rigorous manner to allow more accurate estimation of target pollutant concentrations (see above under EQO's).

In addition, where pilot experiments are conducted to assess the feasibility of water quality remediation on-site (eg by neutralization, SAPS etc.), there is potential for using the outflows, at appropriate dilutions, as source wastewaters to test toxicity to macroinvertebrates in simple artificial streams. Such experiments are being proposed for assessing water quality remediation targets for Mt Lyell (under the MLARDP). They also allow the testing the impact of the resulting composite effluent i.e. including the mixture of dissolved metals as well as flocculated material on aquatic invertebrates.

2. Fish

Fish data is highly inadequate. A quantitative survey of fish populations at the invertebrate sampling sites should be conducted once in January – March. Sampling should also be done semi-quantitatively at the same time (this will not require additional resources) to allow rapid electrofishing assessment to be used in the future to reduce the resources required. A number of habitat variables should be measured to enable data to be compared with HAFA (Habitat Attribute Fish Abundance) models developed by Davies (1989) for Tasmanian riverine trout populations. Deviations from HAFA trout biomass predictions can be used as an index of human impact on trout biomass.

Data analysis

The entire 'baseline' data set should be analysed for:

1. Median and percentile metal concentrations at all stations;
2. Median sediment metal concentrations at all stations;
3. Total metal loads entering the South Esk at SCJ;
4. Total metal loads at the three locations downstream of SCJ;
5. relationships between metal concentrations, metal speciation (total/dissolved) and flow stage;
6. relationships between water and sediment metal concentrations, catchment based environmental variables and biological condition – measured as invertebrate AUSRIVAS O/E scores, number of taxa, abundance and dissimilarity, and as fish biomass and abundance and deviation from HAFA predictions.

The above analyses should be used to derive target EQO water and sediment metal concentrations for Storys and Aberfoyle Creeks and for the South Esk River at Avoca, Milford, and Evandale.

A standard database containing all information should be established, and formally used as a basis for evaluation of remediation success.

Monitoring Program

A monitoring program can be designed to address a variety of questions. It is assumed here that monitoring will be done in relation to the efficacy of remediation of SCR and hence will focus on:

- Directly measuring the efficacy of reduction of metal loads/concentrations in SC and to the South Esk River;
- Measuring the efficacy of reduced metal loads/concentrations in restoring environmental (biological and water quality) values in the Storys Creek and South Esk catchments.

Thus a monitoring program for SRC remediation should have two sequential stages, with primary water quality assessment in the SC catchment followed by secondary environmental assessment in both SC and South Esk catchments, as follows:

1. Routine monitoring of water quality within and at the downstream end of the Storys-Aberfoyle Creek drainage. This should consist of two permanent stations at each of Storys Creek upstream of Aberfoyle Creek and Aberfoyle Creek upstream of Storys Creek. Each station should continuously record conductivity, pH and stage. In addition, routine collection of water samples for pH, sulphate, total zinc, iron, cadmium and copper analyses should be conducted. Where possible, relationships between ion concentrations and conductivity should be developed to estimate continuous concentration records.

When conditions are judged to have changed significantly, then :

1. Periodic monitoring (e.g. five yearly) of water and sediment quality and biota in the Storys Creek and South Esk catchments. This should replicate the baseline data program outlined above.

