Government of South Australia
Primary Industries and Resources SA

WATER MONITORING REPORT FOR THE BRUKUNGA MINE SITE FOR 2006

EPA site Licence No. 10577

Biological monitoring reports prepared by staff of the Australian Water Quality Centre

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Mine Regulation & Rehabilitation Branch
Minerals and Energy Resources Division
Department of Primary Industries and Resources SA

Water Monitoring Report for the Brukunga Mine Site for 2006

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WATER MONITORING REPORT FOR THE BRUKUNGA MINE SITE FOR 2006

Abstract

The Brukunga pyrites mine operated as an open pit mine from 1955 to 1972 to recover sulphur from iron sulphide minerals. The concentrated ore was converted to sulphuric acid, and subsequently used in the manufacture of superphosphate fertiliser. The pyrite and pyrrhotite minerals that remain on site naturally oxidise in air to form acid and the resultant Acid-Rock-Drainage (ARD) subsequently dissolves other minerals creating heavy metal pollution in the local watercourse.

The land is freehold title to the Crown and has been managed by the Department of Primary Industries and Resources - Minerals and Energy Resources Division since 1998.

The key work undertaken on site is the interception of acid seepage and the treatment of the acid with lime to prevent acid and metals from entering and polluting the local watercourse. The acid water is neutralised in a plant to remove the soluble heavy metals before the cleaned water is released back to Dawesley Creek. The water-monitoring program undertaken in accordance with conditions of the Environment Protection Agency site licence No.10577 provides a measure of the success of the interception and treatment program.

In 2003 a major improvement in water quality in the creek downstream of the mine site was achieved primarily due to the construction of a 1.7 km creek diversion drain. In 2005 upgrading of the lime treatment plant was completed, effectively doubling its capacity. The continuing improvements achieved in water quality since these two capital initiatives are evident in the water monitoring results obtained for calendar year 2006, which are presented in this report.

1 SUMMARY

The Dawesley Creek which flows north to south through the Brukunga mine site was contaminated by sulphuric acid and soluble heavy metals, shortly after mining commenced in 1955, as the acid drained from the waste rock dumps into the watercourse. In 1972 the mine closed and the sulphide minerals exposed in the rock freshly broken by mining, continued to oxidise to produce acid drainage. After a plea from the company for assistance the government accepted responsibility for the site in August 1977. Government research indicated that a lime neutralisation plant was the best approach to address the problem and a treatment plant was duly commissioned in September 1980. SA Water Corporation was the operator of the plant until it was transferred to PIRSA in January 1998.

Acid drainage from the site is collected from three main sources;

- Seepage from 8M-tonnes of waste rock, in two main dumps,
- Seepage from the toe of the 3.5M-tonne tailings dam; and to a lesser extent
- Seepage from in-situ minerals exposed in the quarry floor.

Fig 1. Collecting acid seepage at the toe of the southern waste rock dump.

Fig 2. Acid seepage collected at the toe of the wall of the tailings storage facility.

During the period that the lime treatment plant operated from 1980 to 2003, the interception system was partially successful and captured only half the pollution from the site. The seepage that escaped to the creek polluted the water up to 22 km downstream of the mine site, making the water unsuitable for livestock or irrigation use.

In 1998 the ‘Brukunga Taskforce’ and later the ‘Brukunga Mine Site Remediation Board’ were established to examine the pollution problems and to develop strategies for their remediation. A number of engineering options were developed and several were presented to, and subsequently supported by the Premier and cabinet in 2000 resulting in approval for substantial new capital initiatives.

A major improvement occurred in the quality of creek water in June 2003 when a $M1.9 diversion drain was completed which took the flow of the creek past the mine site, separating it from the main source of pollution. The 1.7 km drain produced an immediate improvement in the quality of water downstream of the mine and the continuing improvements are clearly evident in the water monitoring results presented for 2006 in this report.

Fig 3. Open section of the diversion drain carrying Dawesley Creek flow past the mine

In May 2005 the second significant improvement was completed with a $M0.8 upgrade to the acid treatment plant, which added a parallel stream of mixing tanks effectively doubling the plant’s peak capacity that enabled most of the pollution surges in winter to be processed. The results of this improvement began to have an influence in the latter part of 2005 and are reflected in the monitoring results of 2006.

Fig 4. New mixing tanks installed next to the original tanks, doubling the plant’s peak treatment capacity.

The scope of the water-monitoring program was established by negotiation between the EPA and SA Water Corporation in August 1996. The water monitoring requirements are described in condition 1 of the EPA site licence for Brukunga, number 10577.

Significant improvements achieved in the water quality in Dawesley Creek are now clearly evident in the water monitoring results recorded for calendar years 2004 to 2006, i.e. post-construction of the diversion drain, as compared with results for the years prior to the drain. Soluble metal and sulphate levels in the watercourse downstream of the mine site are now generally at levels, as recommended by ANZECC/ ARMCANZ[1], suitable for livestock and irrigation use, for the majority of the time.

2 BACKGROUND

Historic mining at Brukunga from 1955 to 1972 produced 5.5 million tonnes of iron sulphide ore as a source of sulphur for the manufacture of sulphuric acid. The acid was used to convert phosphate ores into superphosphate fertiliser, crucial to the success of agriculture in SA. Mining ceased in May 1972 on the withdrawal of the Commonwealth production subsidy and no mining has occurred on the site for past 34 years.

Quarrying of the hillside produced approximately 8 million tonnes of broken waste-rock, and ore processing produced 3.5 million tonnes of sand tailings. Both the rock dumps and sand-tailings dam contain randomly distributed low-grade sulphide mineralisation, which continues to oxidise and form leachate.

Mining activity exponentially increased the surface area of the exposed sulphide minerals and the natural oxidisation process produces acid seepage at a rate greatly elevated above natural background rates. A scientific study undertaken by ANSTO[2] in 1993 for PIRSA indicated that the accelerated rate of oxidation is likely to continue as a long-term problem producing at elevated rates for in excess of 240 years.

Pollution control at Brukunga is exacerbated by the flow of Dawesley Creek, passing through the site, and the creek's close proximity to the toe of the waste rock dumps. Acid conditions enable the breakdown of other minerals, which are released creating high levels of soluble heavy metals, e.g. iron and aluminium in the watercourse. The acid seepage escapes into the creek and from there it is carried from the site.

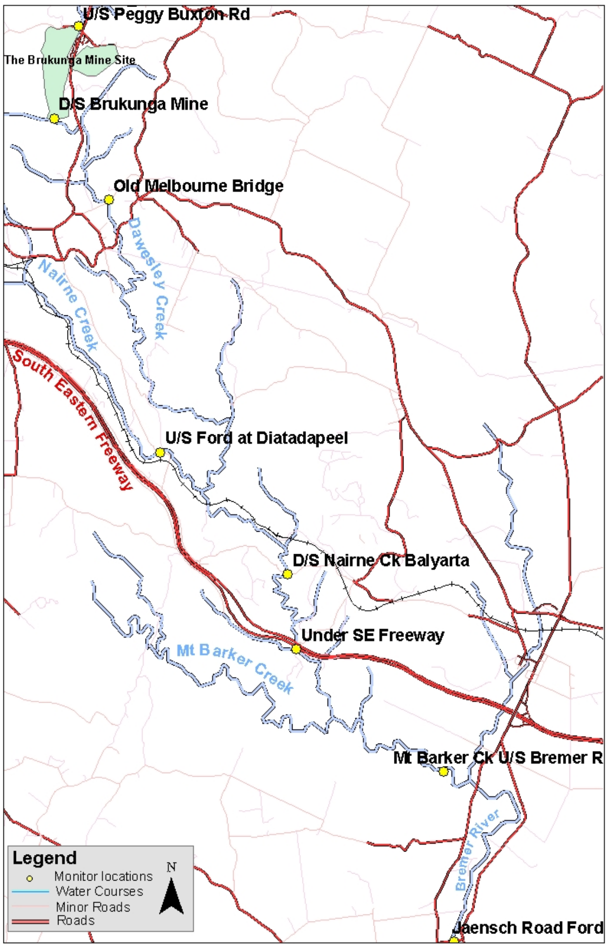

Fig 5. Dawesley Creek flow to the Bremer River and location of monitoring stations.

[1] ANZECC/ARMCANZ, Australian and New Zealand Environment and Conservation Council, and Agriculture and Resource Management Council of Australia and New Zealand

[2] ANSTO, Australian Nuclear Scientific and Technical Organisation.

The first objective of the Brukunga Board was to restore the water quality in Dawesley Creek downstream of the mine site, to a level that would be suitable for livestock and irrigation use. PIRSA's activities at Brukunga are oriented to intercepting the acid drainage and treating it to neutralise and remove the heavy metals before returning the water to the creek. Considerable work also has been and is continuing to be done towards landscaping the site by progressively planting areas with native vegetation.

The intercepted acid water is treated in an active lime neutralisation plant, which was established on the site in September 1980. Operation of the plant over the initial 25 years had made significant improvement however, despite best efforts until July 2003 the interception program was only able to capture approximately half of the acid seepage generated. The remnant seepage evaded capture and then contaminated the Dawesley watercourse to such an extent that the water downstream of the mine site was not suitable for livestock use.

In June 2003 PIRSA completed the construction of a $1.9 Million large diameter 1.7 km diversion drain. The drain diverts the regular flow of Dawesley Creek past the mine site enabling the remnant acid seepage to be isolated in a section of the creek and collected at a small downstream weir. Diversion of the creek resulted in an immediate and significantly noticeable improvement in water quality in the watercourse and those results are reflected in the values presented in this report.

In addition to the construction of the drain the decision was taken to double the peak treatment capacity of the acid treatment plant so that additional pollution generated during the wet winter period could also be neutralised.

A second series of three mixing tanks were installed in June 2005. The upgrade of the plant enabled additional pollution to be treated and reduced the duration and volume of any overflow that may occur during persistent storm events.

3 THE WATER MONITORING PROGRAM

The water-monitoring program consists of three independent strategies that bring a focus on determining the condition on the watercourse.

The three strategies as described in licence condition No.1 are:

1. *Determines the annual and seasonal loads of heavy metals entering Dawesley Creek from the Premises by measuring the stream flow and their concentration upstream and downstream of the Premises;*

2. *Determines the extent of impact of the Premises (the zone of impact) on Dawesley Creek and the Bremer River by undertaking a biological (macro invertebrates) monitoring program at three-monthly intervals; and*

3. *Determines the temporal and spatial variations of pH and heavy metal concentrations within the zone of impact by undertaking a monthly sampling program at a selection of fixed sites within the zone for the purpose of assessing compliance with the water quality guidelines for the protection of the aquatic ecosystem pursuant to the ANZECC Fresh and Marine Water Guidelines.*

The tabulated results and graphic representation for each monitoring strategy is presented as three separate appendixes A, B, and C to this report and a discussion of the results are presented in Section 8 of this report.

4. HYDROLOGY AT BRUKUNGA

Flow in Dawesley Creek is described as intermittent, with small steady flows through most of the year, elevated and flushed during storm events particularly in winter, and in most years in late summer the creek dries to periods of no-flow. High evaporation and low flow in summer concentrates the contaminants with higher levels recorded. In winter with more consistent rain and significant surface run-off the extra water dilutes the contaminant levels lowering recorded concentrations.

Short-lived storm events overflow the diversion drain's capacity resulting in short-term flushes through the old creek, i.e. for a few hours or a few days. The capacity of the diversion drain was selected at a 1 in 1 year average overflow of the system. Any overflow at the upstream weir mixes with polluted water in the isolated section of creek and if the rate of inflow exceed the capacity of the two pumps transferring pollution from the creek to the holding ponds, then a pollution overflow downstream of the mine will occur, in a greatly diluted form.

The variable seasonal effects on; flow rate, temperature and nutrient levels, exerts significant influence on the rates of growth or decline and the distribution of macro-invertebrate communities, and can result in significant natural variations in community health, from year to year and season to season, and hence observed variations cannot necessarily be directly attributed to pollution from the mine site.

Water samples collected for both load and temporal monitoring programs are analysed by the Australian Water Quality Centre, a business unit of the South Australian Water Corporation and a NATA accredited organisation, Corporate accreditation number 1115 for chemical and biological testing.

Biological monitoring is undertaken by employees of the South Australian Water Corporation, a NATA accredited organisation, Corporate accreditation number 1115 for chemical and biological testing.

Flow monitoring and data logging and continuous water sample collection is undertaken by Water Data Services Pty Ltd, a South Australian consultancy based in Adelaide, with NATA certification number 7642-2 (AS/NZS ISO 9001:2000) for: *"Design, construction and installation of water quantity and quality monitoring stations. Provision of environmental and natural resources information services including monitoring of water quality and quantity, data analysis and presentation, monitoring of meteorological sites and data analysis and hydrological studies."*

5 ANNUAL AND SEASONAL CONTAMINANT LOADS

The annual and seasonal contaminant loads are determined for an agreed suite of chemical contaminants as they leave the mine site in the waters of Dawesley Creek.

The volume of flow in Dawesley Creek is determined as it passes over concrete flat v weirs established in the creek immediately upstream and downstream of the mine site.

Fig 6. Upstream flat v weir located in Dawesley Creek, for monitoring water flow.

Fig 7. Downstream v weir monitors the volume of water leaving the site.

Flow data logged at the two hydrometric stations enables a water balance for the mine site to be calculated.

The hydrometric stations at Brukunga were established in 1993 by the Department of Engineering & Water Supply (E&WS) as part of a system of automatic logging stations to record creek flows in the Adelaide Hills. In 1998 automatic water sampling facilities were installed at Brukunga and chemical analysis commenced on 3rd February 1998.

The sampling pumps activate automatically at intervals proportional to the flow-rate of the stream. The samples are deposited in a bucket to form a representative composite mix and a sample is sent for analysis approximately every two weeks, when the buckets are emptied and reset.

Fig 8. Automatic flow data recording and composite water sample collection equipment located in the monitoring huts.

The monitoring equipment is supplied and maintained by contractors *Water Data Services Pty Ltd* (WDS) who provide a full field service sending water samples to the *Australian Water Quality Centre* (AWQC) laboratories for analysis.

The assay results and flow volumes for each two-week period are tabulated and the product of the two values is the load in kilograms of the particular pollutant that leaves the mine site in the water of Dawesley Creek. The flow and assay data is also entered by WDS direct to the Department of Environment *'HYDSYS'* water data archive.

6 EXTENT OF IMPACT BIOLOGICAL MONITORING

Biological monitoring, collecting and identification of macro-invertebrate species living in the watercourse is undertaken by biologists from the *Australian Water Quality Centre* (AWQC) on a quarterly basis during the months of March, June, September and December of each year.

Fig 9. A biologist netting a sample of macro-invertebrates at Peggy Buxton Rd

Biological monitoring in the Dawesley Creek – Bremer River system commenced in September 1996 with the selection of six monitoring sites. Monitoring of riffle zones commenced in 2006. The relative health of the streams influenced by acid drainage can be compared with observations obtained at the two control sites that are not impacted by acid drainage from the mine site, i.e. in Dawesley Creek immediately upstream of the mine site, and in Nairne Creek before it enters Dawesley Creek.

At each monitoring location, AWQC biologists use a 250 µm mesh net to sweep a 10 metre section of the creek using the standard edge habitat method to collect macro-invertebrates in accordance with the standard Monitoring River Health (MRH) technique. The number of different macro-invertebrate animal species is identified and the populations are counted in the laboratory to provide a comparative measure for estimating the relative health of the stream.

7 TEMPORAL AND SPATIAL WATER VARIATION MONITORING

Water samples are taken monthly at eight separate locations, one upstream of the mine site and one in Nairne Creek as control sites. There are four in Dawesley Creek below the mine and Mt Barker Creek and Bremer River. A plan showing the location of the eight sampling stations is presented in Fig 5, page 6. The grab samples are taken at near mid-month for each year.

