Rossarden/Storys Creek

Overview of Environmental Monitoring Data

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AMG REFERENCE POINTS ADDED

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1. INTRODUCTION

Below the southern scarp of Ben Lomond are situated two old mine sites associated with the townships of Storys Creek and Rossarden (see Map 1). Heavy metal contamination of the watercourses draining these old mines has been recognised and documented as a problem for many years. The aim of this report is to summarise the research conducted to date on the environmental health of this catchment area.

The report commences with a brief background about the sources of contamination. It then discusses what is known from various studies about the concentrations of metals in the water and sediments and the downstream effects on aquatic flora and fauna. The known sources of data collected in the Rossarden/Storys Creek catchment area (and some downstream data from the South Esk) are listed and their scope very briefly described in Attachment 1.

2. BACKGROUND

2.1 Storeys Creek Mine

Tin and wolfram were first mined from Storys Creek in 1895, originally via blind adits driven into outcrops in Side Creek which drains into Storys Creek below the later established mine site (see Map 2). Storeys Creek Mining Company (note different spelling of name) was established soon after the turn of the century, and expanded the Side Creek workings. By the early 1920s the Storeys Creek Tin Mining syndicate was the main wolfram producer in the State and an important producer of tin. By 1960 Storeys Creek Mine had produced about 800 tonnes of tin and 6300 tonnes of wolfram concentrates. Ore was processed at the Storeys Creek Mine until December 1971 when the processing plant was shut down, and then ore was transferred to the Rossarden mine for processing.

Tailings were originally discharged directly into Storys Creek, then later dumped along the west slope alongside the creek, and later in tailings dams east of Storys Creek. Mine water was pumped directly into the creek, until the 1970s when it was pumped to an old tailings dam (now known as the precipitation dam) and treated with lime and later with soda ash to raise the pH and enhance the precipition of metals out of solution. The fine solids settled out giving a clear overflow from the dam. A high spillway was constructed in the dam wall to ensure that the sludge was kept under water to inhibit the oxidation of sulphide minerals.

2.2 Aberfoyle Mine

The tin and wolfram mine at Rossarden was established by Aberfoyle in 1931. By 1960 Aberfoyle was the major producer of wolfram in the State as well as being the most important tin mine, having produced 11,000 tonnes of tin and 3500 tonnes of wolfram concentrates.

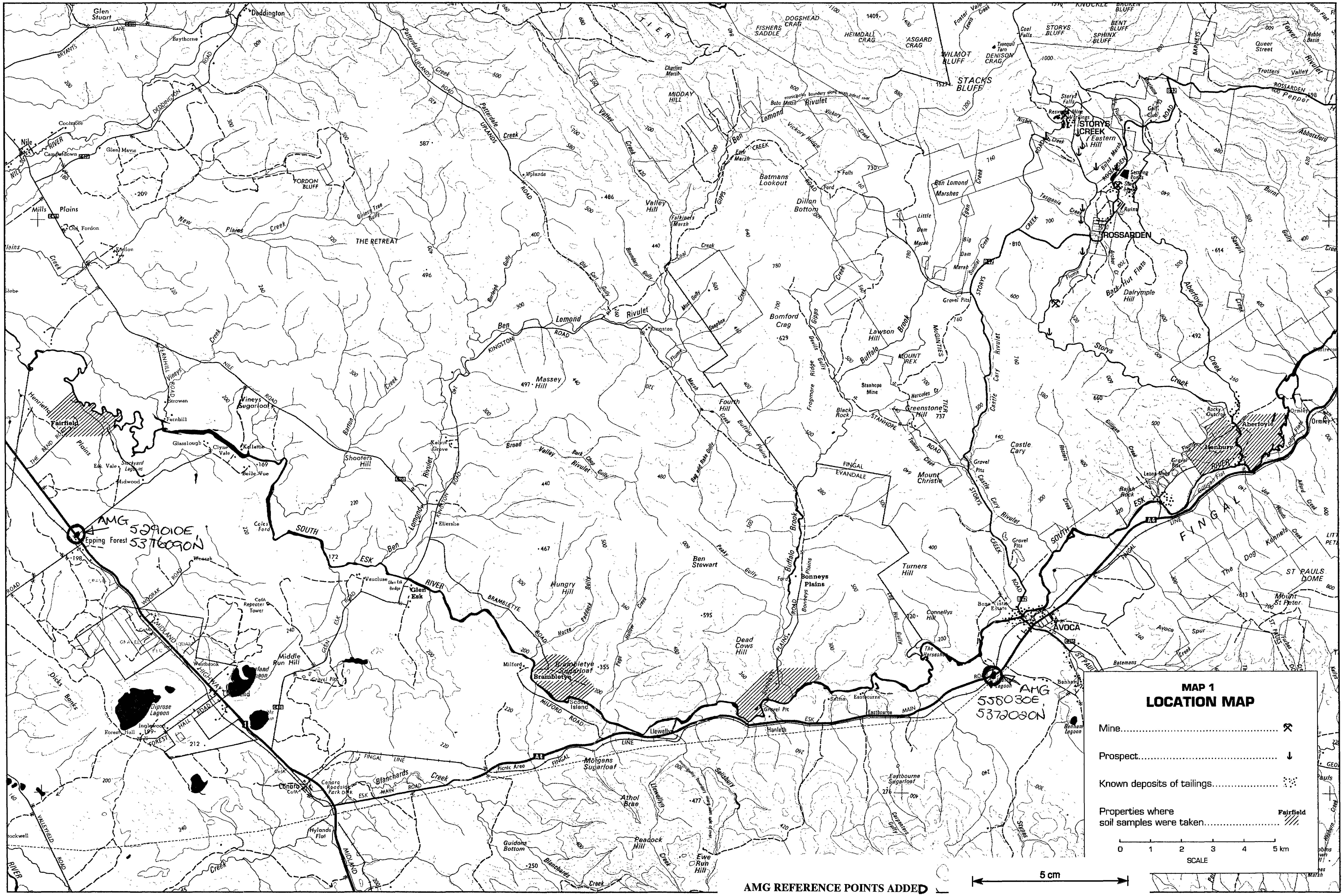
Tailings were disposed of around the mill, and later into conventional tailings dams north of the mine. The mine water ran directly to Aberfoyle Creek from No.4 adit. Unlike at Storeys Creek Mine, metal sulphides were removed from the Rossarden ore and treated by flotation to recover economic amounts of copper and silver, resulting in lower metal loads in the discharge to Aberfoyle Creek.

2.3 Recent history

Mining took place on a reduced scale at both mines up until 1982. Mining ceased in March 1982, after which time the mines were allowed to flood. It is not certain when the mines were completely flooded, but samples taken in late 1984 would certainly have been when the mines were inundated.

A "freak" 100 year storm event occurred in late June 1986 which resulted in a breach to the Storys Creek precipitation dam and allowed slimes to escape. Repairs were made, but seepage below the precipitation dam at Storys Creek continues to be a source of heavy metal contamination.

As a consequence of historical tailings disposal methods and the dam breaches in 1986, deposits of washed tailings are found in streamside deposits downstream of the mine sites in Storys and Aberfoyle Creeks. These consist largely of jig tailings which are generally less than 3mm in particle size.


MAP 1
LOCATION MAP
Mine
Prospect
Known deposits of tailings
Properties where soil samples were taken
Fairfield
0 1 2 3 4 5 km
SCALE
5 cm
AMG 529010E 5376090N
AMG 558030E 5372080N
AMG REFERENCE POINTS ADDED
Epping Forest
AVOCA
ROSSARDEN
STORYS CREEK
Aberfoyle
Henbury
Brambletye
Fairfield
Ben Lomond Rivulet
SOUTH ESK RIVER
FINGAL
MIDLAND HIGHWAY
Stanhope Mine
Greenstone Hill
Castle Cary
Mount Christie
Bonneys Plains
Ben Stewart
Hungry Hill
Massey Hill
Glen Esk
Conara
Nile