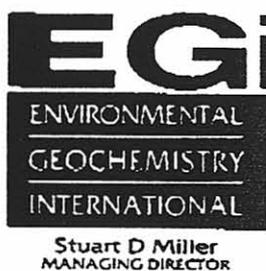
References

- ANZECC 1992. Australian water quality guidelines for fresh and marine waters. ANZECC, Canberra.
- ANZECC/NHMRC 1992. Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites. ANZECC/NHMRC, January 1992, Canberra.
- Belbin L 1993. PATN - Pattern Analysis Package. CSIRO Division of Wildlife and Rangelands Research, Canberra.
- Bobbi C, Fuller D and Oldmeadow D 1996. South Esk Basin: State of Rivers Report. Technical Report, DPIF/National Landcare Program, Hobart.
- Carr MC 1996. PRIMER user manual, Plymouth Marine Laboratory, UK.
- Davies, PE 1989. Relationships between habitat characteristics and population abundance for brown trout, *Salmo trutta* L., and blackfish, *Gadopsis marmoratus* Rich., in Tasmanian streams. Australian Journal of Marine and Freshwater Research 40, 341 - 359.
- Davies, PE, Humphries, P and Mulcahy, M 1996. An environmental flow study of rivers of the South Esk Basin. DPIF/Landcare project report, Hobart.
- Davies, PE, Sloane, RD and Andrew, J 1988. The effects of hydrological change and the cessation of stocking on a stream population of *Salmo trutta* L. Australian Journal of Marine and Freshwater Research 39 : 337 - 354.
- Davies, PE and Nelson, M 1993. The effect of steep slope logging on fine sediment infiltration into stream beds in ephemeral and perennial streams of the Dazzler Range, Tasmania. Journal of Hydrology, 150, 481-504.
- Davies, PE and Nelson, M 1994. Relationships between riparian buffer widths and the effects of logging on stream habitat, invertebrate community composition and fish abundance. Australian Journal of Marine and Freshwater Research 45, 1289 - 1305.
- Davies, PE and McKenny, CEA 1996. Tasmanian stream macroinvertebrates: Sampling to complete biodiversity assessment and modelling and classification of stream sites. Report to the Tasmanian Environment and Heritage Technical Committee, November 1996.
- Davies, PE, Mitchell, N and Barmuta, LE 1996. The impact of historical mining operations at Mount Lyell on the water quality and biological health of the King and Queen River catchments, western Tasmania, Mount Lyell Remediation R&D Program, Supervising Scientist Report 118, Office of the Supervising Scientist, Barton ACT.
- Davies, PE and WW Thompson 1988. Tasmania's Trout Fisheries: Current Status and changes since 1945. Inland Fisheries Commission Occasional Rep Ser. 88-04.
- Koehnken, L 1992. Pieman River Environmental Monitoring Programme. Technical Report August 1992. Department of Environment and Land Management, Hobart (161 pp.)

- Norris RH 1979. The ecological effects of mine effluents on the South Esk River (North East Tasmania). PhD Thesis, Zoology Department, University of Tasmania.
- Norris RH, Lake PS and Swain R 1980. Ecological effects of mine effluents on the South Esk River, North-eastern Tasmania. I study area and basic water characteristics. *Australian Journal of Marine and Freshwater Research* 31, 817-827.
- Norris, RH, Lake PS and Swain R 1982. Ecological effects of mine effluents on the South Esk River, North-eastern Tasmania. III Benthic macroinvertebrates. *Australian Journal of Marine and Freshwater Research* 33, 789-809.
- Norris RH, Swain R and Lake PS 1981. Ecological effects of mine effluents on the South Esk River, North-Eastern Tasmania. II Trace metals. *Australian Journal of Marine and Freshwater Research* 32, 165-173.
- Norris RH and Lake PS 1984. Trace metal concentrations in fish from the South Esk River, northeastern Tasmania, Australia. *Bulletin of Environmental Contamination and Toxicology* 33, 348-354.
- Schofield, NSJ and Davies, PE 1996. Measuring the health of our rivers. *Water (AWWA Journal)* 23, 39-43.
- Thorp VJ and Lake PS 1973. Pollution of a Tasmanian river by mine effluents. II. Distribution of macroinvertebrates. *Internationale Revue ges. Hydrobiologica* 58, 885 - 892.
- Tyler PS and Buckney RT 1973. Pollution of a Tasmanian river by mine effluents. I. Chemical evidence. *Internationale Revue ges. Hydrobiologica* 58, 873 - 883.
- Wright JF 1995. Development and use of a system for predicting the macroinvertebrate fauna in flowing waters. *Australian Journal of Ecology* 20, 181-197.