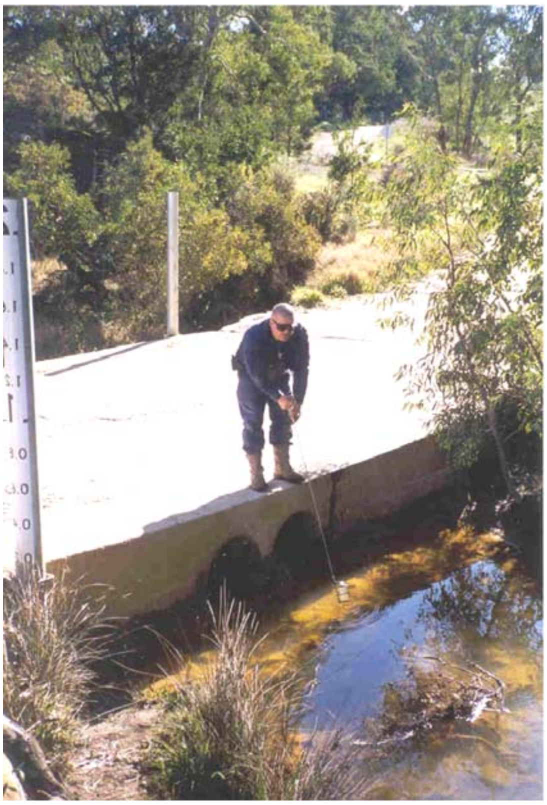

Fig 10. Grab sampling of creek water for chemical analysis at Melbourne Bridge.

The water samples collected are forwarded to *Australian Water Quality Centre* (AWQC) for chemical analysis for a suite of nine metals, i.e. aluminium, cadmium, chromium, copper, iron, lead, manganese, nickel and zinc and for sulphate, pH, conductivity in µS/cm and Total Dissolved Solids by EC. The acidity of samples as $CaCO_3$ to a pH 9.5 was added to the suite of items from August 2003 for four locations, to provide additional information.

All assay values reported are total samples, i.e. the samples are unfiltered and include values from dissolved metals and from particles in the water. The results are tabulated and when reported values exceeding ANZECC Water Quality Guideline recommenced guidelines for livestock, irrigation and ecosystems are colour coded to provide an enhanced visual recognition of occurring trends. Some graphic representation of data is also presented.

8 DISCUSSION OF MONITORING RESULTS

The 2006 water monitoring results for all three monitoring strategies (as described on page 6), continue to show pleasing signs that indicate significant improvements in the quality of water leaving the mine site.

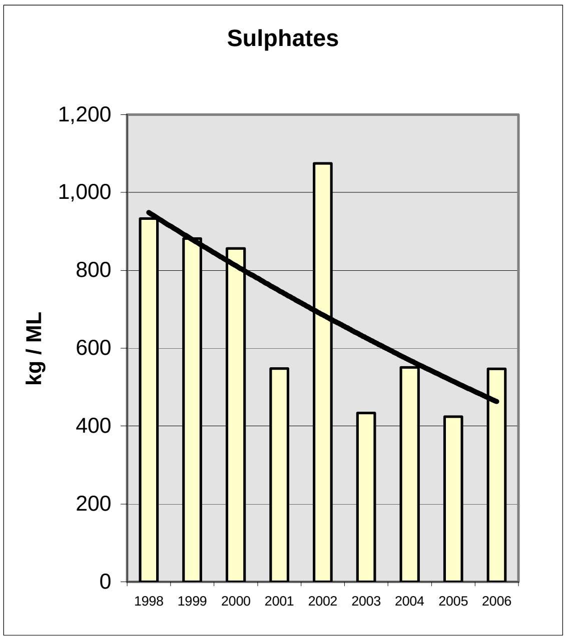

Fig 11. Graph of annual sulphate load leaving the mine site in Dawesley Creek.

Data for 2004 to 2006 represents post installation of the diversion drain in Dawesley Creek at Brukunga and the results obtained confirm that the key goal to reduce pollution is being achieved following the implementation of this engineering solution to more effectively isolate the source of pollution.

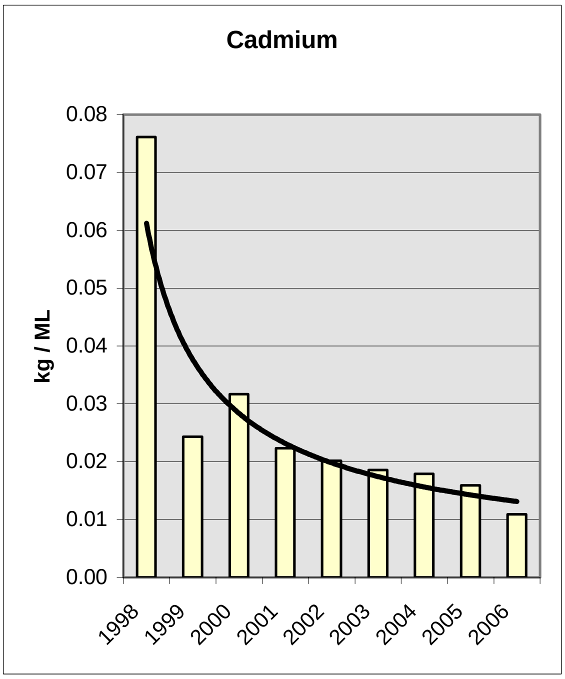

Fig 12. Graph of annual cadmium load in kg/ML of water leaving the mine site

The ‘annual metal load’ monitoring strategy provides good evidence of the decreasing load of pollutant in water leaving the mine site. The pollutants loads are calculated for each year however large variations in flow, due to drought (as in 2006) and flood make direct trend comparisons very difficult. To provide a comparison between years, the results have been normalised by dividing by the annual volume of water. The load graphs for sulphates and cadmium (fig 11 & 12 for example) show the trend of net annual load of pollutant reducing over the past nine years.
The graphs are for normalised values in kilograms per megalitre of water and the trend lines are a second order polynomial (Fig 11) and power curve fit (Fig 12).

The biological monitoring strategy results also provide indications that significant improvements in water quality have recently occurred. This improvement is demonstrated in the graph of 'Mean-taxon-richness from 1996 to 2006' for quarterly biological monitoring of macro-invertebrates. To provide a comparison, the data was separated and plotted into two averages for each of the six monitoring sites, one average for data collected prior to construction of the diversion drain (1996-2002 'red') and the other for data collected post construction (2003-2006'blue').

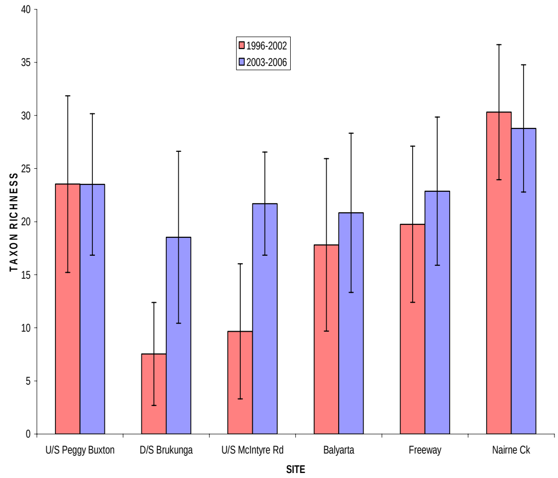

Fig 13. Species richness average value pre and post the diversion drain for locations along the watercourse. Error bars show two standard deviations.

Since March 2003, all sites on Dawesley Creek that are influenced by acid drainage from the mine site have on average supported more macro-invertebrate taxa. The monitoring strategy includes two sites as a control, i.e. two sites not influenced by acid drainage from the mine site, the Peggy Buxton Road site immediately above the mine, and the Nairne Creek site that flows into Dawesley Creek.

The monthly grab sampling strategy records the level of concentrations and spatial variations as the water moves downstream. The levels of a suite of metals are recorded on a spreadsheet for each monitoring location.

PIRSA - Office of Minerals, Petroleum and Energy
BRUKUNGA MINE SITE, CHEMICAL ANALYSIS OF MONTHLY WATER GRAB SAMPLES
Dawesley Creek water - downstream of the Brukunga Mine Site Grab Sampling Location AWQC 3158

DATE	pH units	TDS by EC total mg/l	CONDUCTIVITY uS/cm	SULPHATE total mg/l	ALUMINIUM total mg/l	CADMIUM total mg/l	CHROMIUM total mg/l	COPPER total mg/l	IRON total mg/l	LEAD total mg/l	MANGANESE total mg/l	NICKEL total mg/l	ZINC total mg/l
11-Feb-1998	2.9	3,000	5,370	3,240	323.0	0.200	0.022	0.162	37.70	0.0004	33.20	1.24	18.30
10-Mar-1998	3.1	1,900	3,410	1,170	82.4	0.024	0.006	0.035	12.40	0.0004	9.96	0.496	5.58
15-May-1998	3.0	2,700	4,790	2,700	232.0	0.092	0.025	0.131	41.40	0.0004	16.60	0.772	13.10
10-Jun-1998	4.1	1,700	3,040	1,140	88.9	0.055	0.013	0.058	28.20	0.0004	7.52	0.482	6.52
17-Jul-1998	4.2	1,800	3,180	1,580	116.0	0.131	0.019	0.150	56.40	0.0004	12.70	0.428	6.68
17-Sep-1998	4.2	1,600	2,870	990	31.5	0.029	<0.005	0.041	8.50	<0.001	4.82	0.195	3.27
16-Oct-1998	3.4	1,700	3,020	1,260	32.1	0.031	0.015	0.041	10.70	<0.001	8.47	0.27	4.04
20-Nov-1998	4.7	1,000	1,900	566	44.9	0.016	<0.005	<0.005	4.91	<0.001	1.98	0.122	1.46
9-Dec-1998	3.5	2,000	3,600	1,960	52.0	0.023	<0.030	0.249	4.63	<0.001	6.36	0.323	4.93
15-Jan-1999	5.3	1,600	2,830	3,740	186.0	0.045	<0.030	0.274	56.60	<0.001	44.30	0.955	15.30
17-Feb-1999		No Flow											
17-Mar-1999	3.1	3,100	5,540	3,890	356.0	0.082	<0.030	0.130	31.10	<0.001	29.70	1.24	18.00
23-Apr-1999	3.1	2,900	5,110	3,580	286.0	0.110	<0.030	0.144	18.40	<0.001	32.70	1.13	18.10
13-May-1999	3.0	2,800	4,950	3,700	316.0	0.059	<0.030	0.088	42.60	<0.001	27.70	1.17	19.20
7-Jun-1999	4.3	1,600	2,920	1,270	39.6	0.032	<0.030	0.042	10.20	<0.001	4.29	0.255	3.91
16-Jul-1999	4.1	1,500	2,760	1,350	61.6	0.046	<0.030	0.031	13.60	<0.001	4.66	0.283	4.45
13-Aug-1999	4.4	1,200	2,130	899	35.0	0.035	<0.030	<0.030	10.50	<0.001	4.31	0.255	3.29
8-Sep-1999	4.4	1,200	2,090	767	20.0	0.020	<0.030	<0.030	11.60	<0.001	4.84	0.239	2.47
15-Oct-1999	4.0	1,900	3,400	938	31.4	0.008	<0.030	<0.030	8.94	<0.001	4.01	0.144	2.83
12-Nov-1999	4.0	1,300	2,360	968	36.2	0.019	<0.030	<0.030	8.35	<0.001	3.33	0.052	2.75
6-Dec-1999	3.7	1,100	1,910	718	29.3	0.019	<0.030	<0.030	8.87	<0.001	3.82	0.203	2.72
14-Jan-2000	3.2	2,600	4,690	3,270	247.0	0.031	1.520	3.500	21.20	<0.001	26.70	0.839	14.30
3-Feb-2000	3.3	2,600	4,640	4,000	208.0	0.040	0.052	0.258	21.80	<0.001	18.90	0.744	11.80
6-Mar-2000	2.9	2,300	4,210	2,650	156.0	0.063	<0.030	0.086	47.10	<0.001	21.90	0.746	12.10
3-Apr-2000	3.6	1,800	3,220	2,100	179.0	0.091	0.055	0.366	46.20	<0.001	14.40	0.703	13.80
12-May-2000	3.6	1,400	2,590	1,050	63.6	0.049	<0.030	<0.030	20.80	<0.001	7.63	0.418	5.12
14-Jun-2000	3.6	1,900	3,400	2,000	170.0	0.066	0.070	0.305	57.30	<0.001	15.10	0.531	9.28
7-Jul-2000	3.3	1,900	3,420	1,590	107.0	0.062	0.135	0.517	36.50	<0.002	10.90	0.496	6.84
11-Aug-2000	4.7	1,200	2,100	475	13.2	0.015	<0.030	<0.030	7.02	<0.001	2.66	0.12	1.66
13-Sep-2000	4.0	1,100	1,920	647	41.5	0.045	<0.030	0.067	14.20	<0.001	3.61	0.179	3.24
2-Oct-2000	3.6	1,700	3,080	1,150	97.9	0.054	<0.030	0.049	4.95	<0.001	3.91	0.458	4.27
10-Nov-2000	3.4	1,700	3,020	1,210	58.8	0.034	<0.030	0.036	4.79	0.002	5.91	0.0873	4.45
6-Dec-2000	3.5	1,500	2,660	961	55.3	0.019	<0.003	0.013	3.84	0.0007	6.35	0.0931	3.98
12-Jan-2001	2.8	2,900	5,220	4,070	397.0	0.066	0.005	0.019	23.40	0.007	31.50	0.12	19.60
5-Feb-2001	2.8	4,200	7,380	7,730	698.0	0.108	0.012	0.013	41.60	0.0016	73.30	0.127	38.90
13-Mar-2001	2.8	5,000	8,760	8,870	943.0	0.207	<0.030	0.083	48.00	0.008	80.80	0.678	49.40
6-Apr-2001	2.9	2,600	4,580	2,770	209.0	0.025	0.008	0.030	25.80	0.0016	31.30	0.118	10.70
7-May-2001	3.0	2,700	4,820	3,470	249.0	0.030	0.008	0.013	16.30	0.0033	22.40	0.0914	12.60
13-Jun-2001	3.4	1,300	2,340	1,060	60.3	0.070	<0.003	0.042	16.20	0.001	5.03	0.0851	5.18
2-Jul-2001	3.8	1,100	2,080	963	54.6	0.008	<0.003	0.015	22.10	0.0007	3.82	0.0628	3.65
8-Aug-2001	4.3	960	1,740	438	23.6	0.013	<0.003	0.026	9.40	0.002	1.98	0.0628	2.02
12-Sep-2001	4.4	610	1,100	218	13.2	0.010	0.003	0.028	5.57	0.0013	0.83	0.04	1.03
9-Oct-2001	6.3	1,100	2,050	318	5.3	0.005	<0.003	0.010	3.55	<0.0005	1.16	0.053	0.83
10-Nov-2001	4.0	1,200	2,160	530	17.4	0.013	<0.003	0.018	5.11	<0.0005	2.92	0.129	1.94
5-Dec-2001	4.4	1,100	1,960	487	14.8	0.006	<0.003	0.011	6.87	<0.0005	2.72	0.0657	2.00
15-Jan-2002	3.4	1,700	3,050	1,420	112.0	0.036	0.004	0.061	5.34	0.0008	10.20	0.371	5.52
13-Feb-2002	3.6	1,700	3,010	1,050	29.8	0.016	<0.003	0.025	3.59	0.0006	4.58	0.233	3.72
13-Mar-2002	3.2	2,500	4,450	2,440	208.0	0.030	0.014	0.058	15.70	0.0012	16.80	0.538	10.10
16-Apr-2002	3.4	1,700	3,050	1,250	69.3	0.011	<0.003	0.026	3.00	0.0006	9.72	0.416	5.04
14-May-2002		No Flow											
12-Jun-2002	4.4	1,300	2,270	602	13.1	0.012	<0.003	0.018	6.89	0.0005	2.96	0.14	2.00
16-Jul-2002	4.2	1,200	2,210	840	33.3	0.018	0.005	0.025	9.08	<0.0005	3.40	0.148	2.54
13-Aug-2002	4.4	1,100	2,080	730	26.8	0.007	<0.003	0.009	9.79	<0.0005	3.63	0.0562	1.69
11-Sep-2002	4.5	1,000	1,890	545	29.0	0.016	<0.003	0.022	18.20	0.0012	3.30	0.1589	2.25
15-Oct-2002	4.3	1,600	2,960	1,137	32.0	0.004	<0.003	0.006	14.30	0.0005	5.29	0.0491	2.73
12-Nov-2002	3.8	1,300	2,280	817	27.5	0.009	<0.003	0.015	2.31	<0.0005	4.70	0.1766	2.87
12-Dec-2002	3.4	1,500	2,700	1,120	56.9	0.012	<0.003	0.016	9.87	0.0007	6.40	0.2507	3.80
14-Jan-2003	3.7	3,400	6,000	4,020	336.0	0.030	<0.003	0.024	5.95	0.0011	24.70	0.0602	12.90
03-Feb-2003		No Flow											
10-Mar-2003	3.6	3,700	6,590	2,550	406.0	0.116	<0.003	0.215	9.40	0.0023	51.60	1.227	27.90
1-Apr-2003	3.4	3500	6200	4,006	294.0	0.060	0.011	0.095	11.1	0.0020	30.2	0.0681	22.6
5-May-2003	3.3	2,900	5,180	3,738	216.0	0.041	0.006	0.087	4.81	0.0021	28.90	0.5142	13.03
12-Jun-2003	5.6	1,400	2,440	887	4.8	0.010	<0.003	0.012	7.10	<0.0005	8.17	0.0796	1.02
22-Jul-2003	6.5	1,400	2,550	941	27.1	0.007	<0.003	0.007	15.60	0.0013	1.95	0.0238	1.23
19-Aug-2003	5.2	1,400	2,450	772	17.1	0.018	<0.003	0.029	4.53	0.001	1.47	0.0365	1.16
10-Sep-2003	5.2	1,400	2,560	756	18.5	0.015	<0.003	0.032	4.37	0.0008	2.65	0.1037	1.39
21-Oct-2003	5.6	1,600	2,800	928	9.0	0.017	<0.003	0.023	3.48	0.0006	3.58	0.072	1.22
11-Nov-2003	6.7	1,500	2,760	1,014	4.2	0.007	<0.003	0.007	2.48	<0.0005	4.67	0.0427	0.40
10-Dec-2003	7	1,100	1,920	348	2.3	0.004	0.003	0.006	2.11	<0.0005	0.84	0.0319	0.12
20-Jan-2004	7	1100	2,040	277	1.2	0.002	<0.003	0.005	1.34	<0.0005	0.56	0.0327	0.13
17-Feb-2004	6.9	1300	2310	423	1.0	0.003	<0.003	0.005	2.06	<0.0005	1.20	0.0462	0.31
10-Mar-2004	6.3	1800	3,230	774	1.2	0.002	<0.003	0.002	1.12	<0.0005	1.05	0.0288	0.15
15-Apr-2004	7.2	1300	2,360	564	1.2	0.002	<0.003	0.003	0.97	<0.0005	0.70	0.024	0.11
19-May-2004	6.2	2000	3550	1930	2.3	0.005	0.006	0.003	2.54	<0.0005	1.83	0.0352	0.73
18-Jun-2004	4	1300	2430	1710	129.0	0.016	0.008	0.090	7.19	0.0022	8.63	0.3819	9.82
14-Jul-2004	7	1300	2280	806	2.5	0.003	<0.003	0.008	1.30	<0.0005	1.24	0.0415	0.21
19-Aug-2004	6.4	1300	2350	662	3.3	0.008	<0.003	0.011	1.96	<0.0005	3.57	0.0388	0.71
15-Sep-2004	7	1300	2330	574	5.2	0.004	<0.003	<0.001	2.01	<0.0005	0.86	0.0269	0.28
19-Oct-2004	6.8	1600	2910	956	2.9	0.008	<0.003	0.010	1.60	<0.0005	2.92	0.045	0.57
9-Nov-2004	7.4	1200	2160	535	1.3	0.002	0.004	0.007	0.68	<0.0005	1.60	0.0223	0.10
15-Dec-2004	7.3	960	1740	217	0.6	0.001	<0.003	0.006	0.49	<0.0005	0.49	0.0293	0.04
12-Jan-2005		no flow											
11-Feb-2005	7.2	1400	2440	692	1.5	0.002	<0.003	0.005	11.00	0.001	8.77	0.0298	0.19
22-Mar-2005	7.5	970	1760	211	2.6	0.001	<0.003	0.006	6.12	0.0012	1.02	0.027	0.21
13-Apr-2005	7.3	1600	2870	1220	2.0	0.001	<0.003	0.005	3.02	0.0006	4.35	0.014	0.16
18-May-2005	8.8	1200	2130	528	1.7	0.001	<0.003	0.003	2.11	<0.0005	2.41	0.0359	0.15
15-Jun-2005	4.2	1200	2150	1090	87.1	0.025	0.004	0.034	11.60	0.0007	6.79	0.1473	4.85
13-Jul-2005	6.4	1200	2180	660	24.1	0.008	<0.003	0.015	8.46	0.0015	1.31	0.0355	1.21
23-Aug-2005	7.1	1100	2020	382	8.5	0.004	<0.003	0.010	4.35	0.0016	0.72	0.0181	0.39
5-Sep-2005	6.7	1300	2410	766	3.0	0.004	0.003	0.011	2.25	<0.0005	2.59	0.0383	0.28
18-Oct-2005	6.6	1700	2990	1240	5.2	0.007	<0.003	0.150	2.26	<0.0005	4.09	0.0373	0.40
21-Nov-2005	4.4	1480	2680	969	2.9	0.036	<0.003	0.015	17.80	<0.0005	15.88	0.2282	4.07
15-Dec-2005	7.4	1060	1920	405	4.3	0.005	<0.003	0.012	4.00	0.0006	1.38	0.0346	0.89
11-Jan-2006	7	1210	2190	342	1.6	0.007	<0.003	0.018	3.49	<0.0005	1.81	0.0616	0.33
14-Feb-2006		No Flow											
14-Mar-2006		no flow											
17-Apr-2006	7.5	1130	2050	279	3.1	0.003	<0.003	0.007	3.74	0.0005	1.32	0.0243	0.24
22-May-2006	7.4	844	1530	97.5	28.9	0.009	0.006	0.012	20.50	0.0039	1.08	0.0212	1.35
13-Jun-2006	7.4	899	1630	125	3.5	0.001	0.004	0.003	2.30	<0.0005	0.39	0.0158	0.17
17-Jul-2006	6.4	1300	2420	747	9.9	0.007	0.004	0.013	9.81	0.0007	1.68	0.0492	0.88
15-Aug-2006	7.4	1100	1960	1550	4.1	0.009	<0.003	0.010	1.94	<0.0005	7.71	0.0573	1.25
12-Sep-2006	7.4	1100	1940	369	1.7	0.002	0.004	0.005	0.76	0.0176	1.91	0.0201	0.10
12-Oct-2006	6.9	1800	3260	1440	1.4	0.004	<0.003	0.003	0.94	<0.0005	<0.0005	0.0437	0.33
15-Nov-2006	7	1500	2740	804	1.3	0.002	<0.003	0.004	1.15	<0.0005	6.16	0.0358	0.20
13-Dec-2006		dry											