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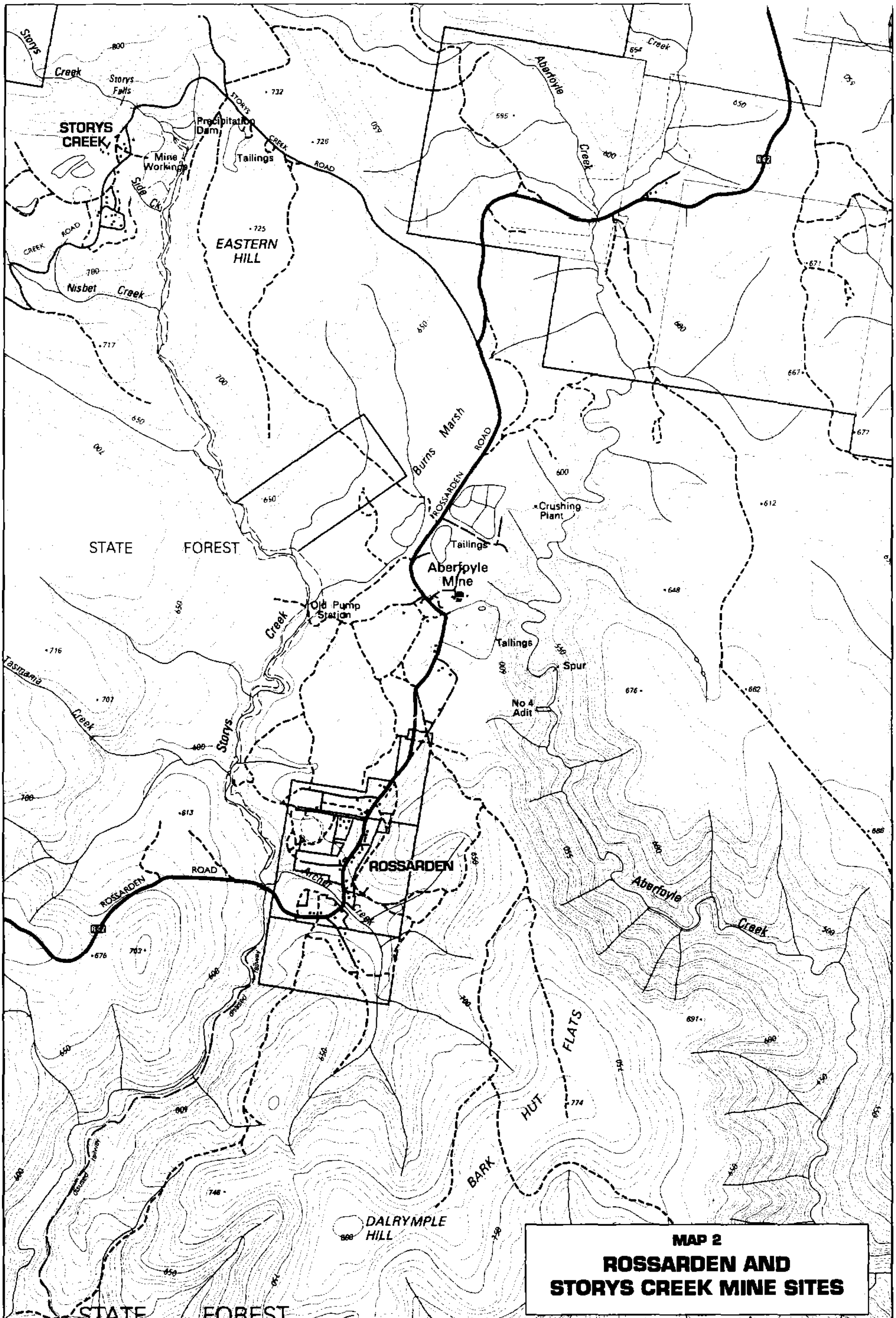

MAP 2

ROSSARDEN AND STORYS CREEK MINE SITES

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Dams at both mines contain slimes (< .2mm) as well as jig material, but mostly jig tailings are visible on the banks of the watercourses draining the mine sites, as the fines have presumably been carried farther downstream.

The tailings distribution in the streams has not been accurately documented, as the mines are in difficult terrain with limited access to watercourses. Known areas of jig tailings deposit are marked on Map 1. The tailings banks are exposed during drier periods which results in the oxidation of the metal sulphides, so that during initial flood conditions the waters carry an increased load of contaminants.

Another identified source of contamination is Side Creek (see Map 2), in which the old adits have become a mine water drainage point for the water-filled Storeys Creek Mine. As well, heavily contaminated discharge was discovered from the Eastern Hill prospects (between Side and Nisbet Creeks) which flow into Storys Creek downstream of the mine site.

3. REVIEWS OF HISTORICAL MONITORING DATA

3.1 Sources of data

Much of the raw data has been consolidated in Government reviews/reports or in published scientific papers as listed in Attachment 1. Numerous other reports have been written on various facets of the mining operations, including archaeological, economic and engineering aspects, but only those references which provide environmental quality data are included here. This overview is believed to be a comprehensive summary of the data which have been collected within the Storys Creek/Rossarden catchment area, and a partial compilation of monitoring conducted in the South Esk River and its floodplains.

Government departments are referred to by their name at the time a particular report was written or samples collected. The Department of Environment became the Department of Environment and Planning, and is presently known as the Department of Environment and Land Management. The Department of Agriculture is now known as the Department of Primary Industry and Fisheries.

Table 1 summarises the frequency and type of samples collected by various agencies/parties between 1968 and 1992.

3.2 General behaviour of metal contaminants

The major metal contaminants in the watercourses draining the mine sites are metals, most particularly cadmium and zinc, and to a lesser degree copper, lead, iron and manganese.

The behaviour of metals in aquatic systems is highly complex because there are a multitude of possible interactions between dissolved and particulate components and the existence of non-equilibrium conditions. Precipitation of metal compounds may take place due to changes in pH, oxidation potential, temperature, or ionic strength. Metal ions may be adsorbed onto iron oxides, clays and organic materials and effectively taken out of solution. A good reference for the behaviour of metals in water and sediments and their uptake by organisms is Salomons and Forstner (1984).

High metal levels in the Rossarden and Storys Creek catchment are exacerbated by a phenomenon known as acid mine drainage or acid rock drainage, which occurs in regions where metal sulphide minerals are exposed to air and water. At Rossarden and Storys Creek, tin and wolfram were mined from quartz-wolframite-cassiterite veins which included base metal sulphides such as pyrite (iron sulphide). Pyrite and other sulphides are oxidised by exposure to air to form ferric iron and sulphuric acid. Ferric iron will remain in solution if the pH is less than 4. Under acidic conditions, enhanced by the production of sulphuric acid, ferric iron is a potent oxidising agent and oxidises more pyrite. Certain bacteria catalyse the oxidation of ferrous to ferric iron, which increases the rate of reaction and also provides an energy source for the bacteria to build up organic material.

The acid mine drainage process results in streams with low pH and high heavy metal levels, and is well illustrated in the Rossarden-Storys Creek catchment area. A good summary of the processes which give rise to acid mine drainage, its impacts and possible control measures is found in the proceedings of the "Acid Mine Drainage Workshop, Strahan Tasmania 1992", held by the Tasmanian Chamber of Mines.

3.3 Metals in the Rossarden/Storys Creek catchment

Information on sources and behaviour of metals and other components in the Rossarden/Storys Creek catchment has been drawn from the various Mines Department reports, and is summarised below. Specific locations of inputs are shown on Maps 1 and 2.

Whether or not a particular metal will occur in solution is strongly dependent upon the pH. Storys Creek above all mining activity has a pH of 6. The Precipitation Dam seepage is only slightly acidic. The tailings dump area lowers the pH of Storys Creek close to 4, and the small flow in Side Creek is very acidic. Nisbet Creek increases the flow in Storys Creek and causes an increase in pH to about 5, which remains until the confluence with Aberfoyle Creek. Aberfoyle Creek maintains a steady pH of 6.5 from above the mine workings until it reaches the South Esk River - the creek's pH is unaffected by inputs from No.4 adit (pH 7) and from Storys Creek (pH 5). The South Esk has the same pH as Aberfoyle Creek (pH 6.5) above and below the confluence with Storys Creek.

Observations of the sources and behaviour of particular metals are as follows:

Cadmium. Cadmium remains in solution until a pH of around 8.5 and therefore does not precipitate in the catchment. High cadmium concentrations have been found regularly in both Storys and Aberfoyle Creeks. Cadmium chemistry closely resembles that of zinc, and the following zinc:cadmium ratios were found for the mine sites - Aberfoyle Mine from 31 to 34:1, and Storeys Creek Mine from 21 to 28:1. This ratio is useful because some of the government reports/reviews do not include results for cadmium, but do have results for zinc.

Zinc. Side and Aberfoyle Creeks have about equal inputs of zinc. The precipitation dam seepage contributes about 15% of the mass loadings of either the Side or Aberfoyle Creek inputs. About 50% of the zinc comes from unmeasured input(s) between Side and Nisbet Creeks (old Eastern Hill prospecting?). Further oxidation of zinc sulphide occurs in the tailings in the streambed below Nisbet Creek. Zinc is removed from the water column after Storys Creek joins the South Esk River, before the water reaches Avoca. In 1976 it was determined that zinc was being deposited in the bed of the South Esk between Aberfoyle Bridge and Avoca at a rate of 20 t/yr.