**APPENDIX C LABORATORY TRIALS - RIVER
BANK TAILINGS DEPOSITS**

MEMORANDUM



TO: John Miedecke
COPY:
FROM: Stuart Miller
DATE: 18 March 1998
SUBJECT: Story's Creek

John,

I understand that there is some concern with the technical feasibility of the proposed limestone addition to creek-deposited tailings for reducing the metal loads in Story's Creek and that a laboratory based testing program is suggested before this strategy is scaled up to the field. I assume there are 2 issues to be addressed:

1. That due to the low acidity in the system, the limestone may only react very slowly and therefore may not provide sufficient alkalinity to effect a reduction in dissolved metals.
2. That the crushed limestone may simply erode from the creek-bank deposits and be transported downstream away from the tailings.

The first of these issues can be addressed at laboratory scale while the second issue would need to be evaluated in the field.

With respect to the laboratory scale test work the following is suggested.

The objective of the laboratory test work is to evaluate the effect of small amounts of limestone (agricultural lime grade or similar) on the alkalinity and metal solubility in creek deposited tailings. It is suggested that column test are used for this work. The columns must be designed to simulate wetting and drying cycles and to ensure that the availability of atmospheric oxygen is not limiting oxidation processes. A column design, using standard Buchner funnels, to meet these requirements is shown on Figure 1.

The internal dimensions of the Buchner funnels are approximately 175 mm diameter and 100 mm high, giving a capacity of about 2.5 litres. Typically, they will hold about 2 to 2.5 kg of sample.

The conventional Buchner funnel columns need to be supported by a shelf located approximately 270 to 320 cm above a bench, as shown in Figure 1. The best height will need to be determined so that the leachate collection bottles can be easily positioned immediately below the funnel spouts. Holes also need to be drilled through the shelf to support the columns. Typically, 120-130 mm diameter holes are suitable for these Buchner funnels.