1992 ANZECC GUIDELINES FOR WATER QUALITY **(highlighted value indicates the recorded value exceeds the recommended guideline)**

For Aquatic		1,000	**for pH<6.5**	no value	0.005	0.0002	0.01	0.002	1.0	0.001	no value	0.015	0.005
Ecosystems	6.5 - 9.0	1,000	**for pH>6.5**	no value	0.1	0.002	0.01	0.005	1.0	0.005	no value	0.15	0.050
Irrigation	4.5 - 9.0	3,500		no value	5	0.01	1.00	0.20	1.0	0.2	2	0.2	2
Livestock	no value	3,000		1,000	5	0.01	1.00	0.5	no value	0.1	no value	1	20

Fig14. Pictorial of spreadsheet recording assay values over past twelve years; Note the colour change for 2004 - 2006 towards the bottom.

Values exceeding the ANZECC recommended guidelines are colour coded and each passing year the colours provide a visible indication of the change in pollution level. The figure shows nine years of monitoring results for nine metals and sulphate. Moving down the sheet with each year it is noticeable that the pink exceedance values for sulphate, aluminium and cadmium begin to clear in the last two recorded years i.e. 2004 and 2005. In 2006 cadmium levels are below ANZECC guidelines set for irrigation and livestock for the entire year. In 2006 pH levels in the Dawesley Creek were compliant with ANZECC recommended guidelines for aquatic ecosystems

9 ADDITIONAL MINE SITE MONITORING WORK

9.1 Site rainfall and plant utilisation

The annual rainfall significantly influences the volume of seepage from the waste rock dumps that requires capture and processing. Seasonal variations i.e. wet years or drought years, influence the volume of pollution requiring treatment and the cost of pumping and plant operation. Seepage is greatest in winter when plant utilisation is high with the plant operating 24 hours per day and 7 days per week. Site rainfall is read daily and entered into a spreadsheet.

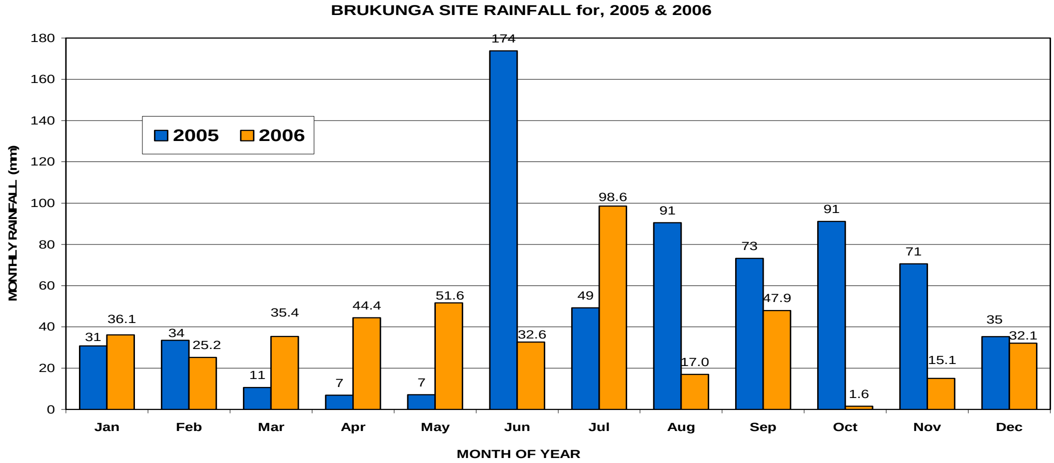

Fig 15. Monthly rainfall (mm) recorded at Brukunga for 2005 and 2006.

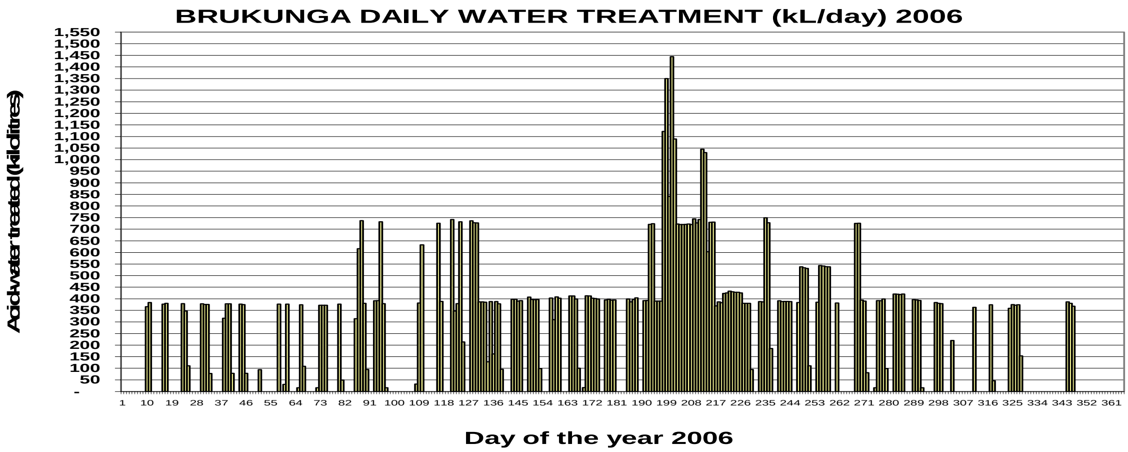

Fig 16. Plant shutdowns and throughput in kilolitres, for each day of 2006.

Year	Plant operation as a percent of available time (i.e. 24/7 > 100%)												Rainfall mm	Kilolitres treated
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
2001	30%	33%	46%	10%	80%	94%	94%	95%	98%	92%	59%	33%	**618**	**106,905**
2002	32%	33%	34%	28%	46%	47%	77%	51%	36%	40%	28%	40%	**392**	**53,472**
2003	27%	25%	10%	25%	47%	89%	100%	100%	100%	76%	80%	10%	**607**	**123,098**
2004	47%	15%	36%	33%	24%	81%	100%	99%	98%	55%	66%	35%	**531**	**115,051**
2005	41%	52%	18%	23%	8%	72%	95%	100%	100%	93%	73%	44%	**673**	**160,797**
2006	26%	35%	35%	27%	69%	58%	83%	81%	52%	49%	20%	10%	**438**	**79,565**

Fig 17. Monthly plant operation as a percentage of available time 24/7

9.2 *Sand tailings dam monitoring*

During mining the treatment of ore to produce a concentrate also produced 3.5Mt of finely ground sand tailings that were deposited in a shallow farm valley. Since 1980 the tailings dam has been progressively covered with native vegetation to rehabilitate the surface. The vegetation cover stabilises the surface from the forces of erosion and reduces the volume of rain that otherwise would percolate deep through the sands and result in acid seepage at the base of the dam. The trees also provides habitat for wildlife.

The effect of the vegetation cover in reducing deep-percolation of rainwater is monitored in two methods;

- A v-notch weir is used to measures the flow of seepage from the base of the dam, and
- Internal measurements are taken to the watertable via boreholes on a monthly basis.

Graphic presentation of annual seepage over thirty years, records the reduction in seepage that has occurred and a graph of the depth to watertable, for each year indicates the amount of internal drying of the tailings dam.

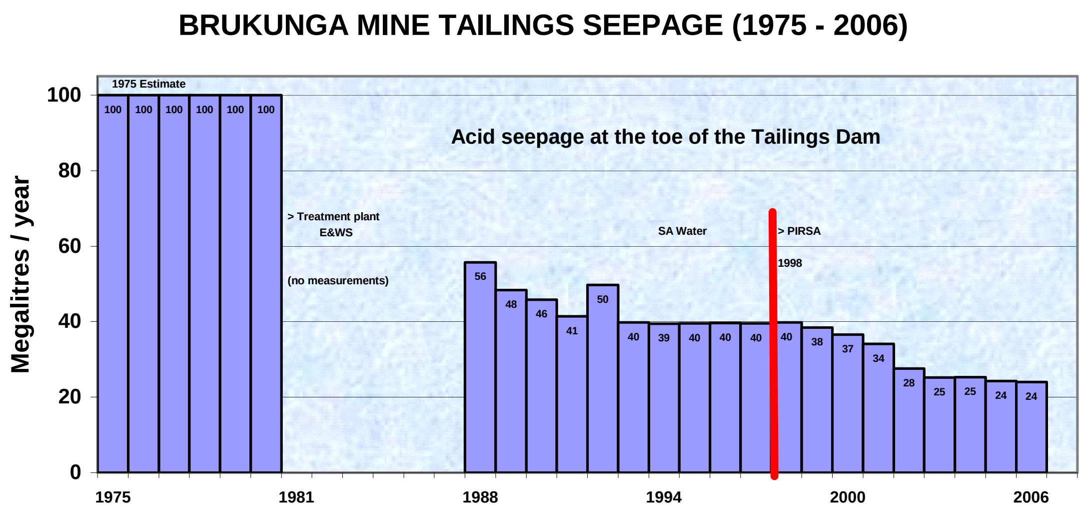

Fig 18. Annual volume of acid seepage from the sand tailings dam as measured at the v-notch

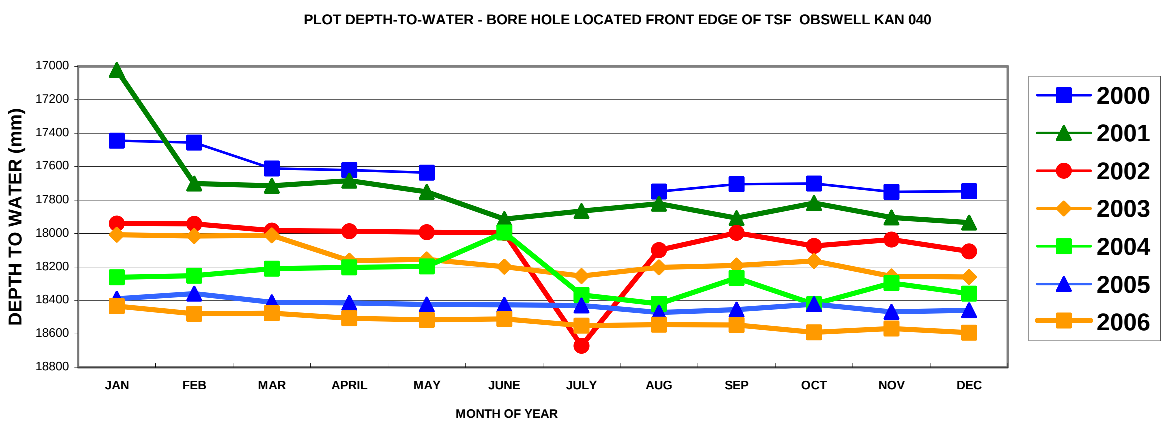

Fig 19. Depth measured to water in a monitoring bore in the tailings dam indicates progressive annual internal drying is being achieved.