TABLE 1
Overview of historical sampling

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1968									8,9	8		
1969							10					
1970					A					A		
1971	A											
1972		B						B				
1973												
1974					8,9							
1975		C		C		C	1	C	1	C		C
1976	1	1,4,C,D	1	1,C		1		C	1		1,4	C
1977		1,4							4			
1978			4	4	4	4	4	4	4	4	4	4
1979	4	4	4	4	4	4	4	4	4	4	4	4
1980	4	4										
1981					1							
1982			*	1,4,5	1,4,5		4				1,4,5	1
1983												
1984										8,9	1	1,2,3,4,5
1985	4						4					1
1986		1	1	1	1,5	1,5 #	1,5	1,5	1,5	1,5	1,5	1,5
1987	1,5	1,5	1,5		1				1			1
1988		1										
1989		1,5									1,5	
1990					1,5		1,6		1			
1991	E		E	E	E		E	E	1		1	E
1992								7	7			

KEY:

1 = Rivers & Water Supply Comm. database - Water quality
2 = Hydro-Electric Commission (1985) - Aquatic biota
3 = Mines Department (1985) - Water quality
4 = Mines Department (1986a) - Water quality, precipitation dam
5 = Mines Department (1990a) - Water quality
6 = Mines Department (1990b) - Water quality, precipitation dam, bank sediments
7 = Department of Environment samples - Water quality
8 = Department of Agricriculture (1984a) - Floodplain soil and silt
9 = Department of Agriculture (1984b) - Floodplain plants
10 = South Esk Pollution Committee (1970) - Water, soil

A = Tyler and Buckney (1973) - Water quality, sediments, trout
B = Thorp and Lake (1973) - Macroinvertebrates
C = Norris (1979) and Norris et al (1980, 81, 82) - Water quality, river sediments, invertebrates
D = Norris and Lake (1984) - Fish
E = Morrison (1992) - Water quality

* - Date by which both mines were closed
# - Major floods caused dam breaches

Copper. Copper remains in solution until a pH of around 6. The Aberfoyle mine water has a relatively high pH and so the copper is not in solution. At Storeys Creek Mine the copper concentration is somewhat higher, but appears to be readily reduced by pH rises downstream.

Fluoride. Aberfoyle Creek is the main source of fluoride, with about twice the fluoride input of Storys Creek. Side Creek appears to be the major source of the Storys Creek fluoride inputs.

Manganese. Side and Aberfoyle Creeks have about equal inputs of manganese. The main source is somewhere between Side and Nisbet Creeks, possibly Eastern Hill prospecting.

Iron. Iron remains in solution until around pH 4, as well as being affected by oxidation. Iron in both Storys and Aberfoyle Creeks is removed from solution before either creek reaches their confluence. The precipitation of iron is visually evident by the red brown rust-coloured creek beds and tailings deposits.

Aluminium. Inputs of aluminium have been traced back to Side Creek, although most appears to come from Storys Creek below Side Creek. Aluminium remains in solution while the pH is less than 5.5, above which it is precipitated. When Storys Creek meets the higher pH water of Aberfoyle Creek, it immediately precipitates out and coats the stones of the creek bed.

Sulphate. Aberfoyle Creek has tended to have higher results for sulphate than has Storys Creek. Side Creek has also regularly had high sulphate results. The higher sulphate in Aberfoyle Creek could indicate that more sulphide has been oxidised to sulphate, or that less sulphate has been removed from the water. It would be necessary to do a metal/sulphur water balance incorporating flow rates to properly compare the two creeks.

Mines Department (1990a) highlights that the major metal load is carried by Storys Creek, which is regularly above the Department of Environment (1986) Guidelines for Potable Water for zinc, cadmium and fluoride (discussed in more detail in Section 4). Metal load carried by Aberfoyle Creek is less, with zinc and fluoride usually below the Guidelines for Potable Water but with cadmium levels regularly higher.

It is important to note that all sources of metals have not been thoroughly canvassed. Blissett (1959) shows locations of prospects downstream of Storeys Creek Mine (shown on Map 1), which may also be contributing metals into the drainage courses. As recently as 18 August 1992, drainage from what is probably the old Eastern Hill workings were discovered downstream from Side Creek (see Map 2) by officers of the Department of Environment and Planning and Department of Mines, with concentrations of cadmium (0.11 mg/l), zinc (11 mg/l), iron (110 mg/l) and manganese (0.82-7.8 mg/l) well in excess of recommended guidelines as are discussed in the next section. Accessibility is difficult for some of these old prospecting sites and no comprehensive sampling survey has been done.

4. WATER QUALITY

4.1 Results from RWSC Database

Table 2 presents a summary of water quality guidelines which are referred to in this report. As shown on Table 2, recommended levels vary depending on the intended use or "environmental value" of the receiving waterbody, e.g. for recreation, agricultural irrigation or stockwatering, potable water, or protection of aquatic ecosystems.

For the determination of heavy metal concentrations in water samples, decisions must be made on whether to analyse filtered or unfiltered samples and on the method of sample treatment (e.g. acidified or acid-digested). The most up-to-date reference on water quality guidelines, ANZECC (1992), recommends that toxicant concentrations be measured in unfiltered samples to ensure a conservative approach, because although for metals it is the "biologically available" fraction that is of concern, there is no single analytical technique or instrument to measure this fraction. In the following tables, all results shown are for total metals unless otherwise stated.

Table 3 presents the range of water quality results held in the Rivers and Water Supply Commission's (RWSC) water quality database, for samples collected by officers from the Department of Environment and Department of Mines between 1975 and 1991. Because of some confusion as to the reporting of "total" or "filtrable" metals in the RWSC database, all results are assumed to be total metals. As a consequence, the average metal concentrations presented in Table 3 are probably underestimates because some "filtrable" results are treated as "total".

TABLE 2
Water Quality Standards (mg/l)

Source	pH	Alkalinity	Cadmium	Zinc	Copper	Fluoride	Manganese	Lead	Sulphate	Total Dissolved Solids
Environment Protection (Water Pollution) Regulations 1974										
- Inland Waters	---	---	0.01	5	1	1.5	1	0.05	250	200
- Pre-1975 Mines and Metalliferous	---	---	0.03	5	1	3	1	0.2	600	200
Dept of Environment (1986) Guidelines on Minimum Desirable Ambient Water Quality for Receiving Waters in Tasmania										
- Potable A	---	500	0.005	5	1	1.5	0.5	0.05	400	100
- Agricultural B (Stock Consumption)	---	---	0.01	20	2	2	---	0.1	1000	2000 - 6000**
- Agricultural C (Irrigation)	4.5 - 9	---	0.01	2	0.2	---	---	5	---	---
- Aquaculture A	6.5 - 9	---	0.005	0.2	0.02	---	---	0.05	---	25
ANZECC (1992) Australian Water Quality Guidelines for Fresh and Marine Waters										
- Drinking Water Supply	6.5 - 8.5	---	0.005	5	1	---	0.1	0.05	400	1000
- Agricultural Water Use (Livestock Watering)	---	---	0.01	20	0.5	2	---	0.1	1000	3000
- Agricultural Water Use (Irrigation)	4.5 - 9	---	0.01	2	0.2	1	2	0.2	---	>3500***
- Protection of Aquatic Ecosystems	6.5 - 9	---	.0002 - .002*	.005 - .05*	.002 - .005*	---	---	.001 - .005*	---	---

--- No standard recommended
* Depends upon the hardness of the water
** Depends upon type of livestock
*** Depends upon soil characteristics, crop tolerance, climate and irrigation practices

TABLE 3
Water Quality Results - RWSC Database (mg/l)

Station	Sampling Period	No. Samples	pH			Alkalinity			Cadmium			Zinc		
			Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Storys Creek Mine Water	Jul 75 - Feb 77	10	4.2	8.2	6.5		---		0.002	4.9	1.9	0.1	100	39.3
Side Creek above Storys Creek	May 82 - May 90	14		---			---		0.06	0.86	0.6	0.2	50	16.5
Storys Creek below Side Creek	Dec 84 - Sep 90	13		---			---		0.08	0.38	0.17	1.7	23	5.7
Storys Creek above Aberfoyle Creek	Apr 82 - May 90	29	2.3	6.7	5.4	0.7	31.6	5.4	0.017	0.59	0.15	0.54	14	4.5
Aberfoyle Creek Mine Water	Jul 75 - Feb 77	8		---			---		0.1	1	0.51	1.7	32	11.8
Aberfoyle Creek above Storys Creek	Apr 82 - May 90	34	5.3	7.6	6.3	0.6	41.5	25.8	0.001	0.47	0.06	0.001	11.9	1.69
Storys Creek below Aberfoyle Creek	Apr 82 - Nov 91	23	6.0	6.5	6.2		---		0.002	0.6	0.11	0.196	7.5	2.6
South Esk River below Storys Creek	Mar 86 - Dec 87	5		---			---		0.001	0.142	0.03	0.134	2.1	0.81