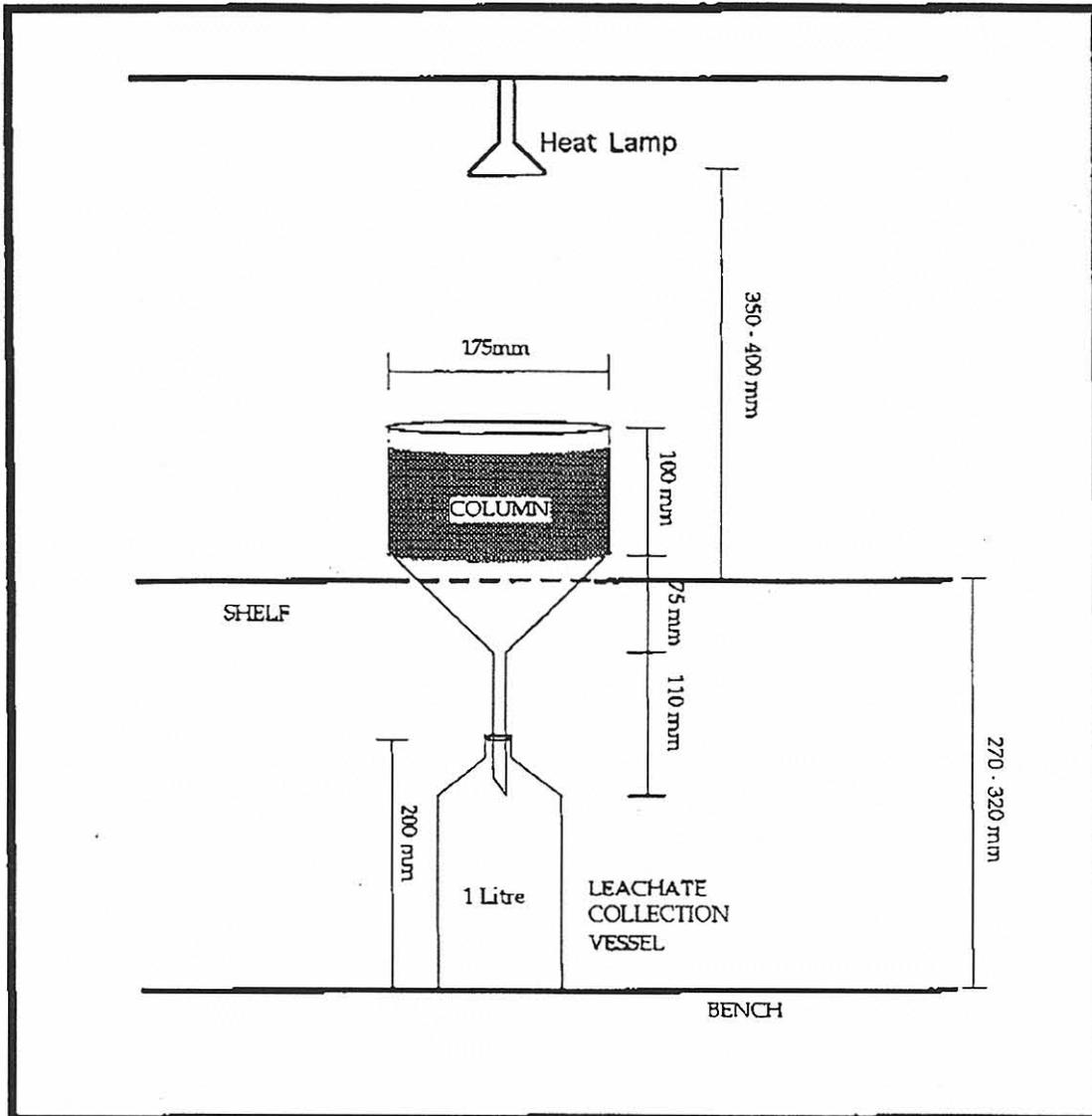


Figure 1: Schematic of Column Set-up (not to scale)

Approximately 2 to 3 kg of tailings will be required for each column. A bulk sample of oxidised (brown surface tailings) and unoxidised (grey underlying tailings) should be collected from site and analysed for total S, ANC, NAG, and total metals. Metal speciation work could also be carried out.

It is recommended that 8 columns are set up as follows:

Oxidised Tailings

- Column 1: Untreated tailings
- Column 2: Tailings + 1 kg CaCO₃/t (equivalent to 2 t/ha)
- Column 3: Tailings + 5 kg CaCO₃/t (equivalent to 10 t/ha)
- Column 4: Tailings + 10 kg CaCO₃/t (equivalent to 20 t/ha)

5 cm

Unoxidised Tailings

Column 5: Untreated tailings

Column 6: Tailings + 1 kg CaCO₃/t (equivalent to 2 t/ha)

Column 7: Tailings + 5 kg CaCO₃/t (equivalent to 10 t/ha)

Column 8: Tailings + 10 kg CaCO₃/t (equivalent to 20 t/ha)

The samples should be air dried and the limestone thoroughly mixed. Sub-samples should be taken and analysed for ANC and NAG. After loading the columns, record the total weight (this will be a baseline dry weight to allow the water content to be monitored during the leaching program).

The leaching and leachate analysis program will need to be discussed but as a general guide the following is recommended:

It is recommended that the columns are initially operated on a 1 week leach cycle (this may be extending to 2 or 4 week cycles depending on actual behaviour). The columns should be watered on ONE day each week (preferably on Friday).

Apply deionised water (could use rain water from site, if available) to the surface of each column at a rate of 200 mL per kg of sample per week. Apply water slowly and allow the water to soak into the sample over the week-end.

If the sample surface is cracked, the surface should initially be moisten with a small amount of the water then the sample re-worked to fill in the cracks.

During the week-end the overhead drying lamps should be left off. The following Monday or when flow of leachate from the column stops, remove the leachate collection bottle and record the volume of leachate collected. Switch the drying lamps on and allow the sample to slowly dry out. Drying lamps can be run continuously during the week or intermittently (e.g. only at night or during day), depending on the rate of drying. The surface temperature of the tailings should not be greater than 35°C.

NOTE: Before the Friday watering, weigh each column and record the weight. Compare this weight to the initial dry weight to determine the residual water content. This is a precautionary measure to confirm that the tailings have dried sufficiently between watering events. If necessary, the leaching cycle will be modified.

The following parameters should be included in the leachate analysis:

Volume collected, pH, EC, alkalinity, acidity, sulphate, calcium, magnesium, iron, aluminium, zinc, cadmium, copper, manganese.

Please call if you have any queries or require additional information.