9.3 *Water in the holding ponds (feed to the plant)*

Since September 1999 a quarterly sample has been taken from the acid-water holding ponds to provide information on the quality of feed water to the treatment plant (figure 20). Significant fluctuations in the concentration level of sulphate and various soluble metals are noticeable with high values tending during the summer and dryer conditions, and more diluted values occurring in winter. June 2006 values show reduced dilution and higher winter values due to the effect of the severe drought .

ACID HOLDING POND (ie. water feed to treatment plant)

DATE	pH	SULPHATE total mg/l	ALUMINIUM total mg/l	CADMIUM total mg/l	IRON mg/l	MANGANESE total mg/l	NICKEL mg/l	ZINC mg/l
10-Mar-04	2.6	10,200	406	0.0555	2,180	117.0	0.6194	23.6
18-Jun-04	2.9	5,470	464	0.3570	445	42.4	1.2220	44.0
15-Sep-04	2.9	6,560	603	0.2739	611	40.8	1.2880	34.9
15-Dec-04	2.8	8,930	768	0.0941	935	76.4	0.2216	40.5
22-Mar-05	2.7	8,110	222	0.0249	2,190	105.0	0.1552	14.8
15-Jun-05	2.9	6,000	485	0.0666	631	55.5	0.7611	23.6
05-Sep-05	2.9	6,860	579	0.1732	517	43.0	0.0476	37.1
15-Dec-05	3.0	10,400	839	0.1805	1,430	97.6	1.3130	47.7
14-Mar-06	2.9	13,800	1012	0.1074	2,150	<0.0005	2.002	42.6
13-Jun-06	3.0	9,510	779	0.0862	1,250	72.02	1.495	31.7
12-Sep-06	3.0	6,840	548	0.1300	791	43.53	1.016	28.5
13-Dec-06	3.0	9,390	258	0.0371	2,350	<0.0005	0.520	<0.003

Indicates corrected potentially spurious reporting by laboratory

< values represent detection limits

1992 ANZECC RECOMMENDED GUIDELINE VALUES FOR WATER QUALITY

	pH	SULPHATE	ALUMINIUM	CADMIUM	IRON	MANGANESE	NICKEL	ZINC
Irrigation	4.5 - 9.0	no value	5	0.01	1	2	0.2	2
Livestock	no value	1,000	5	0.01	no value	no value	1	20

Fig 20. Quarterly assay of acid polluted water collected for feed to the treatment plant.

10 CONCLUSIONS

Analysis of 124 years of rainfall data recorded at Nairne the closest official rain gauge to Brukunga revealed that the 2006 drought was an extreme event with less than a 10% probability of occurrence. The effect of extended dry periods of low flow were considered in the analysis of the 2006 data as drought conditions can negatively impact on water quality readings and macro invertebrate survey data. The 2006 annual flow of 383 ML recorded immediately downstream from the mine site was the lowest annual flow recorded since monitoring began in 1998. Approximately 80 ML of acid water was treated in 2006 with 30% of the acid feed water volume originating from the seepage collected from the tailings dam. The treatment plant ran well under full capacity for the entire year (see fig 17) resulting in only minor releases of untreated seepage to the creek.

The completion of new capital works initiatives undertaken by PIRSA in 2003 and 2005 have achieved a dramatic improvement in the quality of water in Dawesley Creek downstream of the Brukunga mine site, (Fig C-11 p.60 and Fig C-13 p.62) demonstrate that sulphate and cadmium pollution is being successfully removed for the majority of the time from the water.

The improvements recorded in the water monitoring results are more clearly evident when a comparison is made between the data collected before the capital works June 2003 and data collected after that date. The improvement is evident in all three monitoring strategies, i.e. the load calculations, biological observations, and monthly chemical concentrations.
Comparison of load calculation data for similar flow years 2006 and 2002 (tables A-2 and A-3) suggests that the creek diversion and treatment plant upgrade are having a significant effect on net pollution from the mine site. Net pollution loads in kg/ML of flow show that sulphate load was approximately 50% less, aluminium load approximately 70% less and cadmium load approximately 50% less in the 2006 calculations.

The macroinvertebrate monitoring studies all support that the water quality in the Dawesley creek is improving compared to the conditions prior to the creek diversion. The results also show that the positive trend in Mean Taxon Richness since operation of the diversion scheme was most marked at the Brukunga downstream site and the Mcintyre road site.

It would seem that the first objective of restoring water quality in the Dawesley Creek to a level that complies with ANZECC 1992 Guidelines for irrigation and livestock, has largely been met. Metal concentrations in the Dawseley Creek immediately downstream of the mine site were consistently low for the majority of the year .In 2006 cadmium levels in the Dawseley Creek were below the ANZECC recommended guidelines for livestock and irrigation use (see fig C-5).

Dawesley Creek watercourse was polluted by acid seepage from the mine site, from soon after mining commenced in 1955. With the installation of the diversion drain in 2003 and upgrading and extensions to the treatment plant in 2005, water quality is showing signs of returning to a condition suitable for livestock and irrigation use and it is rapidly returning to a condition that will sustain a wide diversity of aquatic ecosystems living in association with the stream.

11 REFERENCE

(ANZECC) Australian and New Zealand Environment and Conservation Council (1992) Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Environment Australia Publications.

APPENDIXES

APPENDIX A

ANNUAL LOAD OF HEAVY METALS

2006 CALCULATED POLLUTION LOAD IN DAWESLEY CREEK

Dawesley Creek up-stream of Brukunga Mine A4260658 Samples below detection levels, calculations using detection value

2006 date	Sulphate kg	Aluminium kg	Cadmium kg	Chromium kg	Copper kg	Iron kg	Lead kg	Manganese kg	Nickel kg	Zinc kg
05-Jan-06	207.47	30.906	0.0461	0.0826	0.0532	71.910	0.0386	1.531	0.0046	0.5447
17-Jan-06	231.62	13.102	0.0181	0.0292	0.0585	17.927	0.0041	22.018	0.1702	1.6728
01-Feb-06	5.49	0.272	0.00005	0.0013	0.0006	0.675	0.0004	0.021	0.0005	0.0066
15-Feb-06	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**
01-Mar-06	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**
15-Mar-06	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**
29-Mar-06	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**
12-Apr-06	321.34	9.532	0.0020	0.0201	0.0253	25.715	0.0148	0.831	0.0261	0.1524
24-Apr-06	290.53	12.538	0.0029	0.0406	0.0429	27.604	0.0139	1.094	0.0638	0.2204
10-May-06	685.90	18.074	0.0035	0.0420	0.0266	27.128	0.0126	1.204	0.0371	0.1398
24-May-06	1843.38	56.828	0.0182	0.2545	0.1091	81.443	0.0400	1.902	0.1891	0.3999
07-Jun-06	904.39	17.979	0.0077	0.4638	0.0402	35.093	0.0170	0.914	0.0572	0.0077
21-Jun-06	480.72	7.723	0.0031	0.0246	0.0141	5.882	0.0061	0.343	0.0246	0.1044
05-Jul-06	493.13	9.308	0.0049	0.0778	0.0302	12.061	0.0088	0.584	0.0428	0.1848
19-Jul-06	3495.34	96.486	0.0455	0.3641	0.3277	154.742	0.1001	5.398	0.2913	1.1833
02-Aug-06	3258.92	14.753	0.0237	0.2846	0.0901	52.655	0.0237	5.247	0.1850	0.3795
16-Aug-06	1706.41	24.472	0.0110	0.1323	0.0485	45.857	0.0220	4.980	0.0970	0.3087
30-Aug-06	1380.98	25.465	0.0122	0.1469	0.0784	62.928	0.0220	2.946	0.1102	0.2938
13-Sep-06	1111.68	12.494	0.0125	0.1753	0.0976	37.557	0.0476	3.343	0.1177	0.4256
28-Sep-06	925.45	47.444	0.0098	0.1562	0.0957	84.930	0.0566	3.741	0.1054	0.4881
11-Oct-06	494.94	11.374	0.0051	0.1537	0.0728	57.999	0.0656	3.259	0.0769	0.5021
24-Oct-06	257.49	13.947	0.0024	0.0780	0.0527	45.646	0.0332	1.836	0.0493	0.3024
08-Nov-06	365.06	22.531	0.0047	0.0761	0.0513	57.992	0.0342	2.144	0.0551	0.2947
22-Nov-06	421.48	23.699	0.0071	0.0851	0.0525	62.583	0.0369	1.761	0.0553	0.2271
05-Dec-06	200.02	25.612	0.0041	0.0732	0.0504	61.306	0.0333	1.777	0.0496	0.2277
20-Dec-06	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**
Total Load	**19081.74**	**494.540**	**0.2447**	**2.3446**	**1.4183**	**1029.633**	**0.6315**	**66.874**	**1.8088**	**8.0665**

detection levels used for Cadmium, Nickel and Zinc 0.0005 mg/L, 0.003 mg/L for Chromium

Dawesley Creek down-stream of Brukunga Mine A4260659

DATE	Sulphate kg	Aluminium kg	Cadmium kg	Chromium kg	Copper kg	Iron kg	Lead kg	Manganese kg	Nickel kg	Zinc kg
05-Jan-06	2444.88	22.204	0.0288	0.0146	0.0766	22.106	0.0029	9.311	0.0087	1.5030
17-Jan-06	305.49	39.737	0.0088	0.2458	0.1264	207.759	0.0872	5.157	0.0603	0.7725
01-Feb-06	7334.04	44.305	0.0491	0.0250	0.0453	66.332	0.0043	58.848	0.2833	9.1112
15-Feb-06	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**
01-Mar-06	2331.82	16.348	0.0299	0.0075	0.0333	14.854	0.0012	28.065	0.1629	3.5185
15-Mar-06	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**
29-Mar-06	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**	**no flow**
12-Apr-06	10924.33	124.602	0.1240	0.0193	0.0790	25.512	0.0064	60.084	0.3798	9.4463
24-Apr-06	3167.26	12.960	0.0085	0.0182	0.0552	19.173	0.0030	5.275	0.1887	0.8434
10-May-06	27408.63	1437.499	0.3405	0.0623	0.3322	336.379	0.0810	116.943	2.2716	69.7674
24-May-06	10539.27	148.114	0.0439	0.1255	0.1631	110.411	0.0157	14.460	0.4862	4.4855
07-Jun-06	8226.16	56.970	0.0180	0.0541	0.0667	33.915	0.0090	10.097	0.2526	1.6055
21-Jun-06	7057.93	656.557	0.0400	0.0970	0.2692	546.929	0.0303	11.825	0.2595	4.0747
05-Jul-06	11566.86	713.748	0.1148	0.2984	0.8721	885.874	0.0987	16.393	0.5187	12.3472
19-Jul-06	45334.85	9977.541	1.8405	1.7436	14.0364	9192.899	0.8428	217.569	6.1900	247.9855
02-Aug-06	15525.40	501.555	0.2895	0.0684	0.3648	269.016	0.0410	92.309	1.2972	24.3938
16-Aug-06	7660.47	94.965	0.0412	0.0253	0.0728	34.187	0.0063	23.057	0.2526	3.8176
30-Aug-06	11950.86	1567.982	0.3456	0.3092	0.7240	938.607	0.1255	104.611	1.3915	78.3991
13-Sep-06	6177.37	3095.244	0.9758	0.1574	1.1384	1770.584	0.4210	58.574	1.4322	148.2045
28-Sep-06	13014.57	90.874	0.0000	0.0685	0.0251	59.136	0.0160	4.557	0.4293	0.4110
11-Oct-06	7195.90	41.189	0.0242	0.0363	0.0630	26.530	0.0061	12.163	0.1926	1.8414
24-Oct-06	11419.27	28.714	0.0211	0.0333	0.0754	17.184	0.0055	0.0055	0.3293	1.5854
08-Nov-06	7688.66	31.072	0.0261	0.0340	0.0771	21.773	0.0057	0.0057	0.3549	2.9938
22-Nov-06	4516.92	19.068	0.0109	0.0469	0.0594	17.349	0.0078	21.803	0.2235	0.9065
05-Dec-06	8805.20	8.973	0.0077	0.0386	0.0412	8.728	0.0064	0.0064	0.1905	0.4377
20-Dec-06	22.81	0.035	0.0000	0.0002	0.0004	0.023	0.00003	0.029	0.0010	0.0017
Total Load	**230618.95**	**18730.26**	**4.4000**	**3.5294**	**18.7971**	**14625.26**	**1.8239**	**871.147**	**17.1569**	**628.4532**

detection levels used for Nickel, Lead, and Manganese 0.0005 mg/L, 0.003 mg/L for Chromium

NET CONTRIBUTION FROM THE BRUKUNGA MINE SITE (kilograms per annum)

2006	**Sulphate**	**Aluminium**	**Cadmium**	**Chromium**	**Copper**	**Iron**	**Lead**	**Manganese**	**Nickel**	**Zinc**
kilograms	**211537**	**18236**	**4.16**	**1.18**	**17.38**	**13596**	**1.19**	**804.28**	**15.34**	**620.38**

TableA.1 Calculated loads of pollution in Dawesley Creek at Brukunga mine site 2006

NET POLLUTION LOAD FROM THE BRUKUNGA MINE SITE (kilograms per annum)

Year	Water flow ML	Sulphate kg	Aluminium kg	Cadmium kg	Chromium kg	Copper kg	Iron kg	Lead kg	Manganese kg	Nickel kg	Zinc kg
1998	696	649,219	108,376	53.0	29.0	127.0	46,485	10.00	3,832	224.0	2,995
1999	904	796,743	81,642	22.0	76.0	187.0	19,576	7.00	4,668	211.0	3,054
2000	2,180	1,866,054	231,425	69.0	603.0	1,221.0	111,028	24.00	12,816	507.0	8,689
2001	1,703	932,150	24,496	38.0	47.0	185.0	91,724	17.00	5,815	146.0	5,247
2002	416	447,016	71,368	8.4	9.1	35.4	18,869	1.96	2,460	78.6	1,761
2003	1,179	511,087	75,991	21.88	32.3	103.2	37,626	13.79	2614	119.8	2,604
2004	**1,032**	**568,244**	**63,954**	**18.5**	**13.1**	**77.7**	**28,584**	**4.96**	**1,822**	**81.7**	**1,944**
2005	**1,258**	**533,105**	**54,296**	**20.0**	**5.9**	**53.3**	**25,115**	**4.39**	**3,773**	**97.7**	**2,521**
2006	**383**	**211,537**	**18,236**	**4.16**	**1.2**	**17.4**	**13,596**	**1.19**	**804**	**15.3**	**620**

Table A2. Annual net pollution loads in Dawesley Creek at Brukunga mine site

NET POLLUTION LOAD FROM BRUKUNGA MINE SITE (kilograms per megalitre of flow)