Station	Copper			Fluoride			Manganese			Sulphate			Total Dissolved Solids		
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Storys Creek Mine Water	0.1	2.2	0.48		---			---		660	940	780	1130	1770	1384
Side Creek above Storys Creek		---		0.3	19	10.2	0.1	11	4.6	5.6	670	308	35	1130	526
Storys Creek below Side Creek		---		0.5	3	1.5	0.2	2.2	0.8	5	135	62	73	230	135
Storys Creek above Aberfoyle Creek	0.014	0.69	0.35	0.3	2.2	1	0.013	1.6	0.49	3.9	185	61	45	307	129
Aberfoyle Creek Mine Water	0.1	0.2	0.12		---			---		38	920	428	100	1480	800
Aberfoyle Creek above Storys Creek	0.009	1.02	0.11	0.52	1.7	1	0.009	1.3	0.23	25	265	109	103	450	210
Storys Creek below Aberfoyle Creek		---		0.4	1.8	1	0.1	1.3	0.43	12.5	230	84	79	390	161
South Esk River below Storys Creek		---			---			---		6.7	102	40		---	

It should be noted that average metal concentrations shown in Table 3 and the following tables may not be representative because of the small size of some data sets.

As can be seen from Table 3, average cadmium levels exceed all recommended levels at almost all sampled locations, and average zinc levels frequently exceed recommended levels, despite the fact that these results err on the conservative side. Other parameters such as copper and fluoride also at times exceed recommended guidelines, although these elements have not been analysed for as consistently as cadmium or zinc. Results for the South Esk River below Storys Creek suggest that metal concentrations are significantly reduced at this stage, but unfortunately there are only a few samples in the RWSC database from which to base this observation.

The ANZECC (1992) guidelines for protection of aquatic ecosystems are dependent on the hardness of water for cadmium, zinc and copper concentrations. An increase in hardness tends to reduce the toxicity of these particular metals to aquatic organisms. In carbonate controlled waters, hardness (the sum of calcium and magnesium ions) is generally equivalent to alkalinity because both measures derive from the same carbonate bedrock source. Alkalinity is a measure of the bicarbonate concentration in the water, which indicates its buffering capacity. Although there are only a few results of alkalinity analyses included in the RWSC database, these can be considered quite low. Alkalinity results lower than 50 mg/litre are generally associated with low hardness, which indicates that the lower end of the range of metal concentrations for protection of aquatic ecosystems apply (ANZECC 1992). Limestone outcrops in the rocks which drain to Aberfoyle Creek, which may explain its slightly higher alkalinity as shown in Table 3.

Efforts to correlate variations in metal concentrations in the RWSC database to variations in flow rates or precipitation found no meaningful trends. Flow data have been recorded for some samples included in the RWSC database, but not on a continuous basis. Precipitation data are available from the Bureau of Meteorology for Rossarden (1975 - 1982), Storys Creek (1983 - present) and Avoca (1975 - present). Unfortunately, discontinuities in the sampling periods and uncertainty about the reporting of metals as "filtrable" or "total" do not permit any meaningful correlations to be determined.

4.2 Published Results - Storys and Aberfoyle Creeks

Table 4 shows water quality results from published sources for samples taken in the Rossarden/Storys Creek catchment.

Tyler and Buckney (1973) found that by all international guidelines, copper, cadmium and zinc concentrations are undesirably high in the Storys Creek waters. Table 4 shows data from filtered samples from sites downstream of the mines, where all cadmium concentrations exceed recommended levels for the whole range of intended uses, and zinc levels frequently exceed many of the guidelines shown in Table 2. Copper levels are undesirably high for agricultural uses, and all three metals occur in concentrations well in excess of ANZECC's guidelines for protection of aquatic ecosystems.

The most recent results for water samples were collected just below the confluence of Storys and Aberfoyle Creeks by Morrison (1992). These results were obtained using Inductively Coupled Plasma Mass Spectrometry (ICP-MS), a technique which allows determination of a wide range of metals at very low detection limits (e.g. 0.005 ng/ml for cadmium). Morrison's results for ten sample periods over nine months show cadmium concentrations in excess of the Tasmanian *Environment Protection (Water Pollution) Regulations 1974* on all occasions, and zinc frequently above and copper occasionally above these regulations. In all cases levels of these metals greatly exceed ANZECC's guidelines for protection of aquatic ecosystems. Morrison's results for lead show that concentrations of this metal are generally well within recommended levels, with occasional exceedances of the guidelines for protection of aquatic ecosystems.

4.3 Published Results - South Esk River

Table 5 shows water quality results from published sources for samples taken in the South Esk River.

Tyler and Buckney (1973) found elevated concentrations of cadmium, zinc and copper in the South Esk as far downstream as Evandale (roughly 80 km), using filtered samples. Samples collected from three sites on the South Esk above Storys Creek (at Mathinna, Fingal and just above Storys Creek) had cadmium, zinc and copper levels below detection limits using atomic absorption spectroscopy.

TABLE 4
Water Quality Results - Storys Creek Catchment (mg/l)

Source	Station	Alkalinity			Cadmium			Zinc			Copper			Lead		
		Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Tyler & Buckney (1973)	Storys Creek above Aberfoyle Creek	0.31	0.9	0.61	0.21	0.25	0.23	7.3	12.2	9.6	0.25	0.85	0.56			
	Aberfoyle Creek above Storys Creek	32.5	36	34.2	0.03	0.1	0.07	1.3	2.4	1.9	---	---	0.18			
	Storys Creek below Aberfoyle Creek	7.3	9.2	8.2	0.13	0.21	0.17	4.1	4.3	4.2	0.15	0.25	0.2			
Morrison (1992)	Storys Creek above South Esk				0.06	0.41	0.17	1.4	9.9	4.1	0.18	1.2	0.53	0.003	0.014	0.007

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TABLE 5
Water Quality Results - South Esk River (mg/l)

Source	Station	Alkalinity			Cadmium			Zinc			Copper			Lead		
		Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Tyler & Buckney (1973)	South Esk below Storys Creek	12.8	21.7	16.4	---	---	0.04	0.15	0.5	0.33	---	---	0.1			
	South Esk below Buffalo Brook	---	---	24.7	---	---	0.04	—	—	0.26	---	---	0.15			
	South Esk at Ben Lomond Rivulet	25	26.5	25.7	---	---	0.04	0.09	0.24	0.17	---	---	0.1			
	South Esk at Evandale	27.5	29.1	28.3	---	---	0.03	0.05	0.14	0.1	0.05	0.1	0.07			
Thorp & Lake (1973)	South Esk at Fingal Bridge	17.7	19.8	18.7	0	0.06	0.03	0.05	0.2	0.13	---	---	0.06			
	South Esk at Storys Creek	12.3	15	13.6	0.24	0.33	0.29	3.5	8	5.7	0.04	0.12	0.08			
	South Esk at Avoca	21.8	22.6	22.2	0	0.05	0.02	0.27	0.3	0.29	0.02	0.03	0.02			
	South Esk at Glen Esk	26.9	27	26.9	0	0.002	0.001	0.17	0.2	0.19	0.04	0.05	0.04			
	South Esk at Evandale	28.2	33.7	30.9	0	0.01	0.005	0.06	0.22	0.14	0.04	0.06	0.05			
Norris (1979)	South Esk above Fingal	12	44	21.6	0	0.003	0.0003	0.0001	0.095	0.025	0.001	0.007	0.003	0	0.022	0.004
	South Esk below Fingal	15	57	28.4	0	0.002	0.0003	0.0008	0.117	0.036	0.001	0.008	0.004	0	0.018	0.003
	South Esk above Storys Creek	18	61	35.3	0	0.002	0.0002	0.0006	0.108	0.029	0.001	0.016	0.004	0	0.011	0.002
	South Esk below Storys Creek	15	57	28.3	0.0015	0.021	0.0075	0.1106	0.287	0.190	0.004	0.019	0.009	0	0.035	0.006
	South Esk at Avoca	12.5	57.5	28.7	0.004	0.016	0.008	0.1127	0.379	0.215	0.005	0.020	0.011	0	0.029	0.009
	South Esk above Buffalo Brook	17.5	78.5	36.6	0.0025	0.012	0.0064	0.0794	0.244	0.153	0.005	0.022	0.009	0	0.053	0.011
	South Esk below Buffalo Brook	20	85	43.9	0.0022	0.01	0.0052	0.0534	0.250	0.146	0.004	0.018	0.010	0	0.032	0.009
	South Esk below Ben Lomond Rivulet	14.5	85	35.5	0.0007	0.009	0.004	0.0305	0.229	0.105	0.004	0.016	0.009	0	0.047	0.011

Tyler and Buckney found that water quality in the South Esk was within international guidelines, with the possible exception of cadmium. In comparison with ANZECC's guidelines shown on Table 2, reported cadmium levels exceeded recommended levels for all intended uses, and zinc and copper levels were above those recommended for protection of aquatic ecosystems. Tyler and Buckney believed their results were such as to merit a comprehensive examination of cadmium concentrations in the South Esk River using more sensitive analytical methods.