Regards,



Stuart Miller

APPENDIX D WATER MONITORING PROPOSAL



Hydro-Electric Corporation ARBN 072 377 158,
Incorporated in Tasmania

OUR REF

YOUR REF

ASK FOR

HYDRO-ELECTRIC CORPORATION
GPO BOX 355D
HOBART TASMANIA 7001
4 ELIZABETH STREET
HOBART TASMANIA 7000
CIVIL & WATER RESOURCES
ENGINEERING GROUP

TELEPHONE (03) 6230 5382
FACSIMILE (03) 6230 5363

Friday, 20 February 1998

John Miedecke and Partners PTY LTD.
41 Tasma St
North Hobart
Tasmania 7001

Dear John,

Water Quality Assessment - Storys Creek

Thank you for the opportunity to submit a proposal for monitoring of water quality in Storys Creek. Attached are costs involved, recommended instrumentation, and officers to be involved in the project.

If successful in this proposal it will take 4 to 6 weeks to take delivery of the pH, level and conductivity sensor. We have SIGMA samplers that are available for lease and can be used for the collection of water samples.

HEC Water Resources will archive all the collected data on our HYDROL database and supply the results to JMP in a summary of statistical data and also on disk. We would suggest that the collection of the data be on an 8 week cycle.

Any replacement costs of instruments arising from damage by vandals would have to be covered by JMP.



Hydro-Electric Corporation ARBN 072 377 158,
Incorporated in Tasmania

Instrumentation

GREENSPAN	\$4000.00
Conductivity/Temp/pH/ pressure sensor	
UNIDATA logger	\$1,000.00
Field termination strip and B&R enclosure	\$600.00
Weather proof shed	\$1,800.00
Battery and Solar panel (12 to 24v converter)	\$650.00
Solar panel mount	\$120.00
Instrumentation locating bracket (in the river)	\$650.00
Gauge boards 0 to 2 metre range with posts and benchmark	\$220.00
Concrete	\$200.00
Conduit - Stainless fittings etc	\$200.00
Track cutting and site clearing	\$400.00
	\$9,840.00

Staff

Mark Johnston

District Hydrographer with 21 years experience in water resources with HEC and the Rivers and Water Supply Commission. Has worked at CMT for the past three years monitoring stream flow and water quality. Conducted and reported on stream flow and sampling survey of the Haulage Creek catchment in July 1996.

Lukas Salkeld

Hydrographer for 9 years with the Rivers and Water Supply Commission and HEC Water Resources. Has been involved at CMT with data collection and the installation of stations at Savage River for DELM and ABM.



Hydro-Electric Corporation ARBN 072 377 158,
Incorporated in Tasmania

Labour Costs

Allowances are included for travelling. The number of days has been estimated without a site visit.

Project Component	Staff	Number of days	Total Days
• Ordering, preparation and check calibration of recording equipment	1	3	3
• Installation of station	2	2	4
• Reporting and analysis of data • 6 visits on a 12 month basis.	2	6	12

Labour Installation \$ 4,600.00
Instrumentation and associated structures \$ 9,840.00

Installation Total \$ 14,440.00

If automatic collection of water samples are required, the shed can be used for housing the shelter and the level setting switch and intake hose can be attached to the gauge boards. The lease of the sampler and purchase of tubing and conduit, would be \$800.00. The installation could be included on a routine visit. Allowances have been made in the power supply to operate the sampler.

Another option is to lease all the instrumentation including the sampler and associated infrastructure at a fixed cost of \$3500.00 per annum. At the end of the 12 month period, all the infrastructure and instrumentation would be retrieved and belong to HEC Water Resources.

Annual servicing Fee and data reporting \$ 7,200.00



Hydro-Electric Corporation ARBN 072 377 158,
Incorporated in Tasmania

Third Party Accreditation Agent & Certification Number

Bureau Veritas Quality International (BVQI) is the accreditation agent, certification number 9467.

HEC Water Resources is committed to the use of a formal Quality Management System (QMS) and due to the size and diversity of our work accreditation has been implemented to AS 3901 (ISO 3901).