YEAR	Sulphate kg/ML	Aluminium kg/ML	Cadmium kg/ML	Chromium kg/ML	Copper kg/ML	Iron kg/ML	Lead kg/ML	Manganese kg/ML	Nickel kg/ML	Zinc kg/ML
1998	933	156	0.0761	0.0417	0.182	66.789	0.0144	5.506	0.3218	4.303
1999	881	90	0.0243	0.0840	0.207	21.646	0.0077	5.162	0.2333	3.377
2000	856	106	0.0317	0.2766	0.560	50.930	0.0110	5.879	0.2326	3.986
2001	547	14	0.0223	0.0276	0.109	53.860	0.0100	3.415	0.0857	3.081
2002	1076	172	0.0201	0.0220	0.085	45.402	0.0047	5.919	0.1892	4.237
2003	434	64	0.0186	0.0274	0.088	31.919	0.0117	2.218	0.1016	2.209
2004	**551**	**62**	**0.0179**	**0.0127**	**0.075**	**27.698**	**0.0048**	**1.766**	**0.0792**	**1.884**
2005	**424**	**43**	**0.0159**	**0.0047**	**0.042**	**19.964**	**0.0035**	**2.999**	**0.0777**	**2.004**
2006	**553**	**48**	**0.0109**	**0.0031**	**0.045**	**35.500**	**0.0031**	**2.099**	**0.0399**	**1.619**

Table A-3. Annual net pollution loads at Brukunga normalised for annual flow quantity

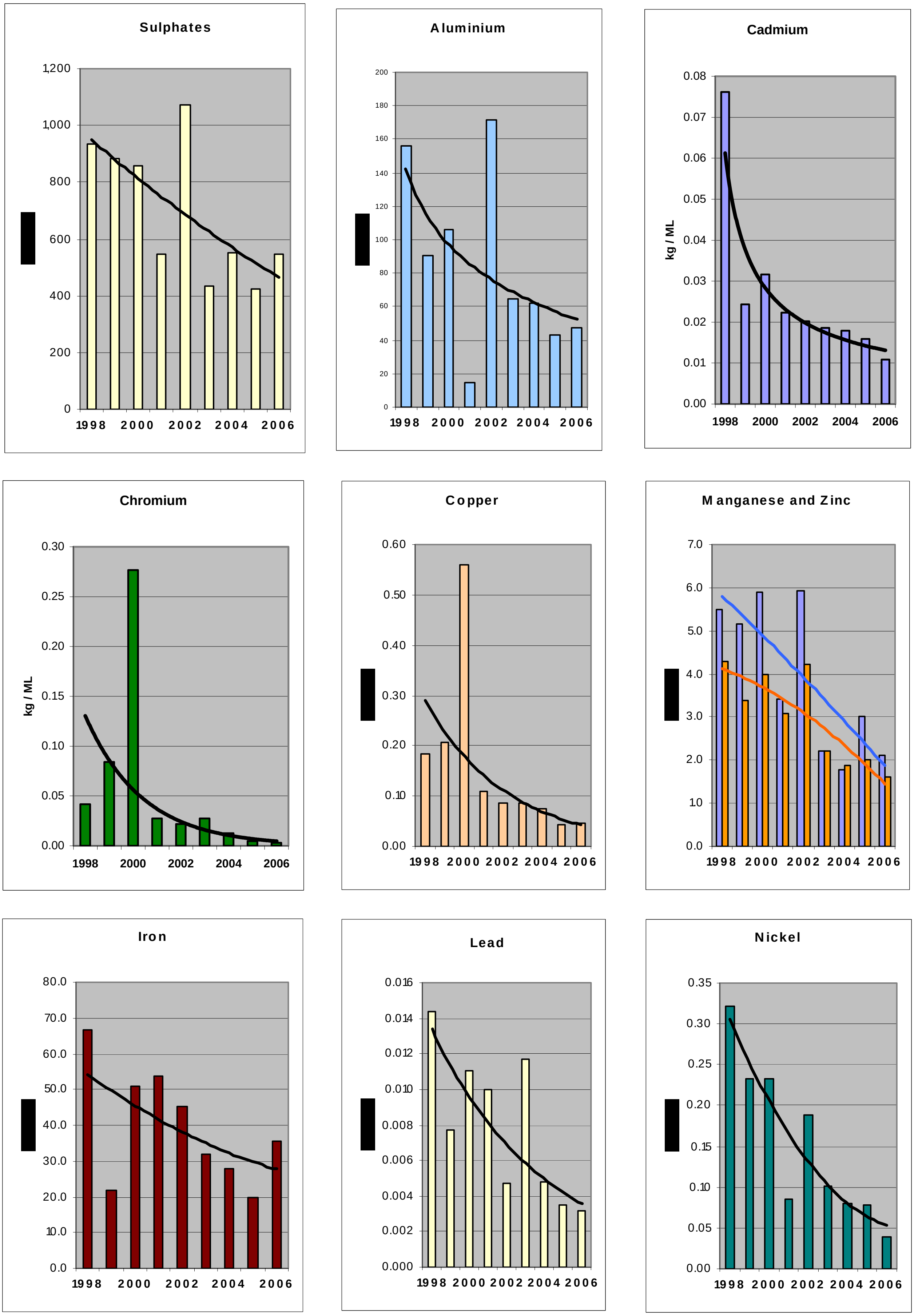

Fig A-1. Graphs of annual load of pollutant in Dawesley Creek 1998 to 2006 (kilograms / megalitre of flow)

APPENDIX B

BIOLOGICAL MONITORING RESULTS

Brukunga Acid Mine Drainage Impact Monitoring Program: Macroinvertebrate Results 2006

Submitted by Australian Water Quality Centre, (compiled by: Darren Hicks) for Primary Industries & Resources, South Australia (PIRSA)

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Tables and Figures

The Brukunga Acid Mine Drainage Impact Monitoring Program
Macroinvertebrate Results 2006

1. Introduction

The Brukunga Acid Mine Drainage Impact Monitoring Program, initiated in the 1996–1997 financial year, involved monitoring macroinvertebrate and chemical parameters at sites on the Dawesley Creek – Bremer River system. The Australian Water Quality Centre (AWQC) has conducted biological monitoring for Primary Industries & Resources SA subject to an Environment Protection Authority licence agreement for management of the disused Brukunga pyrites mine. The principal aim of the monitoring program is to investigate the impact of Acid Mine Drainage (AMD) on Dawesley Creek including the downstream extent of the impact and subsequent to the construction of a diversion channel around the mine site to investigate the recovery of Dawesley Creek.

This report provides a summary of macroinvertebrate results for 2006 and provides comparisons with data from past years, climatic conditions experienced during 2006 have seen winter rainfall the lowest on average since records began and this is likely to have had an added effect on the composition of macroinvertebrates in the catchment and though conditions during 2006 were drier than normal all sites except one had flowing water when macroinvertebrates were collected. A recommendation from the 2005 survey was for riffle habitats to be sampled to determine if the flowing water habitats and fauna of Dawesley Creek are recovering. Monitoring of riffles in the study area commenced in 2006. As there are no previous site-specific data for use in determining if these riffles are improving after the creek diversion, the 2006 and subsequent results will be used to represent the baseline condition.

Sites

Macroinvertebrate monitoring has been conducted in the system since September 1996. The six sites monitored from 1996 to 2006 are listed in Table 1, in order of increasing distance down the catchment. These sites were sampled quarterly (in March, June, September and December).Figure 1 is a map of the streams showing all sites that have been sampled during the project.

***Table 1*. Macroinvertebrate sites monitored quarterly since 1996, and period of entire data record.**

Site Name	Label	Monitoring Duration	AWQC Location Code
Dawesley Ck. at Peggy Buxton Rd	**Site 1**	Sept. 1996 – Dec. 2006	4728
Dawesley Ck. D/S Brukunga	Site 2	Sept. 1996 – Dec. 2006	3158
Dawesley Ck. at McIntyre Rd	Site 3	Sept. 1996 – Dec. 2006	1951
Dawesley Ck. at Balyarta Ford	Site 4	Sept. 1996 – Dec. 2006	1822
Dawesley Ck. at Freeway	Site 5	Dec. 1996 – Dec. 2006	1952
Nairne Ck. at Djatadapeel Ford	Site 6	Sept. 1996 – Dec. 2006	1953

2. Methods

Macroinvertebrate Sampling

All macroinvertebrate sampling was conducted with sweep nets (250 μm mesh) and conformed to the Australian Rivers Assessment System (AusRivAS) standard protocol, where a 10 metre section of stream is sampled (Anon. 2001). Edge habitat was sampled at all sites and is the habitat chosen for comparisons of previous macroinvertebrate assemblages across all sites and times. Riffles were sampled for the first time in June and September 2006 at Dawesley Creek Peggy Buxton Rd, Downstream Mine and Balyarta and at Nairne Creek. The South Australian AusRivAS laboratory scoring protocol was used to process samples. The protocol involves counting all organisms in a randomly chosen 10% of the sample from a Marchant sub-sampler (Marchant 1989). Sub-sampling continued until a minimum of 200 animals had been identified; for the purposes of obtaining a representative sample. Identification was taken to the lowest practical level using the latest available keys and the AWQC voucher collection. Identification was carried out at family level or lower in all groups except Turbellaria, Nematoda and some Oligochaeta (where they were identified at the levels stated). Most Insecta and Mollusca were taken to species. The Dipteran families Ceratopogonidae, Tipulidae, Psychodidae, Stratiomyidae and Simuliidae were taken to species or morpho-species and the Culicidae were taken to genus. The Chironomidae were taken to genus where possible (and in some cases to species) and other dipteran families were not identified below family.

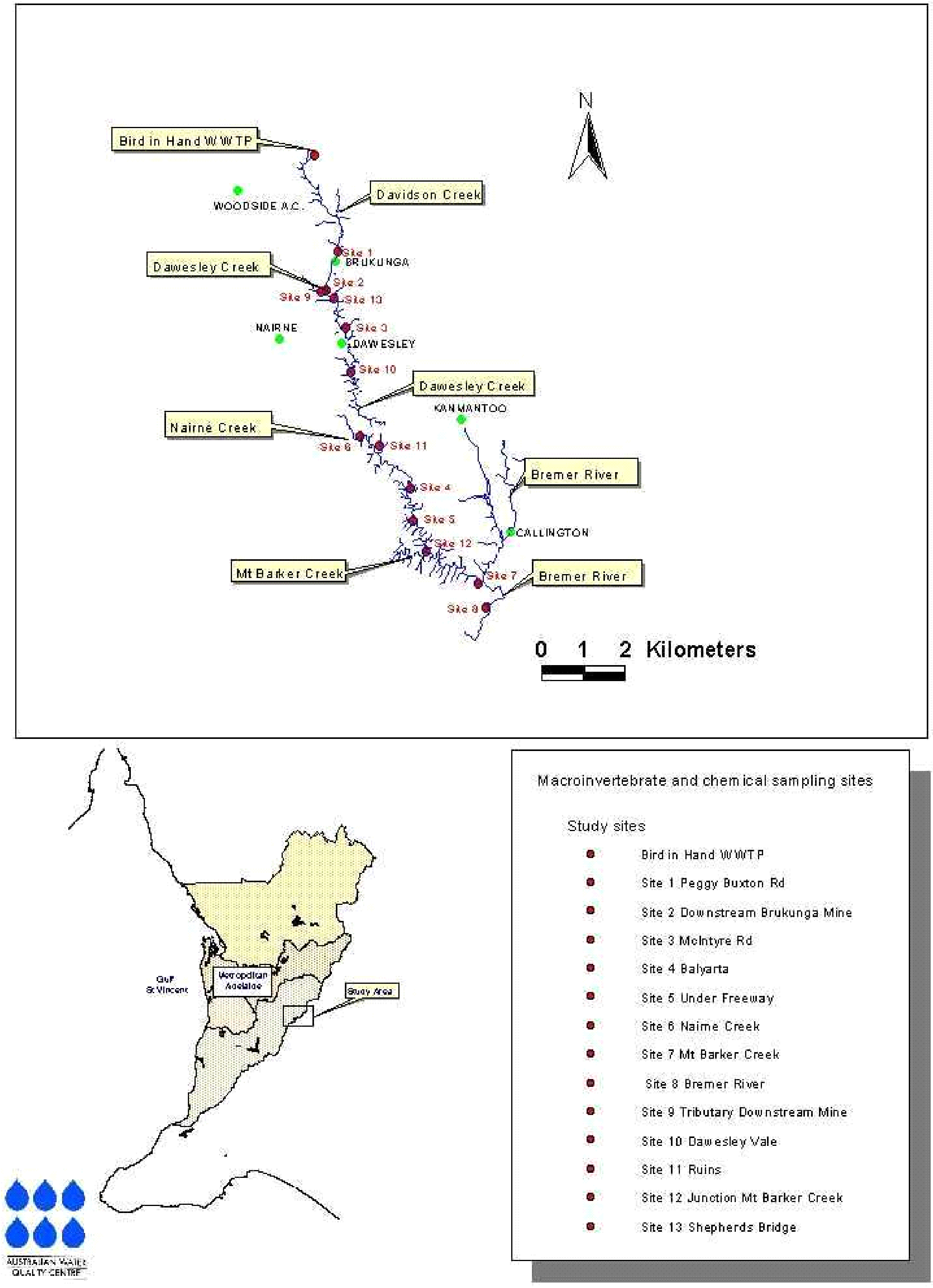

Figure 1. **Location and site map for the Dawesley Creek System.**

Interpretation of Macroinvertebrate Data

Macroinvertebrate data were analysed by several techniques. These were simple indices (taxon richness, abundance); Multivariate analyses (MVA), and AusRivAS predictive models.

Species richness, which reflects the number of different types of macroinvertebrates identified in a sample, can be used to estimate the health of a stream. In this report, the term taxon richness is used - as not all the taxa that were counted are species. As detailed in the previous section, some taxa were only identified to family, some to genus and others to species. The taxa present in each sample and the abundance of each taxon reflects the differences between sites, habitats and conditions prior to the date of sampling. There are no simple rules for interpreting these complex data sets. Variation due to factors such as extreme flow events, time of day, chance colonisation by rare taxa, and weather conditions is always present in addition to the variation due to water quality, season, habitat variability, ambient temperature and plant productivity. Statements regarding abundance in this report refer to the abundance within the sub-sampled portions of each collection.

MVA are statistical procedures that can detect similarities in biological community data (i.e. the taxa present and their abundance). They are a broad set of objective tools that can be used to seek and reveal structure within complex data sets - avoiding investigator subjectivity. Ordination and classification of macroinvertebrate community data provide an assessment of how similar or dissimilar samples are. Both spatial and temporal patterns can be detected, and such patterns may not be revealed by simple diversity indices and raw taxon richness and abundance figures. When two different MVA methods detect the same pattern, the degree of confidence in the validity of the pattern is increased. This is the approach that was followed, by comparing classification and ordination analyses.

In this assessment, MVA were used to conduct a ‘before and after’ comparison of edge samples to investigate for indications of ecological change after several years of operation of the diversion channel. This was done by comparing rainfall averages for the years 1997 to 2006 for SE Australia and the pattern and number of dry sites each year. From the six complete years of data available (1997-2002), the 2002 data were selected, as the hydrological conditions then most approximated those in 2006.

The statistical package PCORD was used to carry out both classification (Group Average UPGMA) and ordination (NMS non-metric multidimensional scaling). Data were grouped at a range of levels, but were predominantly at the genus and species level. No separation of the different life stages or sexes of species was included in the data tested. This gave an analysis matrix of 38 samples by 127 taxa. The Bray-Curtis association measure was used on untransformed abundance data for both methods.

Classification was run with the Groups\Cluster Analysis menu in PCORD. The classification was a hierarchical method run with the group average linkage method. To aid interpretation, a small number of groups were defined by the software. A five group level was chosen, as membership of groups did not change greatly at higher-level groupings.

Ordination was run with the Ordination\NMS menu in PCORD. The Suggested Procedure of McCune and Mefford (1999, p. 114) was followed to determine the final analysis options. A three-dimensional solution was calculated using a maximum of 200 iterations, a random start and a stability criterion of 0.00046. The resulting stress value was 12.04 and the solution was stable after approximately 35 iterations.

AusRivAs is the first national biological assessment of river health to be conducted on a continental scale, AusRivAS involved the sampling of macroinvertebrates from over 6000 sites,

650 of them from South Australia. The condition of a river site is determined by comparing it to a reference site, reference sites are considered to be in an undisturbed unimpacted state.

AusRivAS uses family level data to compare a sample with the community found at best available reference sites with similar environmental characteristics. It produces a rating that is a guide to the level of any impact and also calculates the probability of each family occurring in a sample. These outputs are useful to determine the effectiveness of the rehabilitation of the creek by comparing the fauna to reference sites. The results from AusRivAS analysis of 2006 data are included in this report.