Thorp and Lake (1973) showed zinc concentrations to be higher than background levels as far downstream as Evandale, and cadmium concentrations above background levels as far downstream as above Glen Esk. This study was based on only two sample results for each sampling station and used filtered samples. The one result of 0.06 mg/l cadmium from the South Esk at Fingal is surprisingly high, given that the cadmium level was below detection limits for the other sample at this location. It is also noted that this particular sample was collected five days after the other stations to which it is compared.

Norris (1979) found that total cadmium, zinc, copper and lead levels were well above background levels up to 130 km downstream from Storys Creek. Average levels of these metals from ten regularly spaced sampling periods over two years are above ANZECC's guidelines for protection of aquatic ecosystems. Cadmium levels in the South Esk between Storys Creek and Buffalo Brook are above ANZECC's recommended levels for drinking water. Concentrations of mercury, nickel, cobalt and chromium were consistently below the detection limits (using atomic absorption spectrophotometry), and so determinations of these metals were discontinued.

5. SEDIMENT ANALYSES

5.1 Comparison with Guidelines

Table 6 presents guidelines recommended by ANZECC/NHMRC in "Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites" (January 1992). A contaminated site is broadly defined as

> a site at which hazardous substances occur at concentrations above background levels and where assessment indicates it poses, or is likely to pose an immediate or long-term hazard to human health or the environment (ANZECC/NHMRC 1992, p.2).

TABLE 6
ANZECC/NHMRC Guidelines for Contaminated Sites (ppm)

ANZECC/NHMRC (1992) Guidelines	Zinc	Cadmium	Copper	Lead	Tin	Tungsten	Arsenic
Background Range	2 - 180	.04 - 2	---	<2 - 200	1 - 25	---	.2 - 30
Environmental Investigation Level	200	3	60	300	50	---	20

TABLE 7
Comparison of Different Extraction/Digestion Methods for Cadmium

	Extraction/digestion procedure[a]					
Sample code	Acetic	HCl	DTPA	EDTA	HNO_3	HF
E 801	5.3	0.2	2.3	5.2	6.3	7.8
E 946	1.5	2.1	1.6	2.3	2.1	2.5
E1362	2.8	0.5	1.3	2.9	4.0	3.8

a: Sample result in $mgkg^{-1}$

Acetic acid - 0.5M extracted for 16h at 1:40 ratio

DTPA - 0.005M extracted for 2h at 1:2 ratio (pH 7.3)

HNO_3 - 16M digested for 1h at 100°C at 1:10 ratio

HCl - 1.0M extracted for 16h at 1:2.5 soil:extractant ratio

EDTA - 0.1M extracted for 7 days at 1:2.5 ratio (pH 6.0)

HF - 22M (conc) digested at 1:10 ratio followed by HNO_3/ $HClO_4$ then HCl/H_2O_2

Data derived from Table 7: Clayton, P.M. and Tiller, K.G. (1979). A chemical method for the determination of the heavy metal content of soils in environmental studies. CSIRO Division of Soil Technical Publication No 41, P10.

Background levels refer to ambient levels of a contaminant in the local area of the site under consideration. The background levels should be viewed as indicative values only, as they will vary with soil types, land uses and location. There is no database in Tasmania on the level of total cadmium in soils, but Department of Primary Industry research has shown representative levels to be from 0.05 - 0.1 ppm for soils with no history of superphosphate addition (a source of cadmium), and from 0.05 - 0.2 ppm for soils with a history of superphosphate addition (Mines Department 1990b).

The ANZECC/NHMRC levels refer to the total concentration of a chemical in soil when tested in accordance with approved analytical methods. The most important decision to be made in analysing for metals in sediments is whether to use an extraction procedure or to use 'total' analysis. Values obtained from total analysis are considered to be the most specific and can be determined by a wide range of techniques. However, extraction procedures provide information on bioavailability of a particular metal and so are potentially much more useful (SAHC 1991).

Bioavailability is "the fraction of the total chemical in the surrounding environment (e.g. water, sediment, suspended sediment, food items) that can be taken up by organisms" (ANZECC 1992 p.B-2). Various contaminant and soil factors can affect bioavailability of a given soil contaminant, including particle size and shape, contaminant concentration, physico-chemical properties and the length of time the contaminant has been in the soil.

Table 7 compares results using different extraction/digestion techniques for recovery of cadmium from a soil sample. The HF digest measures 'total' cadmium, while the other methods attempt to determine levels of cadmium more readily 'available' in the system. Obviously it is important that the method of analysis be clearly stated with reporting of results. All results shown in the following tables are for total metals unless otherwise stated. Consideration of the total metal concentrations provides a conservative estimate of the degree of contamination since non-available metals are included.

The ANZECC/NHMRC guidelines indicate concentrations at which a more detailed investigation of the extent of contamination is warranted. As can be seen from the following tables, sediment samples taken at both mine sites, along the stream banks and in sediments from properties along the South Esk River downstream of Storys Creek all have levels of zinc, cadmium and copper which in terms of the ANZECC/NHMRC guidelines warrant further investigation.

5.2 Contents of the Storeys Creek Mine Precipitation Dam

Table 8 shows results of metals analyses in sediments from dams at the mine sites. The highest concentrations of zinc, cadmium and copper in sediments are found in the Storeys Creek Mine precipitation dam, probably the most significant point source of metal contamination in the Rossarden/Storys Creek catchment.

Sampling of materials in the Storeys Creek Mine precipitation dam during 1984-85 is discussed in Mines Department (1986a). The material is layered, with the top 100 mm consisting of fine brown hydroxide and carbonate precipitates produced by the addition of lime and soda ash. Below this level are several metres of sand-like material, thought to be original tailings, which if oxidised would be a source of sulphate and metals over the long term.

Material collected from the precipitation dam during July 1990 (Mines Department 1990b) was analysed and compared with samples taken in 1982 and 1984. It was concluded that the alkalinity of the dam has been reduced to the point at which precipitated hydroxides and carbonates are redissolving and entering the drainage system at Storys Creek. The percentage of carbonates, sulphates, zinc and cadmium had reduced over time (with a relative increase in the percentage of silica), and the percentage of iron in the tailings had stayed the same.

Mines Department (1986a) found that passing laboratory leachate through sphagnum moss removed most of the zinc and cadmium and lowered the pH. However, the moss beds needed replacing regularly. Seepage water from the precipitation dam was found to vary significantly in contaminant concentration between summer and winter, with winter results showing higher concentrations and acidity. Variations in flow and thickness of water cover in the dam may be the cause of these seasonal changes.

5.3 River bed sediments

Table 9 shows results of river bed sediment analyses from studies by Norris (1979) and Norris *et al* (1981).

Norris (1979) analysed metal concentrations (manganese, iron, cadmium, zinc, copper and lead) in South Esk River bed sediments.

TABLE 8

Metal Levels in Sediments from Mine Dams (ppm)

Reference	Location	Zinc	Cadmium	Copper	Lead	Tin	Tungsten	Arsenic
Mines (1990b)	Rossarden Slimes Dam	1500	78	890	210	1400	560	180
	Rossarden Sand Tails Dam	1100	64	520	120	900	350	32
	Storeys Creek Precipitation Dam	36,000	1320	4400	420	180	3100	115
	Precipitate from Storeys Creek dam seepage	5600	224	1600	470	270	740	240

TABLE 9
River Bed Sediments (ppm)