Quality Assurance has been accredited for project management, civil, mechanical and electrical design, and the hydrological and hydrographic studies areas. The quality system currently employed by Consulting Business Unit, Hydrographic group contains a number of key initiatives, that have been continually upgraded over the past 10 years, to ensure the data is collected to specified standards. These initiatives include the following points:

- A set of two manuals has been developed that cover all the technical procedures for the hydrographic group, in the office and field environments.
- An access database has been developed to report all instances of faults with procedures and/or equipment. This database has become a powerful tracking tool and combined with the reporting capability provides invaluable information upon which informed decisions can be made to rectify the situation.
- Management plots have been introduced on the HYDROL database to enable easy assessment of data availability and data quality for time series data, gaugings and ratings.
- Data report have been upgraded to further enforce the requirements for up to date, good quality data. The report is also a valuable hard copy record for existing clients and other data users.
- Software manuals have been produced for all hydrologic software developed by the HEC.
- An instrument and calibration software package, IQS Calibrate has been purchased and is now operational. It not only locates particular equipment items but provides information on when maintenance or calibrations are due as well as calibration details and instrument histories. The software is windows based and shares a common site number/identification with HYDROL.



Hydro-Electric Corporation ARBN 072 377 158,
Incorporated in Tasmania

Database and Data Storage Methods

HEC Water Resources use the HYDROL Windows NT software package to process, archive and disseminate hydrologic, climatic, water quality and now energy and load data. This software is networked throughout the HEC and is used state wide by a variety of groups utilising data in various ways.

HYDROL was developed in Consulting Business Unit to meet the needs of the HEC.

See the attached Hydrol brochure for more information.



Hydro-Electric Corporation ARBN 072 377 158,
Incorporated in Tasmania

Assumptions

- JMP will provide sampling bottles (for spot samples) and our staff will be responsible for the delivery of samples to the lab at the University of Tasmania
- JMP will be carrying out the calculation of metal concentrations and forecast loads from the data supplied and the water sampling results.
- HEC Water Resources will program the automatic sampler (if required) to collect high stage sample events and collect and deliver the samples to the University. These samples will be collected on routine trips every 8 weeks.
- The contract for the operation of this station is for a 12 month period.

The project will be managed for HEC Water Resources by Mark Johnston who is a District Hydrographer experienced in the assessment and monitoring of water flow and quality at mining operations. A Curriculum Vitae is provided. The project will come under HECEC control if a formal arrangement is agreed upon.

Staff allocated for this project will be available from early April 1998. The procurement of instrumentation and fabrication of associated shelters and brackets may take up to six weeks from the date of ordering.

If any part of the project allocated to HEC Water Resources has not been covered in this proposal, please contact Stephen Buckland on 6230 5283. Mark Johnston will be on field duties until March 2nd 1998.

Regards,

A handwritten signature in black ink, appearing to read 'SKrohn', written over a large, stylized signature graphic.

Simon Krohn Principal Engineer
HEC Water Resources

APPENDIX E AQUATIC FAUNA MONITORING PROPOSAL

South Esk and Storys Creek Survey proposal Draft Proposal, 3/98

P Davies, Freshwater Systems

1. Background

Examination of the data available on the biological condition of the South Esk River indicates the absence of any quantitative data on either macroinvertebrates or fish since 1978, when a detailed quantitative survey was conducted by Norris (1979 and papers resulting). A survey conducted in 1995 by DPIF, using a rapid assessment protocol and analysis had several limitations that do not allow either comparison with Norris' data or the establishment of a baseline for assessing future changes. These limitations were:

- the lack of sampling at suitably located sites (the survey was not conducted to address the Storys Creek impact issue);
- a sampling method which differed from Norris' in such a way that data cannot be compared between dates;
- inconsistency in the results, largely due to the use of a single sample at each site, based on live-picking;
- the lack of suitable controls in the survey, with results reported simply using the existing framework of AUSRIVAS model reference sites which are inadequate to adequately assess the condition of large river downstream sites.

It is not proposed that a complete repetition of Norris' invertebrate work be done. Rather, a reduced version of the same invertebrate survey plus a fish survey should be performed which would allow:

- evaluation of changes in invertebrate abundance, diversity and community composition at selected sites since 1978;
- a quantitative snapshot of fish populations at five sites which could be used to assess the current status as well as changes in the future;
- a quantitative snapshot of biological conditions to be made, as a firm basis for quantitatively assessing future changes.