The AusRivAS models function by using chemical and physical variables to classify a sample and then predict the families that should be present in that sample if it were from a reference site based on the classification group probabilities. This predicted (or "***E**xpected*") number of families is then compared with the number of families collected (or "***O**bserved*") in the sample. The comparison is in the form of a ratio of the Observed: Expected number of families – or **OE** in AusRivAS. The models make frequent use of a 50% probability of taxon occurrence at a site. This is because those taxa with a > 50% chance of occurring are considered the most useful for detecting a real decline in the number of taxa (Coysh *et al.* 2000). The AusRivAS output used in this report is the **OE50** which is the observed: expected ratio for families predicted at greater than 50% probability for a sample. The OE50 ratio can be simplified to a band. Band ratings are X (higher than expected observed number of taxa), A (equivalent to reference), B (reduced number of families and therefore significantly impaired), C (severely impaired) and D (extremely impaired). The probabilities which determine the boundaries between bands may be different for each model season, as they are based on percentiles.

3. Results

Macroinvertebrate Richness

2006 Surveys

The primary results consist of a list of the taxa recorded at each site and the abundance estimate of each taxon. To ensure the greatest compatibility between data sets generated at different times by different operators, only the highest level taxonomic data were used for Oligochaeta and aquatic mites. In order to ensure the most accurate representation of taxon richness, in cases where records of both adult and immature specimens of the same taxon were present in the sample, the data were combined. In this report only the taxon richness is discussed in detail. Richness is a measure of the diversity of the macroinvertebrate community. A higher number of taxa generally indicates a more natural site with less human-induced stress. It is also accepted that a more diverse community will recover more quickly from both natural and human-induced stresses compared to a community with low diversity.

In the graphs that summarise the macroinvertebrate data, the pH measured in the field at the time of sample collection have been added to indicate the major differences in water chemistry at different sites and times. It is referred to as spot pH. Even though a clear correlation between taxa and pH is evident, causality is not implied. There are many differences in the chemistry of low pH AMD and higher pH (neutral or alkaline) streams. The reduced diversity is not simply attributable to increased acidity.

March 2006

In previous surveys, it has been common for many Dawesley Creek sites to be dry in March. Consistent with these conditions, only three sites held water in March 2006 (Figure 2). Nairne Creek had been dry during March in the two previous surveys but was flowing with pools containing high taxon richness in 2006. Near neutral pH and taxon richness approaching twenty at the local reference site Peggy Buxton Road was consistent with previous results but the pH and richness at the Brukunga mine site was the lowest it has been since the diversion in 2003.

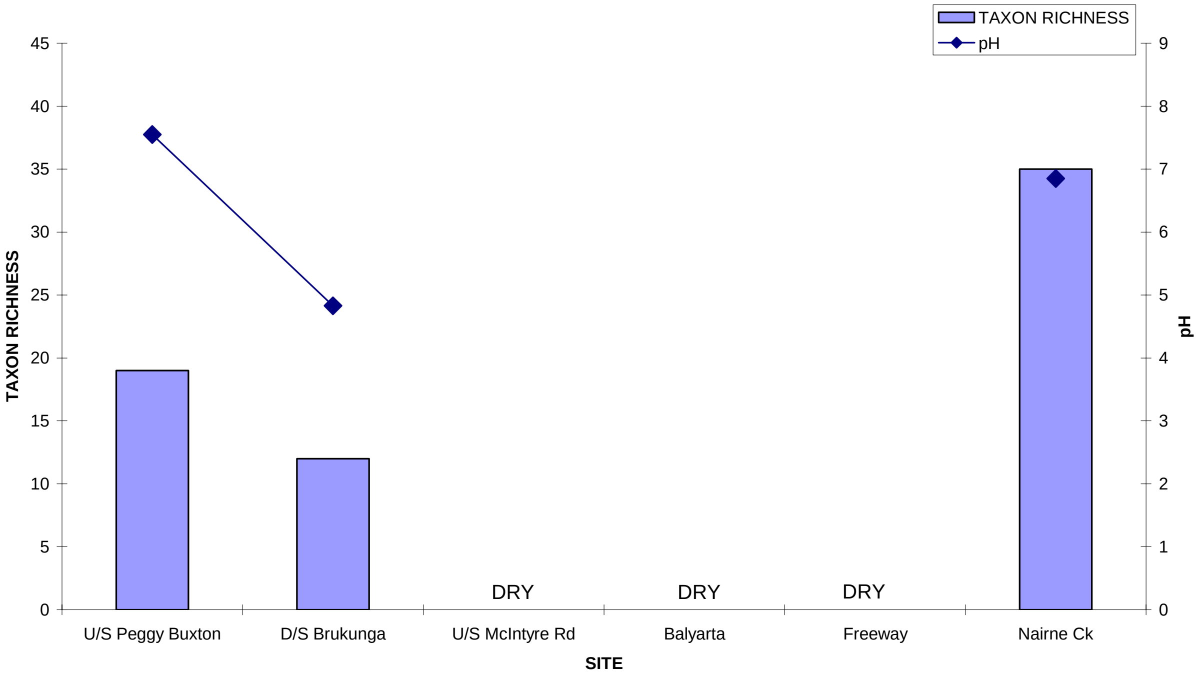

***Figure 2*. March 2006 taxon richness and pH.**

June 2006

Results from the June 2006 samples differed from the pattern shown in previous winter surveys in that all sites held surface water and the pH at all sites was near to, or above, neutral (Figure 3). The spot pH at Brukunga Mine was around 6.5 which is the highest recorded in June since monitoring began. The spot pH at all other sites remained between 7 and 8. Although June was extremely dry, these relatively neutral pH values could be attributed to a period of constant flow prior to sampling as a result of consistent rainfall during the previous autumn.

The non-impacted Nairne Creek site possessed the highest taxon richness which differed from the previous two surveys, during which the site was judged to be recovering from a dry period in March. The Mine and McIntyre Road sites showed macroinvertebrate richness comparable to that of the Peggy Buxton Road site (Figure 3). The lowest taxon richness was seen at the Balyarta and Freeway sites (Figure 3) suggesting the biological communities there were still undergoing the recovery process from the dry spell.

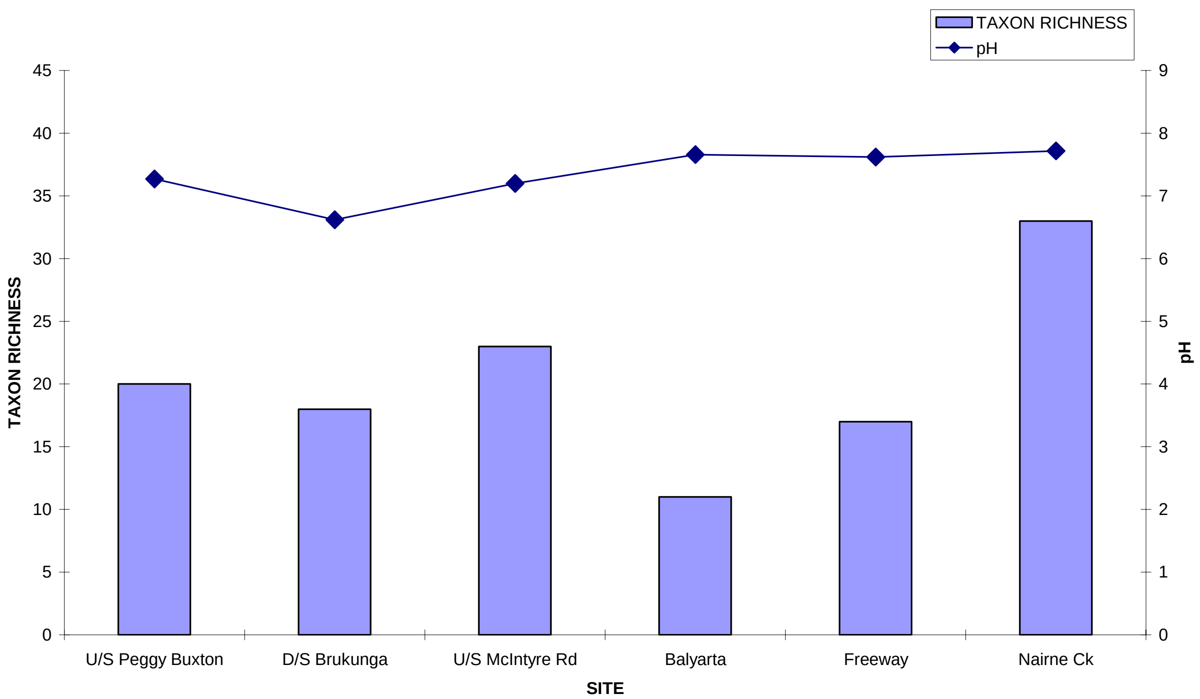

***Figure 3*. June 2006 taxon richness and pH.**

September 2006

Surface water was again present at all sites in September. The pattern of spot values of pH across the sites was almost identical to that seen in June (Figures 3, 4). The Level of macroinvertebrate richness was lower than it had been in June samples for all sites except Balyarta and the Freeway - where the richness almost doubled (Figures 3, 4). This suggests these latter sites had recovered quite well since March, however higher richness than the reference sites suggests macroinvertebrate drift from the nearby confluence with Nairne Creek may have been occurring.

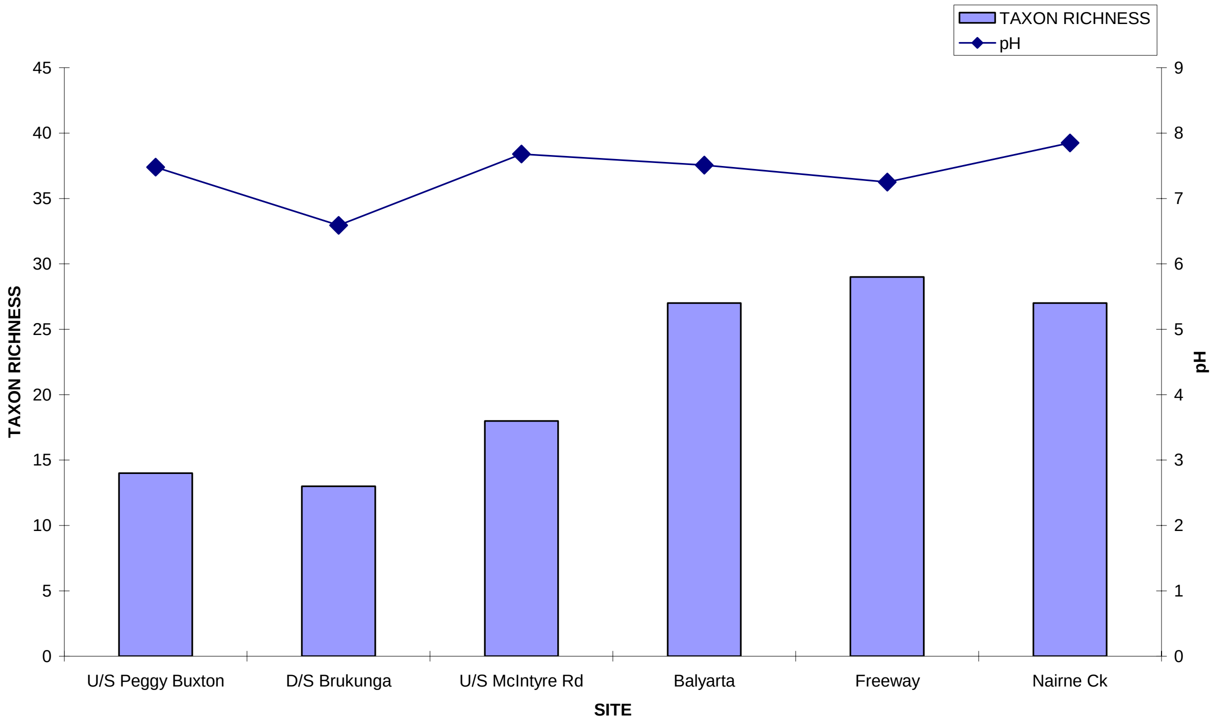

***Figure 4*. September 2006 taxon richness and pH.**

December 2006

An exceptionally dry spring resulted in only 3 sites having surface water present when visited in December 2006 (Figure 5). The Freeway had, on a few occasions, been dry in December however the Brukunga Mine and Balyarta sites have not ever previously been dry during December since monitoring began in 1996. The spot pH values of the three wetted sites ranged between 7.4 and 8.8 with the macroinvertebrate taxon richness ranging from 25 at McIntyre Rd to 35 at Nairne Creek (Figure 5).

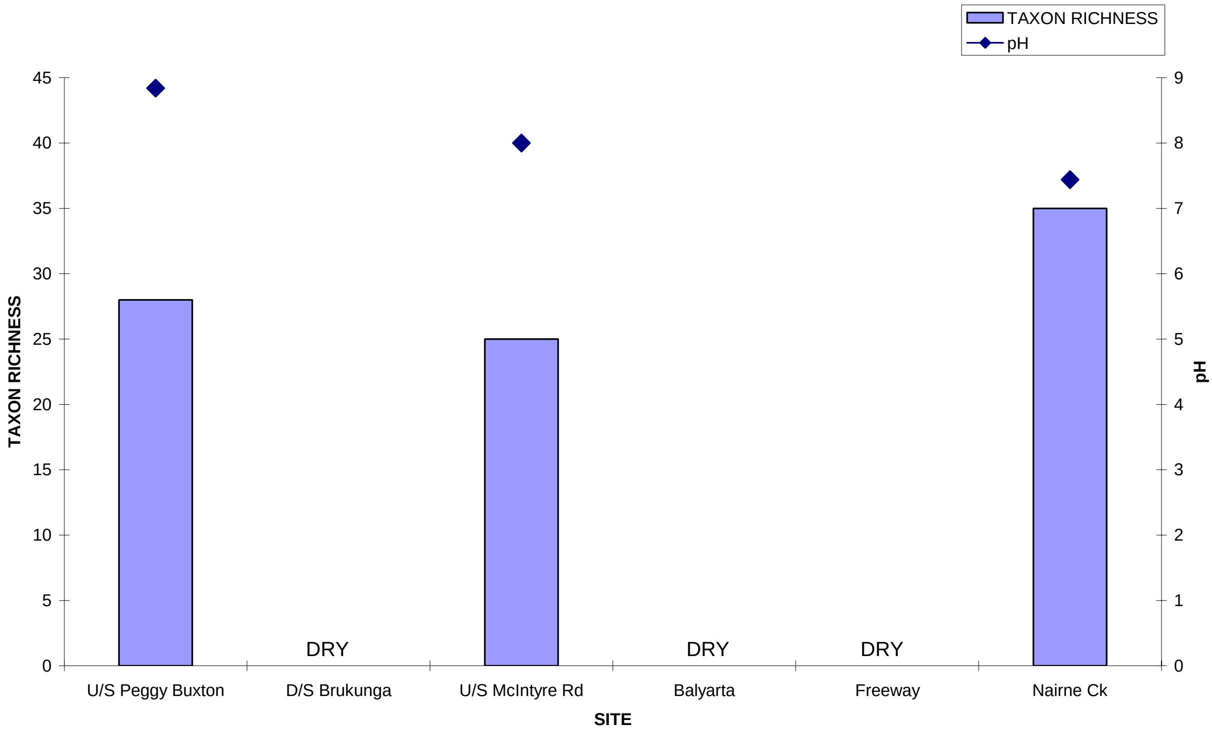

Figure 5**. December 2006 taxon richness and pH.**

Mean taxon richness 1996-2006

A comparison of the macroinvertebrate taxonomic richness prior to and since operation of the diversion scheme is presented in Figure 6. Since March 2003, all sites on Dawesley Creek that have been exposed to AMD have on average supported more macroinvertebrate taxa (Figure 6). This trend of improved ecological health was most marked at the Brukunga and McIntyre Road sites, and indicates that continued improvement will give rise to statistically significant differences (Figure 6).