Reference	Location	Zinc			Cadmium			Copper			Lead			Manganese			Iron		
		Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Norris	South Esk above Fingal	24	48	34	n.d.	2.5	0.2	7.1	11.9	7.6	n.d.	12.9	5.6	204	5730	1100	2790	41,100	16,200
(1979)	South Esk below Fingal	18	40	29	n.d.	1.5	0.1	4.5	11.6	8.4	n.d.	29.0	6.1	231	15,700	2490	2260	20,000	22,800
	South Esk above Storys Creek	12	52	23	n.d.	1.5	0.2	3.2	10.2	6.8	n.d.	10.8	4.6	38	1400	280	2000	72,300	16,200
and	Storys Creek above South Esk	652	3470	1150	23.2	89.6	46.1	16.7	2460.0	524.0	16.3	110.0	43.3	48	809	384	1430	21,700	9580
	South Esk below Storys Creek	16	2910	1130	n.d.	103.0	40.6	7.3	841.0	336.0	3.5	100.0	43.7	38	2070	644	1320	20,000	10,300
Norris	South Esk at Avoca	98	668	281	1.9	35.1	13.4	7.7	317.0	62.8	2.9	137.0	31.8	51	1100	448	2790	24,100	12,100
et al (1981)	South Esk above Buffalo Brook	204	3510	1084	8.0	90.3	29.4	23.0	682.0	237.0	2.2	269.0	76.3	94	4150	1290	2960	26,900	15,300
	South Esk below Buffalo Brook	101	2720	1249	4.9	97.1	51.8	47.9	508.0	234.0	11.5	134.0	58.4	107	3090	1460	1380	41,400	17,000
	South Esk below Ben Lomond Rvt	44	1470	380	3.8	71.7	23.4	15.3	58.0	31.5	n.d.	16.3	9.0	218	2490	960	5070	30,300	15,500
	South Esk below Macquarie River	75	681	172	2.6	20.2	10.4	22.6	46.4	33.1	6.1	29.3	16.5	551	2450	1180	4460	22,600	14,900
	South Esk at Trevallyn Dam	162	380	262	7.3	18.8	12.7	22.9	46.3	35.8	16.3	110.0	43.3	880	2600	1270	6000	28,400	17,800

n.d. - not detectable

He found manganese and iron concentrations to be unaffected by inputs from Storys Creek. As with the water sample results, he found that cadmium, zinc, copper and lead were well above background levels up to 130 km downstream from Storys Creek. In comparison with ANZECC/NHMRC's guidelines, metal concentrations in South Esk river bed sediments Esk below Storys Creek are in places many times higher than environmental investigation levels for cadmium, zinc, and copper.

Norris *et al* (1981) suggest that most of the metal load carried by Storys Creek to the South Esk River is probably dissolved rather than associated with suspended or bed sediment. Because Storys Creek has been heavily contaminated for many years, its bed is denuded, gravelly and unstable with little or no biotic production. Metals show an affinity for clay particle and organic constituents which are more typical of the sediments found in the South Esk River than Storys Creek. (Metals also have an affinity for fine-grained iron hydroxides which may be more important in this case). As a result, sediment type and local conditions appear to be the most important factors in controlling the concentrations of cadmium, zinc, copper and lead in the sediments.

The results in Table 9 show that cadmium, zinc, copper and lead concentrations in the sediments generally decreased with distance downstream of Storys Creek, except for relatively low values at Avoca. At Avoca the river bed appears relatively coarse and unstable, with little retention of fine clay and humic sediment. Norris (1979) attributes spatial variations in metal concentrations to factors such as dilution, flow rate and particle size.

5.4 Stream bank and flood plain sediments

Department of Agriculture (1969) surveyed the areas of arable pastures and marshes affected by siltation, and found variation in silt accumulation from 2-3 feet at "Henbury" to ½ inch at "Brambletye" (see Map 1 for property locations). 433 acres of arable pasture were found to be badly or lightly affected, and 350 acres slightly affected. 588 acres of marsh and stream bank land were affected. Effects ranged from destruction to loss of vigour of clovers and sown grass species, and severe erosion resulting from lack of plant cover.

Table 10 shows results of stream bank and flood plain sediment analyses from studies by Tyler and Buckney (1973), Department of Agriculture (1984a) and Mines Department (1990b).

TABLE 10
Stream Bank and Flood Plain Sediments (ppm)

Reference	Location	Date	Zinc	Cadmium	Copper	Lead
Tyler & Buckney (1973)	"Henbury" property		1500	---	700	1500
	"Bonney Plains" property		4060	153	1986	1444
	'Normal Soil'		10 - 300	1	1 - 100	2 - 200
Department of Agriculture (1984a)	**"Fairfield" property**					
	silt near pump house	Oct '69	1100		400	
	silt deposit on saggs	Sep '69	1600		500	
	pasture paddock silt	Oct '84	735	27	117	28
	"Brambletye" property					
	silt below house	Oct '69	1500		800	
	silt from marsh	Oct '69	2000		900	
	silt near bridge	Oct '69	1000		600	
	soil from flooded area	May '74	240	7	70	10
	soil from unflooded area	May '74	50-70	1	1	10
	silt around poor thistles	May '74	580	23	240	50
	silt around poor clover	May '74	370	16	150	70
	silt around no growth	May '74	800	40	610	130
	"Bonneys Plains" property					
	silt 20m from river	1968	3800		1700	
	silt 20m from river 0-6 mm depth	Sep '69	1500		700	
	silt 20m from river 6-25 mm depth	Sep '69	2600		1100	
	silt 20m from river 25-75 mm depth	Sep '69	3800		2000	
	silt 20m from river 75-125 mm depth	Sep '69	2100		1400	
	silt 20m from river 125-225 mm depth	Sep '69	1500		1500	
	silt 200m from river 0-4 mm depth	Sep '69	900		500	
	silt 200m from river 4-9 mm depth	Sep '69	1400		600	
	silt 200m from river 9-30 mm depth	Sep '69	3000		1100	
	silt 200m from river 30-100 mm depth	Sep '69	1300		1100	
	silt 200m from river 150 mm depth	Sep '69	200		50	
	silt from limed trial area	May '74	1560	67	1300	280
	silt from unlimed trial area	May '74	1460	64	1340	270
	"Henbury" property					
	silt from lucerne paddock 0-75 mm depth	Sep '69	1100		300	
	silt from lucerne paddock 75-125 mm depth	Sep '69	1100		400	
	silt 200 m from river	Oct '69	1300		700	

TABLE 10 (continued)
Stream Bank and Flood Plain Sediments (ppm)

Reference	Location	Zinc	Cadmium	Copper	Lead	Tin	Tungsten	Arsenic
Mines Department (1990b)	Storys Crk banks above Side Crk	560	26	290	220	2100	2900	90
	Storys Crk banks above Aberfoyle Crk	790	51	330	83	410	450	<20
	Aberfoyle Crk banks above Storys Crk	560	32	500	81	520	370	39
	Storys Crk banks above South Esk	580	35	330	78	390	680	29
	South Esk R. flats above Storys Crk (1)	570	41	110	<10	100	84	<20
	South Esk R. flats above Storys Crk (2)		13.5					
	South Esk R. flats above Storys Crk (3)		1.1					
	Farm at Westbury		<1					

Silt samples were taken from pastures along the South Esk River at "Bonney Plains" in 1969 and at "Henbury" in 1970 (Tyler and Buckney 1973), and concentrations of cadmium, zinc, copper and lead were found to be much higher than that of 'normal' soil and significantly higher than ANZECC/NHMRC environmental investigation levels. 'Normal' soil was that defined by Swain (1955).

Department of Agriculture (1984a) results show significantly high zinc, copper and cadmium levels in silt and soil samples taken from properties of "Fairfield" (1969 and 1984), "Brambletye" (1969 and 1974), "Henbury" (1969) and "Bonney Plains" (1969 and 1974). Note that the 1974 and 1984 results are 'HCl Extractable' metals whereas all other results are 'total' metals.

Sediment samples collected in July 1990 (Mines Department 1990b) from the creek banks and South Esk River flats were found to have zinc, cadmium, tin and copper levels in excess of ANZECC/NHMRC environmental investigation limits. Samples 1, 2 and 3 from the South Esk River flats were progressively farther upstream from Storys Creek and show a corresponding decline in cadmium concentrations. It was surprising to find such elevated cadmium levels in the river banks upstream of the Storys Creek confluence, and Mines Department (1990b) considered that they could be natural, a result of wind erosion or a result of irrigation practices. The addition of superphosphate adds cadmium to the soil, but Appendix 2 to the Mines Department (1990b) report shows the superphosphate contribution to be minute compared to the cadmium levels present in the samples collected near the creeks.

According to Mines Department (1990b), no comprehensive soil sampling program has been done in the region (Department of Agriculture silt and soil sampling only covered selected properties) so it is unknown whether cadmium levels are reducing, increasing or are stabilised.

5.5 Bioavailability

As mentioned in Section 5.1, bioavailability is the fraction of the total chemical which can be taken up by organisms. Leach tests can give an indication of the concentrations of metals derived from sediments which will be available in a soluble form and therefore more likely to be uptaken by plants or other organisms.

Oxidised tailings on the banks and bed of Storys and Aberfoyle Creeks were shown to be quite reactive by leach tests discussed in Mines Department (1986b). This report found that dissolution from these tailings must continue to be significant, but difficulties were found in quantifying dissolution.