Recent re-analysis (by Davies and Cook, 1997), showed that Norris study was limited by having no comparable rural catchments as control which could represent the condition of lower reaches of rivers in the

South Esk basin in the absence of mining impacts. There is therefore a high probability that Norris' attribution of changes in invertebrate abundance and diversity in the lower South Esk to the Storys Creek discharge alone was erroneous. Davies and Cook (1997) concluded that, while the reach of the South Esk between SCJ and ~40 km downstream is highly impacted by the SC discharge, this impact is reduced and superimposed on the impacts of catchment and/or riparian disturbance further downstream. The river can therefore be divided into roughly four 'zones':

- upstream of SCJ. River impacted by land clearing, riparian disturbance.
- 0 - 40 km downstream of SCJ. River strongly impacted by SC discharge.
- 40 km downstream of SCJ to the Macquarie River junction. River impacted by catchment disturbance and by lesser impact of SC discharge.
- downstream of the Macquarie River junction. River characteristics influenced by large tributary inputs.

There is potential for differing levels of agricultural impact on stream biota between the South Esk and Meander particularly due to differences in the extent of riparian degradation and irrigation abstraction. However, without such a reference condition, the degree of biological recovery both downstream and through time from changes in the intensity of mining impacts alone cannot be assessed.

Unfortunately while this analysis can be made from the Norris study, the recent rapid assessment data collected by DPIF does not give information on how this might have changed. It should be noted that the rapid AUSRIVAS bioassessment technique, as used by DPIF, while suitable for characterising the general condition of a catchment, is limited in sampling frequency and data quality (involving live-picking and resulting only in presence/absence data at family level). It is therefore unsuitable for making the assessments required in this case.

2. Work Recommended

Two possible levels of study could be done:

- a 'bare minimum' option consisting of a single sampling upstream and downstream of SCJ and in lower Storys and Aberfoyle Creeks in two seasons;
- a 'comprehensive minimum' option with several sites sampled in the South Esk River, with or without sampling in the Storys Creek catchment.

The former, while cheaper, provides only an assessment of any changes in biota immediately downstream of Storys Creek junction and does not provide a basis for making an assessment of recovery of the South Esk River. The latter would provide a comprehensive basis for assessing changes both from the past (by comparison with Norris' data from two seasons) and in the future.

2.1 Bare minimum option

South Esk River survey

A survey in the South Esk River is proposed consisting of quantitative sampling for invertebrates only at two sites, which match sites sampled by Norris:

South Esk River,

Upstream of Storys Creek junction (SCJ)

Upstream catchment control

Downstream of SCJ

Immediately upstream

Invertebrate sampling is to consist of 15 surber samples taken at each site, and pooled. Samples are to be sorted, sub-sampled and identified to family level. Sampling should be conducted once in both spring and autumn.

Storys Creek catchment survey

Biological sampling of Storys Creek catchment, restricted to invertebrates has been suggested. This survey would consist of quantitative sampling in spring and autumn at the following sites:

Storys Creek downstream of junction with Aberfoyle Creek

Aberfoyle Creek upstream of junction with Storys Creek

Analysis and Reporting

Invertebrate data would be directly compared with Norris' data for the same sampling seasons (standardised to unit area). Differences between sites (since the late 1970's) and time would be described. All data would be presented graphically and in tabular form.

2.2 Comprehensive minimum option

South Esk River survey

A survey in the South Esk River is proposed consisting of quantitative sampling for invertebrates and fish at the following sites, which match sites sampled by Norris:

South Esk River:

Upstream of Storys Creek junction (SCJ)	Upstream catchment control
Upstream of SCJ	Immediate upstream control
Downstream of SCJ	Immediately downstream, impacted
Downstream of SCJ	Downstream end of impact zone
Downstream of SCJ	Middle(?) of recovery zone
Downstream of SCJ	Downstream end of recovery zone

It is also proposed to sample two paired catchment' control sites in the mid and lower Meander River which would act as controls for catchment disturbance effects. The sites are as follows:

Meander River at Deloraine	Mid rural catchment control
Meander River at Strathbridge	Lower rural catchment control

Invertebrate sampling is to consist of 15 surber samples taken at each site, and pooled. Samples are to be sorted, sub-sampled and identified to family level. Sampling should be conducted twice as a minimum, once in spring, and again in autumn.