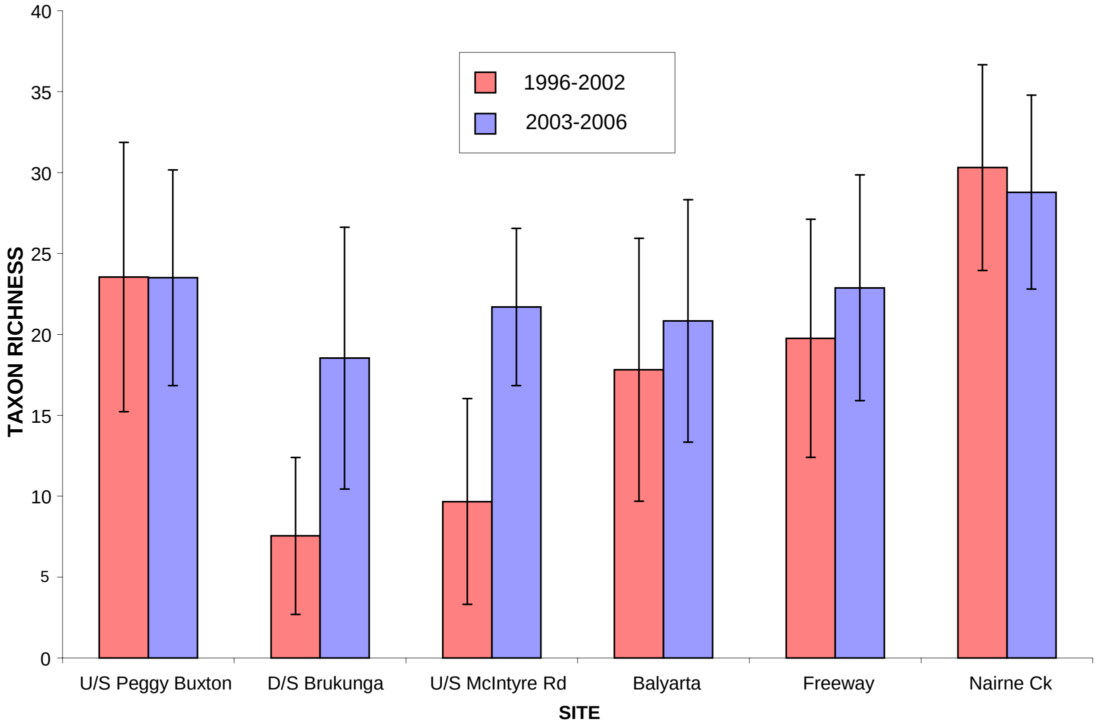

Figure 6**. Dawesley Creek system: taxon richness at six sites: 1996 – 2002 and 2003 – 2006.** Error bars show two standard deviations.

Temporal Changes at Each Site

At each of the six sites, the full data set from September 1996 to December 2006 has been presented (Figures 7-12). This allows the 2006 data to be compared with the findings of earlier years.

Peggy Buxton Road

Water discharged from the Bird in Hand Wastewater Treatment Plant was found to affect conditions at Peggy Buxton Road. Macroinvertebrate species richness was depressed at times due to eutrophic conditions (Figure 7). Flow levels were variable and often ceased in autumn but the pools remained and a macroinvertebrate community was always present. Both floods and periods of ceased flow impacted the community causing reduction in taxon richness. Prolonged periods of normal flow, on the other hand, created favourable conditions for macroinvertebrates which resulted in increased taxon richness. Reduced flow due to dry conditions throughout winter and spring in 2006 resulted in low taxon richness and a pattern similar to that seen during 2003 (Figure 7). Richness was usually much higher than that found immediately downstream where AMD has entered the creek. Taxon richness peaked in 2002 when 42 different taxa were recorded in December. The lowest numbers of taxa were recorded in September 2003 and September 2006 when 13 and 14 taxa were recorded, respectively (Figure 7). Stream spot pH fluctuated over the years from 6 to 8 until December 2006 when it peaked with a value approaching 9.

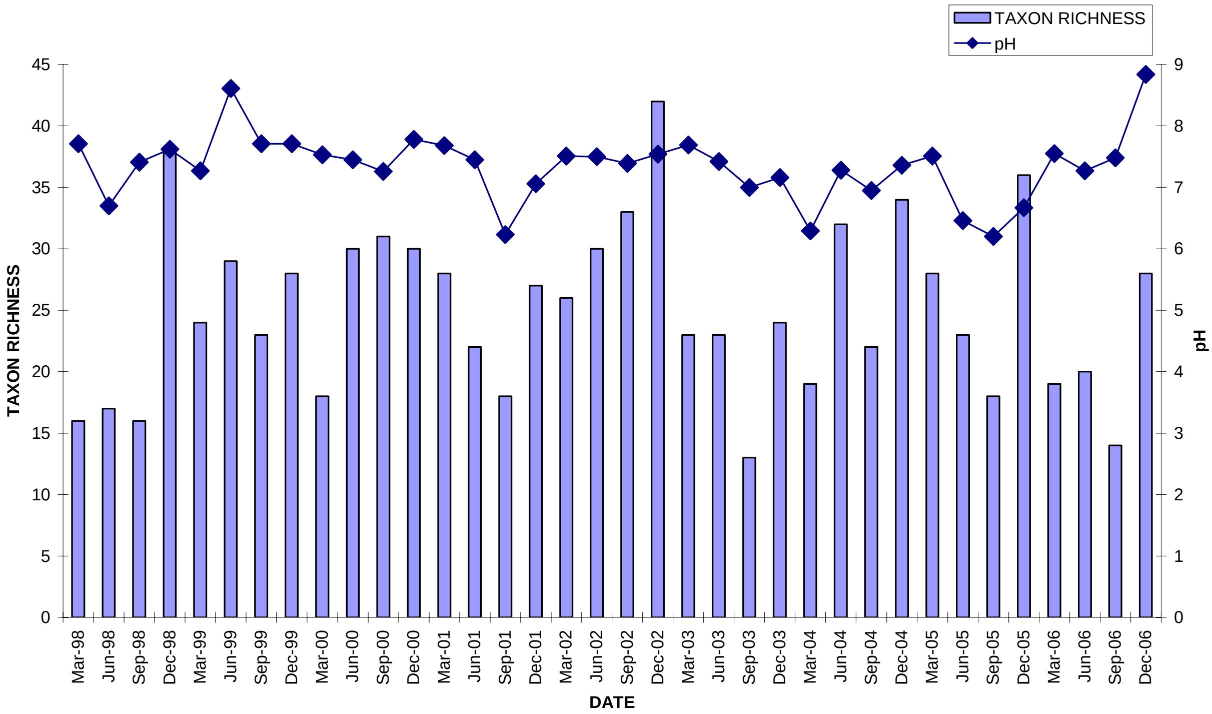

***Figure 7*. Dawesley Creek: Peggy Buxton Road. Taxon richness and pH.**

Brukunga Mine

The pH measurement in December 2003 was the first recorded above 7 since the diversion became operational. Measurements in 2004 followed this trend showing the highest recorded pH for March and June since 1996 and again, circumneutral conditions in September and December 2004 (see Figure 8). In 2004, the maximum taxonomic richness was recorded for all seasons except for December where it was marginally higher in 2003. The second lowest spot pH since the diversion was recorded in March 2006. Although pH had returned to almost neutral in June and September, all samples in 2006 contained the lowest taxon richness, in comparison with respective months, since 2004 (Figure 8). The site was dry in December for the first time since monitoring began.

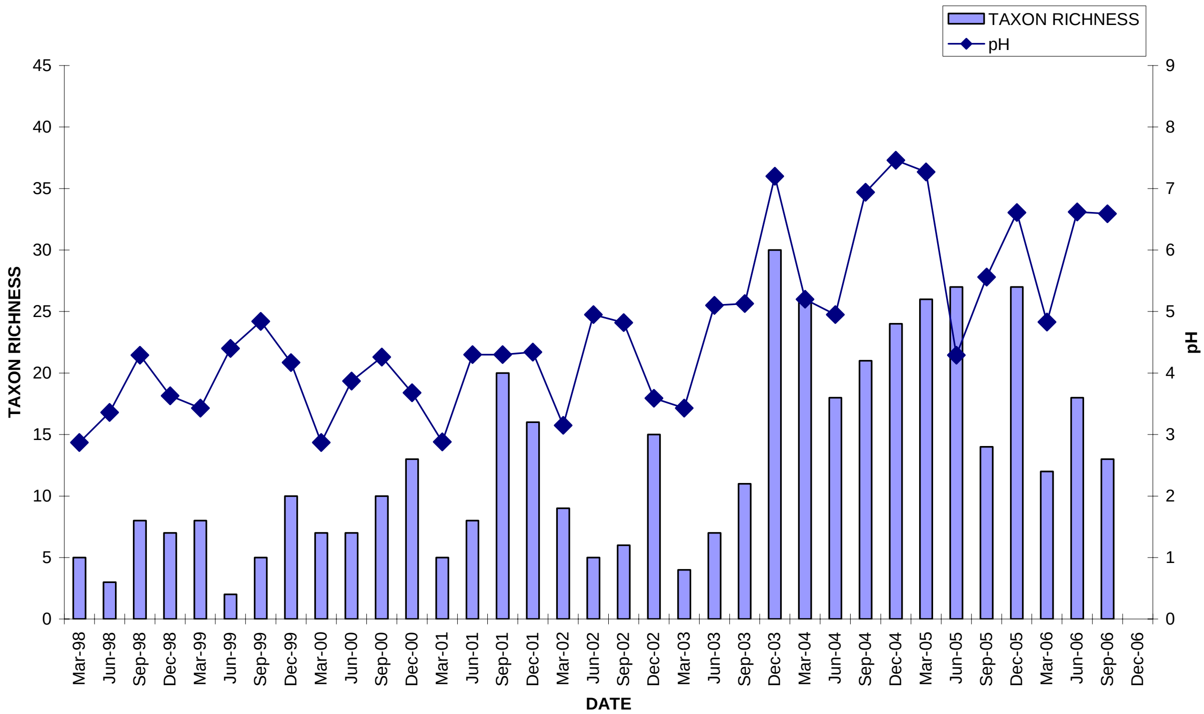

***Figure 8*. Dawesley Creek: Downstream of Brukunga mine. Taxon richness and pH.**

Upstream McIntyre Road

Values of spot pH were the highest in 2006 since monitoring began. The annual minimum was again in June, however the pH was above 7 for all months when surface water was present (Figure 9). The site was not flowing when sampled in December 2006. December 2004 showed the highest richness ever measured at the site. Apart from having a slightly lower richness in September and December, the 2006 samples followed the same taxon richness pattern as that seen in 2004.

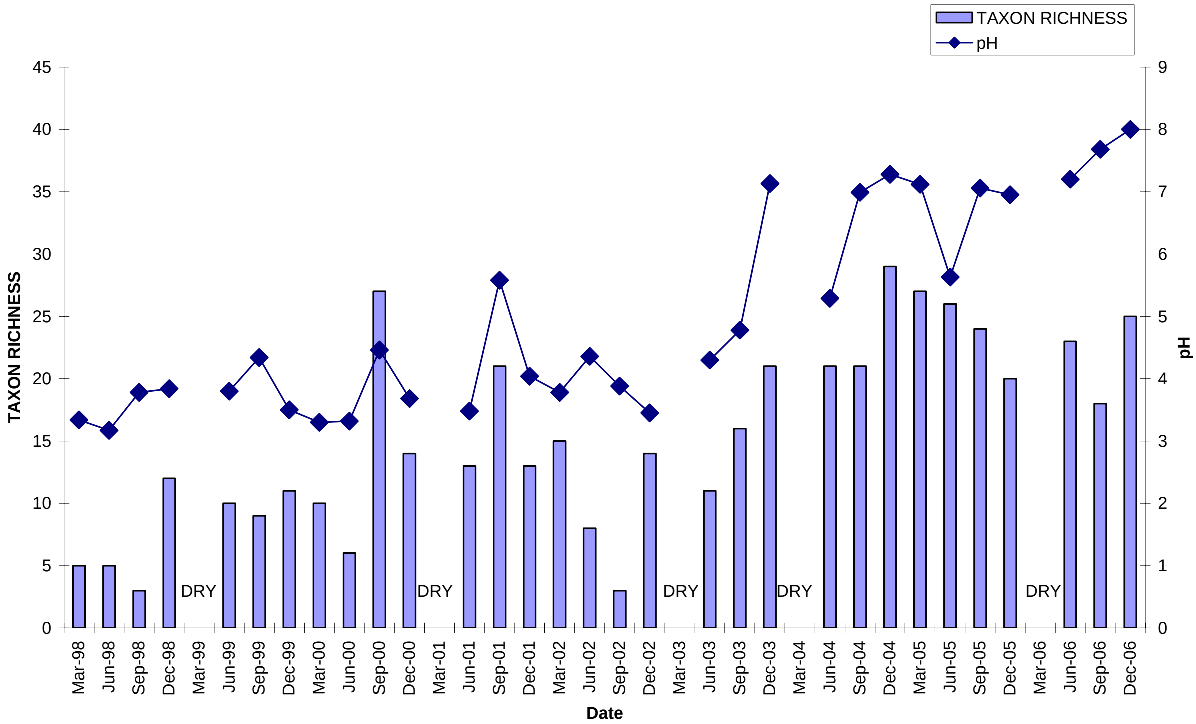

***Figure 9*. Dawesley Creek: McIntyre Road. Taxon richness and pH.**

Balyarta

The section of Dawesley Creek downstream of its confluence with Nairne Creek was usually dry in late summer and early autumn. The 1996/97 and 2004/05 summers were wetter, and drying of the stream was not observed (Figure 10). There was variation from year to year in the degree of effect of low pH water from the mine at this site. These year to year variations are dependent on the amount of rainfall and flow. The 2005 data followed the pattern shown in most years since 1997, i.e. the taxon richness decreased when the AMD influence extended downstream (Figure 10). The stream pH in 2005 provided four consecutive values higher than 6, the first occurrence in the dataset (Figure 10). A pH of 8.3 in September 2005 eclipsed the previous highest measurement recorded at the site in the previous September (Figure 10). During 2006, richness showed a typical stepping up in June and September following a characteristic dry channel in March (Figure 10). Spot pH values were within the range of previous years. As mentioned above, the site being dry in December shows the effect of drought conditions.

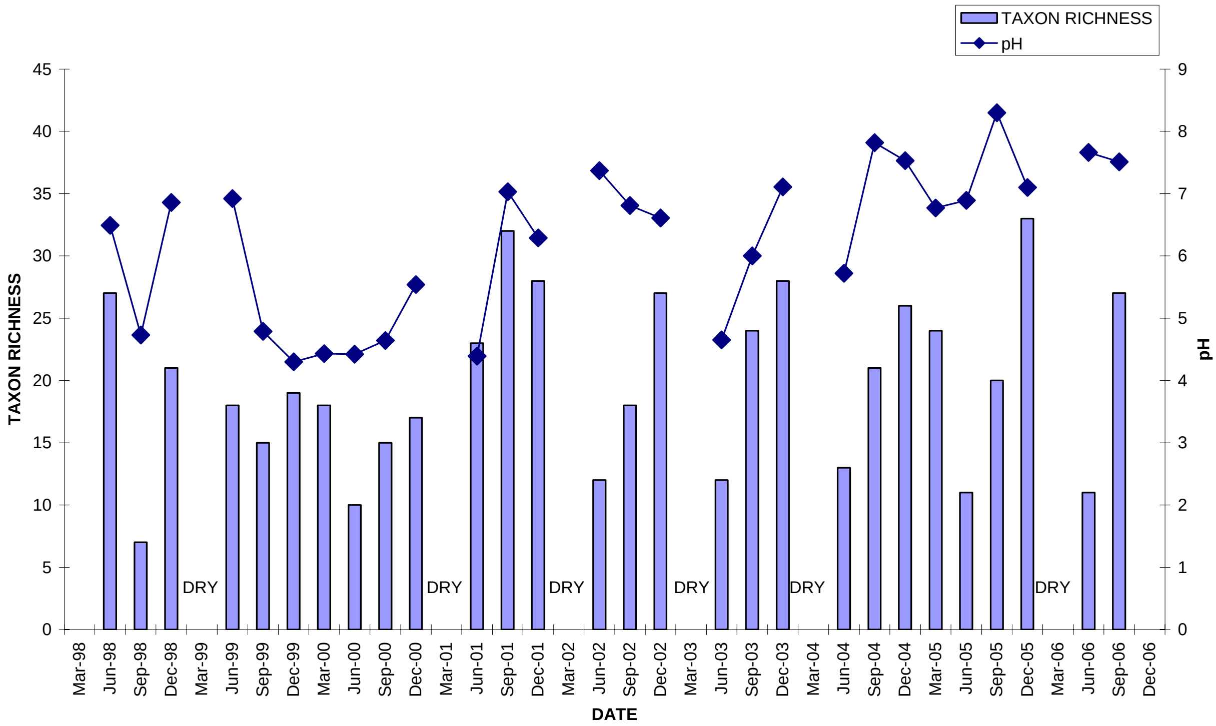

***Figure 10*. Dawesley Creek: Balyarta. Taxon richness and pH.**

Freeway

As this is an intermittently flowing site, the taxon richness has been variable over the years of monitoring (Figure 11). Simply by chance, sampling may have taken place a few days, a few weeks or a few months after the site was wetted. Consequently, the time for the community to establish at the site before sampling occurred also varied. In some cases the time was sufficient for a diverse community to establish but at other times there may have been only a short time between inundation and sampling. The samples from 2003 were thought to be affected somewhat by AMD as the pH was about 5 on each sampling occasion. Results for 2004-2006 were very similar, though surface water appeared earlier, and also dried earlier in the year in 2006 (Figure 11). During 2004-2006, the pH was alkaline to neutral, which suggests that the AMD influence was subdued or absent at these times.