Leach tests were conducted by the Mines Department on the July 1990 soil samples from the Aberfoyle property on the South Esk River upstream of Storys Creek. The percentage of total cadmium extracted in the leaching tests using distilled water for up to 24 hours were 0.73% and 0.87%, from which Mines Department (1990b) interpreted that the majority of cadmium in the soil was in a complexed form inhibiting its dissolution and uptake by vegetation. The uptake of cadmium by plants is complex, and more extensive leach tests on flood plain sediments below the Storys Creek confluence would be desirable.

Department of Agriculture (1984b) results showed that concentrations of metals in plants taken from the "Fairfield", "Brambletye", "Henbury" and "Bonneys Plains" properties discussed above were found for several species to be significantly higher in areas of flooding than in areas never flooded.

The Department of Agriculture (1974) reported that at that time there was no evidence that meat or milk from animals grazing flooded pastures presented a human health hazard. There was some evidence that plants can take up unacceptable levels of cadmium from silt. It was observed that the quantities of cadmium in the silt (up to 150 ppm) may be compared with that in superphosphate (50 ppm), but the quantities of silt deposited are usually well in excess of normal superphosphate dressings.

A letter from the Director of Agriculture to the Director of Environmental Control dated 30 September 1986 stated that the Department of Agriculture had not analysed livestock for heavy metal contamination. A review of Veterinary Laboratory records revealed only one example of a suspected heavy metal poisoning in animals - a ram dying of copper poisoning, but suspected to be from copper pellets and not from silted pasture. The Senior Veterinary Pathologist for the Department of Agriculture (internal correspondence dated 14 August 1986) prepared a list of what he considered to be "at risk" properties. It was intended to retrospectively check records for those properties not already covered for any evidence of heavy metal problems in livestock, but this was not done. The Senior Veterinary Pathologist considered monitoring of livestock tissues from the properties of interest could be a useful exercise, but this has never been done.

6. EFFECTS ON AQUATIC BIOTA

Sampling conducted during 1970-71 (Tyler and Buckney 1973) found no trout in the South Esk between Storys Creek and Evandale.

Sampling conducted during 1972 (Thorp and Lake 1973) found that Crustacea, Mollusca and Annelida were most intolerant of mild cadmium-zinc pollution, and effects on populations were found as far downstream from Storys Creek as Evandale. Indirect effects on macroinvertebrates from heavy metals are caused by unstable physical conditions in the stream bed, due mainly to the elimination of algal and aquatic macrophytic growth. Increased grinding and scouring of the stream bed can cause injury and mortality. Another indirect effect is a reduction in the variety of live plant food. Species diversity and abundance dropped noticeably in winter particularly at polluted stations, probably caused by flooding; this was most marked at Avoca.

Sampling conducted during 1975-76 (Norris 1979) found that absolute numbers of animals and species in the South Esk were affected up to 80 km downstream of Storys Creek. 11 species which were numerically dominant at the uncontaminated sites were almost or completely absent at sites below the inflow of metals. Generally molluscs and crustaceans were found to be sensitive to metal contamination.

Norris *et al* (1982) found little agreement between acute lethal concentrations of metals determined in laboratory studies and concentrations found to produce harmful effects in the South Esk River. They found that multivariate statistical techniques were a sensitive means of detecting metal contamination by grouping those taxa which respond to pollution in different ways.

Norris and Lake (1984) looked at metal concentrations in fish caught in the South Esk River during low flow level, and determined concentrations of cadmium, zinc and copper. All species collected showed discontinuous distribution, varying according to their sensitivity to metal contamination. Tench, the least sensitive species collected (so still present in waters with high metal concentrations), showed evidence of bone deformation likely to be caused by metals. Considerable difference was found between fish species as regards metal concentrating ability. They found that copper and zinc contamination of a watercourse may not be reflected in concentrations of these metals in fish, but contamination of cadmium may be. The liver *consistently* had the highest concentrations of metals in all five fish species collected, followed by the gills and then muscle, consistent with expected trends.

Results of field work during December 1984 (HEC 1985) found that Storys Creek 1 km above its confluence with the South Esk River was completely depauperate of aquatic flora and fauna. The cobbles in the creek bed of Storys Creek were covered with an aqua-coloured gelatinous sediment up to 5 mm thick (this was identified as alumina hydroxide precipitate in the 1986 Mines Department report). The South Esk River below Storys Creek had an extremely low diversity and abundance of fauna as compared to the South Esk River above Storys Creek, and had no apparent aquatic vegetation.

HEC (1985) also found flora and fauna to be low in diversity and abundance at Buffalo Brook above its confluence with the South Esk. The Buffalo Brook catchment has also had a number of prospects and mining operations throughout its history. The South Esk flora and fauna below the confluence of Buffalo Brook were low in diversity and abundance similar to that found below the Storys Creek confluence. At Glen Esk on the South Esk River the fauna and flora had slightly recovered, although not to the levels found in the South Esk above Storys Creek. Ben Lomond Rivulet was included for comparison with Storys Creek and Buffalo Brook, and was found to have a healthy, abundant and diverse aquatic flora and fauna.

7. SUMMARY

As shown in Table 1, a wealth of historical data exists to provide information on the status and downstream effects of contaminants in the Rossarden/Storys Creek catchment area. However, the picture is still far from comprehensive.

The majority of the data collected relates to water quality. Side Creek, the Storeys Creek Mine precipitation dam, and the Eastern Hill adit are contributing to at times serious water quality problems in Storys Creek. Aberfoyle Creek is less contaminated but still frequently exceeds maximum recommended metal concentrations, particularly for cadmium. The relative contribution of remobilised sediments in the streambanks of both creeks to metal concentrations is unknown.

Once the creeks meet the South Esk River, metal concentrations are considerably lower but still often exceed ANZECC's guidelines for protection of aquatic ecosystems. Aquatic biota were shown to be adversely affected even when regulatory water quality standards given in the *Environment Protection (Water Pollution) Regulations 1974* were being met.

The information to be gained from the entirety of the water quality data is limited, because over the years different parties have collected and analysed the data, with variations in collection, analysis and reporting methods. Flow data have not always been reported, and flow data which do accompany metal concentration results may have been measured or may have been just estimated.

There are data on the geographical extent of siltation and the total acreage of unusable arable land in the South Esk River flood plain as of the late 1960s, but there are only very limited data on concentrations of metals in these sediments. Contamination of the sediments in the flood plains of the South Esk River, and implications of pastoral activities in these areas, has been of particular concern to relevant landowners. The data that are available show metals in sediments to be at levels which warrant further investigation, ideally with recently developed techniques which may provide more information on bioavailability of metals.

Very few studies looked at the uptake of cadmium and other metals by plants. There have been no analyses of livestock from the South Esk properties for heavy metal contamination.

Studies of downstream effects on the aquatic biota present some interesting findings, showing effects on total numbers and diversity of species as far downstream as Evandale. No comprehensive study of aquatic biota has been conducted in nearly 8 years, and so the effects of the 1986 dam breaches and continued leaching are undetermined.

This review has covered a considerable amount of existing data in a very brief manner. Interested parties are referred to the references listed in Attachment 1 for specific details.

8. REFERENCES

(other than those listed in Attachment 1)

ANZECC (1992) **Australian Water Quality Guidelines for Fresh and Marine Waters**. Australian and New Zealand Environment and Conservation Council, November 1992.

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ATTACHMENT 1

INFORMATION SOURCES ON ENVIRONMENTAL IMPACTS OF MINING AT ROSSARDEN AND STORYS CREEK

(in chronological order)

Sources of Raw Data

Department of Mines

According to the Mines Department Report R864, there has been some water sampling in the area since the mid-1950s but it was spasmodic until the late 1960s. Sampling became more organised after the 1970 Report on Water Pollution in Australia by the Senate Select Committee on Water Pollution. Data collected by the Mines Department in the early 1970s concentrated on the junction of Aberfoyle and Storys Creeks, and the samples were assayed for heavy metals without flow data. More detailed surveys involving measuring stream flows were conducted in the mid-1970s.

Numerous laboratory reports are held for water samples collected over the years by the Mines Department. Most of these results are included in the Rivers and Water Supply Commission (RWSC) database (below) or in various reports/reviews (next section). Also held by the Mines Department are results of assays of the Storys Creek precipitation dam and of tailings at both mines.

Department of Environment and Planning (DEP)

Numerous laboratory reports are held for water samples collected by the Department of Environment and Planning during the 1980s and as recently as August 1992. Most of these results are included in the RWSC database. The DEP also has records of self-monitoring data required by licence conditions for the two mines. The data were submitted monthly from May 1976 to March 1982. Condition 6 of the Storys Creek Licence No. 1673 required monthly monitoring of the settling pond overflow weir, referred to as "underground dewatering" on the monitoring reports. Condition 5 of the Rossarden Licence No. 1672 required monthly monitoring of the return water settling pond tower and the Level 4 adit discharge.