Fish sampling to consist of three-pass quantitative electrofishing operations at each site, conducted once in January - March. All fish to be measured, weighed and sampled or scales. Scales are to be read for age. Data for the three runs will be used to estimate populations of each species by the standard Zippin removal method.

An additional option to include sampling in Storys Creek could be included, as follows:

Storys Creek catchment survey

Biological sampling of Storys Creek catchment, restricted to invertebrates, has been suggested. This survey would consist of a single quantitative sampling in either spring or autumn of the following sites.

Storys Creek:

Upstream of Storys Creek mine

Downstream of junction with Aberfoyle Creek

Upstream of junction with Aberfoyle Creek

Aberfoyle Creek:

Upstream of junction with Story Creek

Upstream of Aberfoyle mine site.

Tower Rivulet (unpolluted stream of similar size to Storys Ck)

Upstream of junction with South Esk River

Analysis and Reporting

Invertebrate data would be directly compared with Norris' data for the same sampling seasons (standardised to unit area) in both an ANOVA and multivariate classification and ordination analysis. Differences between sites and time would be assessed quantitatively to detect any changes since the late 1970's.

All data (including the Storys Creek and fish data) would be presented graphically and in tabular form.

3. Budget and Justification

3.1 Bare minimum option costs

South Esk River sampling

Field expenses

One week long field trip per season, two seasons.

1 days for preparation and travel to and from Hobart to South Esk river; 2 days for quantitative invertebrate sampling and recording environmental variables at 2 sites in the South Esk River and 2 sites in the Storys Creek catchment.

Total of 3 days for 2 people at \$800/day	\$2400
Total of 2 days' accommodation at \$200/day	\$400
Total of 3 days' vehicle costs at \$65/day	\$195
Minor consumables	\$20
<i>Field component total per sampling round</i>	<i>\$3015</i>

Sample processing

Four pooled invertebrate samples, subsampled, sorted and identified to family level. 2 days at \$300/day.

\$600

Total cost for two sampling rounds *\$7230*

Data analysis and reporting

One day at \$600/day

\$600

Total costs of 'bare minimum' option **\$7830**

3.2 Comprehensive minimum option costs

South Esk River survey

Costs of a single sample round

Field expenses

Two one-week long field trips required per sampling occasion in each of two seasons (spring and autumn). 2 days for preparation and travel to and from Hobart to South Esk river; 3 days for quantitative invertebrate sampling and recording environmental variables at six sites in the South Esk River and two sites in the lower Meander River; 4 days for quantitative electrofishing in 5 sites in South Esk River. 1 day contingency.

Total of 10 days for 2 people at \$800/day	\$8000
plus 4 days for additional 2 person team at \$800/day	\$3200
Total of 8 days' accommodation at \$200/day	\$1600
Total of 10 days' vehicle costs at \$65/day	\$650
Minor consumables	\$150
<i>Field component total</i>	<i>\$13450</i>

Sample processing

Eight sets of invertebrate samples, subsampled, sorted and identified to family level. 10 days at \$300/day.

\$3000

Sub-total, field trips and processing, two rounds *\$32900*

Data analysis and reporting

Three days at \$600/day

\$1800

Sub-total cost, two sample rounds

\$34700

Storys Creek survey component

Additional costs to a single sample round

Field expenses

1 additional day per round for quantitative invertebrate sampling and recording environmental variables at five sites in Storys Creek catchment and one in Tower Rivulet catchment.

Total of 1 day for 2 people at \$800/day

\$800

Sample processing

Six sets of invertebrate samples, subsampled, sorted and identified to family level. Assume no or little fauna in lower Storys and Aberfoyle samples, 2 days at \$300/day. \$600

Sub-total, 2 sampling rounds

\$2800

Data analysis and reporting

No additional costs.

Total costs of 'comprehensive minimum option'

\$37500