Department of Agriculture (now Department of Primary Industry)

Silt, soil and plant samples from several properties in the South Esk River flood plains below Storys Creek have been analysed over a period of years between 1968 and 1984. Some water quality data from the 1960s from Aberfoyle and Storys Creeks are available.

Rivers and Water Supply Commission (RWSC) Water Quality Database

RWSC database has a partial compilation of water quality data collected by the Mines Department and Department of Environment and Planning between 1975 and 1991.

There are limitations to use of this database, due to doubts about exact locations of sampling particularly near the Storeys Creek Mine, few results include flow rates, and confusion about the reporting of metal concentrations alternatively as "Filtrable" or "Total".

Government Reviews/Reports

Government reviews of data collected from Storys and Aberfoyle Creeks are as follows:

Department of Agriculture (1969) South Esk River - Pollution survey.

The seven properties with frontage to approximately 20 miles of the South Esk were surveyed for siltation. Acres affected were estimated. Toxic affects on pasture and production lands are discussed.

Department of Agriculture (1969) Alleged pollution - South Esk - Investigation into reasons for poor plant growth.

Results of analyses of silts and pot trials on silt samples taken from "Bonneys Plains" and "Henbury" during 1967-68.

Department of Agriculture (1974) Heavy metal pollution of grazing areas on the South Esk flood plain.

Analysis of soils, silts and plant material from flooded and unflooded land at "Brambletye" and "Bonneys Plains", collected during 1974. Results of trials of subclover plants grown in soil and silt samples from "Brambletye" are included.

Department of Agriculture (1984a) Chemical analysis of soils and silts taken from flood plains of the South Esk River (1968-1984).

Results of analysis of soil and silt samples collected during September and October 1969, May 1974 and October 1984.

Department of Agriculture (1984b) Chemical analysis of plants taken from flood plains of South Esk River (1969-1984).

Results of analyses of plant samples collected during September 1969, May 1974 and October 1984.

Mines Department (1985) "Storys Creek and Aberfoyle Creek Impact on the South Esk River" Department of Mines Reference No. 313/85, Memo to Director of Mines from Chief Chemist and Metallurgist, 7 January 1985.

Analysis of comprehensive water sampling conducted on 6 Dec 1984.

Mines Department (1986a) "R864: The Impact of Mining on the South Esk River", 29 January 1986 by H K Wellington, Chief Chemist and Metallurgist.

Sampling of water flows and concentrations conducted while the mines were operating (1976-80), while mines were filling (1982), and after mines were filled (1984-85). Some tests conducted on the materials in the Storeys Creek Mine precipitation dam collected during 1984-85.

Mines Department (1986b) "Oxidation of Mine Wastes". Unpublished technical report.

Results of leach tests on 1967 samples of Storeys Creek and Aberfoyle mine tailings are presented. Long-term leach tests were set up between 1974 and 1981 with Storeys Creek and Aberfoyle mine tailings, and comparisons made with samples taken from other mines around Tasmania.

Mines Department (1990a) "Water Monitoring on Aberfoyle Creek, Storys Creek, and the South Esk River", dated 27 June 1990.

Results of water samples collected during 1982, 1984, 1986-87, 1989 and 1990. Flow data included from 1986 onwards. Discussion of metal loads in creeks and comparison with DOE guidelines.

Mines Department (1990b) "Review of the Effect of Past Mining Activity on Storys Creek and Aberfoyle Creek"

Results of assays of water and alluvial sediment samples collected 3 July 1990. Material analysed from precipitation dam and compared with 1982 and 1984 samples.

HEC (1985) "Fingal Valley Aquatic Biota Survey", Consultants Report to the HEC, May 1985.

Preliminary field study conducted on 17-18 Dec 1984, comprising visual observations and qualitative collections of invertebrate fauna using dipnets at 10 locations along the South Esk River, from East of Fingal to Western Junction.

Non-Government Reviews/Publications

Non-governmental reviews and published literature including data from Storys and Aberfoyle Creeks are as follows:

South Esk Pollution Committee (1970) "Pollution of the South Esk River Resulting from Mining Operations on Storys and Aberfoyle Creeks". 7 September 1970.

Summary of activities undertaken by the South Esk Pollution Committee as well as records at their disposal, including partial details of pre-1970 sampling, monitoring and investigations. Investigations of the Senate Select Committee on Water Pollution 1969 are described. Analyses of water and soil samples collected 16 July 1969 were performed by the Mines Department (water) and the Government Analyst and CSIRO (soils), with the results attached as appendices to this report. Also included as an appendix is an October 1969 Department of Agriculture report, with results of silt surveys along the South Esk River floodplains as well as pot trials of affects of contaminated silts on growth of particular crop species.

Tyler P A and Buckney R T (1973) Pollution of a Tasmanian River by mine effluents. I. Chemical evidence. ***Int. Revue Gesamten. Hydrobiol.*** *58: 873-883.*

Water samples were collected from 39 sampling points during May and Oct 1970 and Jan 1971, including comprehensive sampling of both Aberfoyle and Storys Creeks, and the South Esk from Mathinna to Evandale including confluences with Castle Carey Creek, St Pauls River, Buffalo Brook and Ben Lomond Rivulet. Some silt samples were taken near Storys Creek/South Esk confluence.

Thorp V J and Lake P S (1973) Pollution of a Tasmanian River by mine effluents. II. Distribution of macroinvertebrates. ***Int. Revue Gesamten. Hydrobiol.*** *58: 885-892.*

Water samples were collected and macroinvertebrates surveyed during Feb and Aug 1972 from the South Esk River at Fingal, below Storys Creek confluence, at Avoca just above St Pauls River confluence, at Glen Esk just above Ben Lomond Rivulet confluence and at Evandale, and from the St Pauls River just before its confluence with the South Esk.

Norris R H (1979) The ecological effects of mining effluents on the South Esk River (northeast Tasmania). PhD thesis, Department of Zoology, University of Tasmania.

Data were obtained from bimonthly samples over two years (1975-76) over a 130 km section of the South Esk River - 3 sites above Storys Creek confluence, 5 sites below, and 3 supplementary sites including Storys Creek before it meets the South Esk. Norris measured basic water characteristics; metal concentrations (manganese, iron, cadmium, zinc, copper and lead) in the sediments, in NFR and in solution; and quantitatively sampled benthic macroinvertebrate fauna.

Norris R H, Lake P S and Swain R (1980) Ecological effects of mine effluents on the South Esk River, northeastern Tasmania. I. Study area and basic water characteristics. ***Aust. J. Mar. Freshwater Res.*** *31: 817-827.*

Norris R H, Swain R and Lake P S (1981) Ecological effects of mine effluents on the South Esk River, northeastern Tasmania. II. Trace metals. ***Aust. J. Mar. Freshwater Res.*** *32: 165-173.*

Norris R H, Lake P S and Swain R (1982) Ecological effects of mine effluents on the South Esk River, northeastern Tasmania. III. Benthic macroinvertebrates. ***Aust. J. Mar. Freshwater Res.*** *33: 789-809.*

The three articles in this series present analyses of samples collected at 11 sampling sites during 1975-76, as already described under Norris (1979).

Norris R H and Lake P S (1984) Trace metal concentrations in fish from the South Esk River, northeastern Tasmania, Australia. ***Bull. Environ. Contam. Toxicol.*** *33: 348-354.*

Samples were collected from 10 sites in the South Esk Rvier in January 1976, when the river was at a low flow level. A total of 178 fish belonging to 5 species were collected. The usefulness of fish as indicators of environmental contamination is discussed.

Morrison K C (1992) Trace element geochemistry of Tasmanian stream waters. Master of Economic Geology Thesis, Geology Department (Centre for Ore Deposit and Exploration Studies), University of Tasmania.

10 water samples were collected below the confluence of Aberfoyle and Storys Creeks on an opportunity basis (approximately monthly) between December 1990 and August 1991 under a range of flow conditions. These samples were analysed for 64 elements using Inductively Coupled Plasma Mass Spectrometry (ICPMS). Data on water depth, flow and organic carbon were also obtained.

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Other Useful Information

Blissett A H (1959) The Geology of the Rossarden-Storeys Creek District. Geological Survey Bulletin No. 46, Department of Mines, Tasmania.

Blissett (1959) informs us about the history of mining exploration and development of the Rossarden-Storys Creek area, as well as the general and economic geology. Mines and prospects in the area are discussed and their locations identified (see Map 3).

Aberfoyle Tin N.L. (1976) Revegetation of Tailings Settling Ponds at Rossarden (Preliminary Report). 3 September 1976.

Description of work carried out by the Department of Agriculture and the Forestry Commission in conjunction with Aberfoyle Tin N.L. to revegetate the slimes dams at Rossarden.