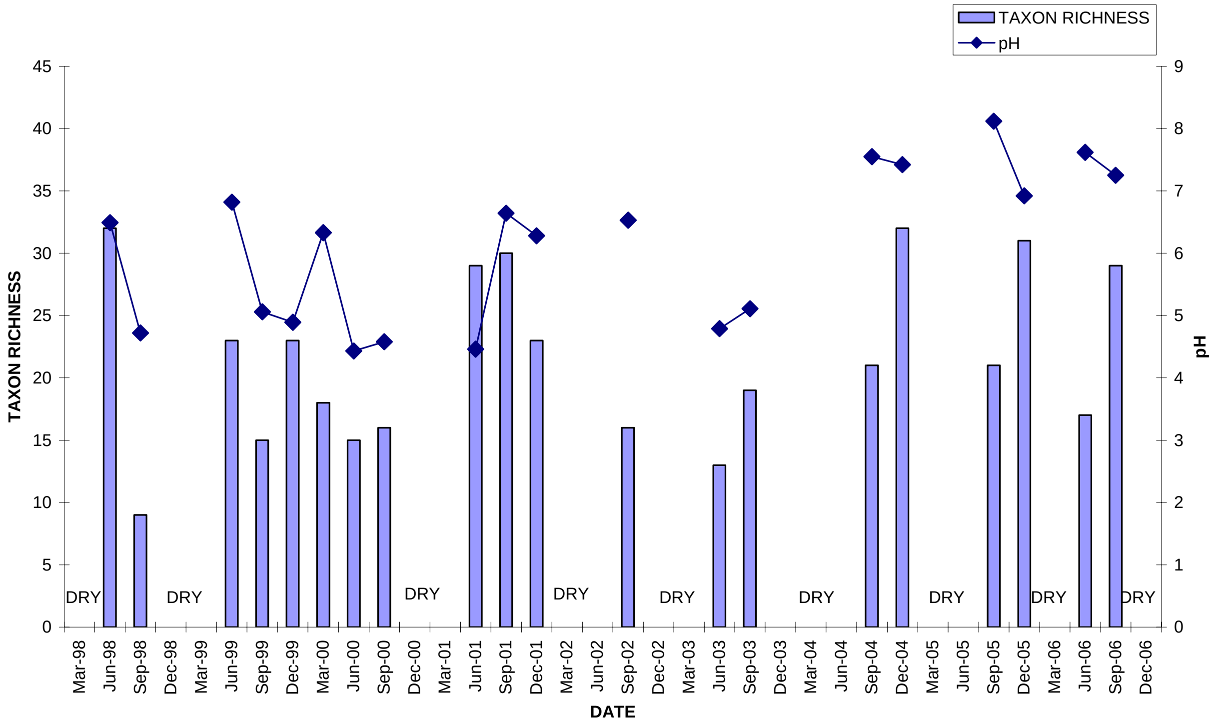

***Figure 11*. Dawesley Creek: Freeway. Taxon richness and pH.**

Nairne Creek

From 1996 to 2003 this local reference site was slightly eutrophic but had a taxon richness and pH that was comparable to other Mount Lofty Ranges streams with reasonable water quality (Figure 12). It reflected the condition expected to prevail in Dawesley Creek if AMD and treated wastewater from the Bird-in-Hand WWTP were not present, with highest taxon richness in winter and spring. The surface hydrology of Nairne Creek experienced a major change during 2004 and 2005. Consequently, ecological changes occurred. During these two years, the stream was dry in March, and June values of taxon richness and pH were markedly lower than for the previous December (Figure 12). That pattern was not continued in 2006; the minimum spot pH for the year was associated with the first sample (March) however, values for taxon richness were >25 in each sample and comparable with 1998-2003 (Figure 12).

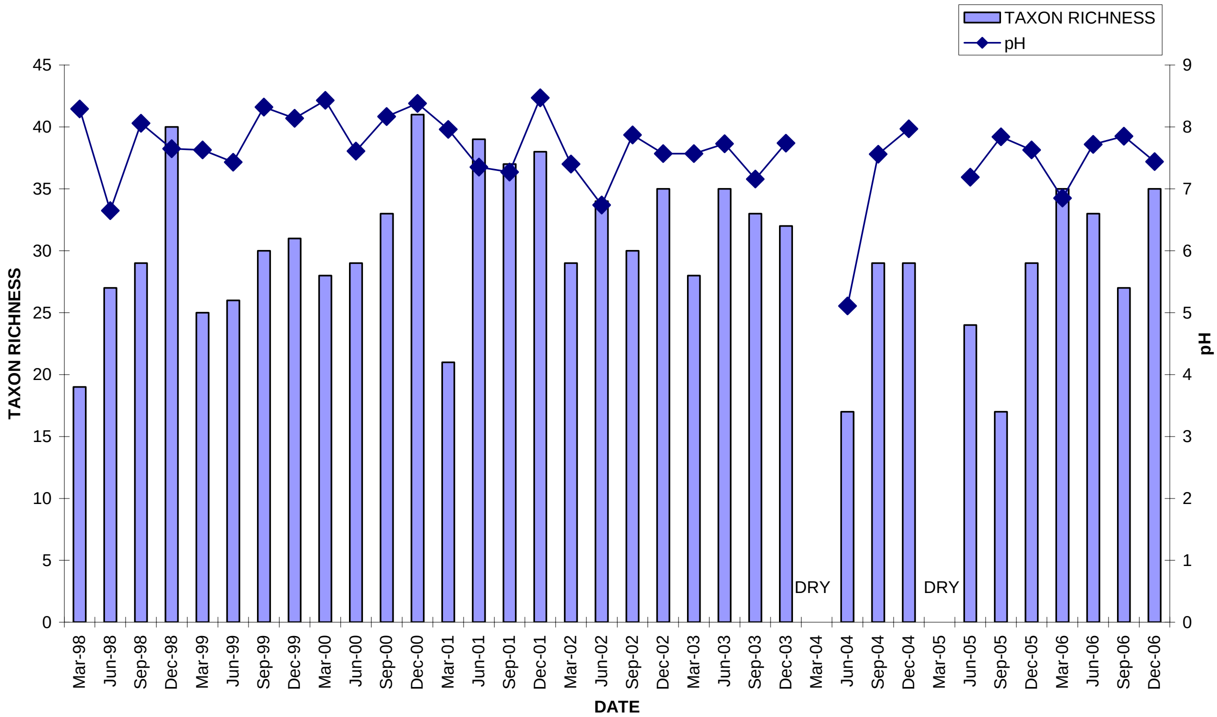

***Figure 12*. Nairne Creek. Taxon richness and pH.**

AusRivAS Results

Six seasonal models were used in this study; the autumn edge and riffle model, spring edge and riffle model and the combined season edge and riffle models. The samples from March and June were tested in the autumn edge model and the samples from September and December were tested in the spring edge model. The combined season edge model data was produced by summing the abundance of each invertebrate family in the June and December samples. The riffle samples from June were tested in the autumn riffle model and those from September were tested in the spring riffle model. The combined season riffle model data was produced by summing the abundance of each taxon in the June and September samples. Results from the AusRivAS models for the 2006 data are shown in Table 2.

Peggy Buxton Road was rated the same as local reference sites for March and December edge models, while the June and September edge and riffle models rated the site as having a slight impairment of ecological health (Table 2). Balyarta and the Freeway were dry in March and December and received ratings indicative of a slight impairment of ecological health (Table 2) in June and September. McIntyre Road was also dry in March, but was rated the same as local reference sites in the June edge model, and received ratings indicative of a slight impairment of ecological health (Table 2) in the September and December edge models. The Brukunga mine site was dry in December and received ratings indicative of a slight impairment of ecological health (Table 2) in the March, June and September edge models. The riffle model ratings for June and September for the Brukunga mine site were indicative of significant impairment of ecological health (Table 2). Nairne Creek was rated the same as local reference sites for all model outputs (Table 2). The combined season edge model improved the rating at the Brukunga mine site from slightly impaired in June and September to equal to local reference sites. All other sites combined model ratings were the same as the individual season (Table 2).

Table 2. **AusRivAS results for sites sampled in 2006. A equal to reference sites, B slight impairment to ecological health, C significant impairment to ecological health.**

		Peggy Buxton 4728		Brukunga 3158		McIntyre Rd 1951		Balyarta 1822		Freeway 1952		Nairne Creek 1953	
		OE50	Band	OE50	Band	OE50	Band	OE50	Band	OE50	Band	OE50	Band
March	edge	0.84	A	0.51	B	Dry		Dry		Dry		1.15	A
	riffle	Riffle not present		Riffle not present								Riffle not present	
June	edge	0.69	B	0.69	B	0.84	A	0.51	B	0.77	B	1.13	A
	riffle	0.51	B	0.19	C	Riffle not present		0.55	B	Riffle not present		1.03	A
Sept	edge	0.6	B	0.58	B	0.59	B	0.64	B	0.72	B	0.8	A
	riffle	0.64	B	0.37	C	Riffle not present		0.66	B	Riffle not present		0.98	A
Dec	edge	1.05	A	Dry		0.73	B	Dry		Dry		0.98	A
	riffle	Riffle not present				Riffle not present						Riffle not present	
Combined Jun/Sept	edge	0.76	B	0.87	A	0.71	B	0.59	B	0.6	B	1.07	A
	riffle	0.59	B	0.24	C	Riffle not present		0.55	B	Riffle not present		0.93	A

A feature of the AusRivAS model is the Predicted Taxa output, the model generates a probability value (ranging between 0 and 1) of each family being present in a sample. This is not based on detailed information of the biology of the animals but on statistical relationships between the physical and chemical characteristics of streams and the distribution patterns of families across reference sites. The larger the percentage that a taxa is predicted at a site the more weighting it carries towards the Observed versus Predicted taxa output (OE50), which is the final probability determining the AusRivAS model output rating. Taxa which are considered to be missing from samples are those which are predicted to be at a site with a probability greater than 0.5, but were not collected. The missing animals of the most concern are those with the highest probability values, particularly if they are absent from a number of samples from a single site or catchment. This being the first time riffles have been sampled there is no previous data with which to draw comparisons. It was recommended in the 2005 report that taxa highly predicted by the AusRivAS autumn and spring riffle models be identified and their presence at sites monitored during 2006 and into the future to see if the riffles are approaching reference site condition and thus improving in ecological health. Table 3 outlines the taxa predicted to be in riffle habitat at the four sites that had riffles sampled in 2006. The light green in Table 3 represents taxa collected, and the dark green represents taxa that were predicted to be collected at a high probability at each site, during the autumn and spring seasons, and were not collected.

By observing the figures in Table 3 it is apparent that the Brukunga mine site received a significantly impaired ecological health rating due to the taxa predicted but not collected throughout the surveys. This amounted to 11 of the highly predicted taxa not being collected during the autumn and six taxa not collected during spring at this site. Peggy Buxton and Balyarta received slightly impaired ecological health ratings, having not collected seven and five respectively of the highly predicted taxa during autumn and four each during spring. Nairne Creek received a rating of ecological health equal to local reference sites; having not collected only one highly predicted taxa during autumn and two during spring.

There are some families of macroinvertebrates marked blue in Table 3 that are predicted at a high probability and missing at most AMD affected sites. The return of these macroinvertebrates should be monitored in future surveys to determine if recovery of riffle habitats is occurring.

Table 3. **Macroinvertebrate families predicted by the autumn and spring riffle AusRivAS model. >> collected at the site, 0.7 to1.0 predicted at site >70 % and not collected, no colour predicted at a site at between 50 and 66 % and not collected. Note that taxa predicted between 50 and 69% which were not recorded from any site were deleted from the comparison. Cells coloured blue represent macroinvertebrates to look for in future surveys as evidence for improvement in ecological health.**

Family	Common name	Balyarta	Nairne	Mine	Peggy Buxton
Autumn Riffle					
Dugesiidae	Flatworm	0.51	»0.50	0.5	»0.50
Nematoda	Nematode	»0.87	»0.87	0.87	»0.87
Hydrobiidae	Freshwater snail	0.9	»0.89	0.9	0.9
Oligochaeta	Freshwater worms	»0.98	»0.98	0.98	»0.98
Acarina	Water mites	»0.88	»0.88	0.89	0.89
Ceinidae	Scuds	0.8	»0.79	0.79	0.79
Collembola	Springtails	»0.58	»0.58	»0.58	»0.58
Ceratopogonidae	Biting midges	»0.83	»0.83	0.83	»0.83
Simuliidae	Black fly larvae	»0.95	»0.95	0.95	»0.95
Tanypodinae	Non-biting midge larvae	0.86	»0.86	0.86	0.86
Orthocladiinae	Non-biting midge larvae	»0.98	»0.97	»0.97	»0.97
Chironominae	Non-biting midge larvae	»0.98	»0.98	»0.98	»0.98
Gripopterygidae	Stone fly	0.84	»0.82	0.83	0.84
Hydrobiosidae	Predacious caddis fly	0.75	0.71	0.72	0.73
Hydroptilidae	Micro caddis fly	»0.74	»0.73	0.73	0.73
Hydropsychidae	Net spinning caddis fly	0.55	»0.53	0.53	0.54
Leptoceridae	Stick caddis	0.54	»0.54	0.54	0.54
Spring Riffle					
Dugesiidae	Flatworm	0.5	»0.55	0.57	0.57
Nematoda	Nematode	»0.97	»0.98	»0.97	»0.97
Hydrobiidae	Freshwater snail	0.9	»0.89	0.85	0.88
Oligochaeta	Freshwater worms	»1.00	»1.00	»1.00	»1.00
Acarina	Water mites	»0.96	»0.96	0.91	0.94
Ceinidae	Scuds	»0.87	»0.91	0.95	»0.96
Collembola	Springtails	»0.50	»0.51	»0.55	»0.56
Ceratopogonidae	Biting midges	»0.87	»0.86	0.83	0.82
Simuliidae	Black fly larvae	»0.96	»0.96	0.96	»0.96
Tanypodinae	Non-biting midge larvae	0.92	»0.91	0.9	»0.91
Orthocladiinae	Non-biting midge larvae	»1.00	»1.00	»0.99	»1.00
Chironominae	Non-biting midge larvae	»0.98	»0.99	»1.00	»1.00
Leptophlebiidae	Mayfly	0.76	0.75	0.59	0.59
Hydrobiosidae	Predacious caddis fly	0.77	0.75	0.59	0.59
Hydroptilidae	Micro caddis fly	0.66	»0.70	0.66	0.72

Multivariate Analysis Results

Cluster analysis

Results of the cluster analysis are presented in a dendrogram (Figure 13) which shows the grouping of samples with similar macroinvertebrate assemblages. For the purpose of interpretation, five groups were identified from the dendrogram. These groups are labelled 1-5 in Figure 13 and the group membership is listed in Table 4. About half of the samples were allocated to Group 1 – which comprised all but one sample from the local reference sites plus three 2006 samples from other sites (Table 4). Group 2 contained only a single Nairne Creek sample. Group 3 contained samples from the downstream section of the study reach, collected in both 2002 and 2006. Samples in Group 4 included a number of taxa that were uncommon in the data set. Finally, the samples in Group 5 were collected in 2002 from sites proximal to the AMD discharge point (Table 4).

Table 4. **Group membership of cluster analysis.**

Group	Designation	Sites	Years	Months
1	Local reference sites and improved AMD-exposed sites	Peggy Buxton	both	All
		Nairne Creek	2002	All
			2006	June-December
		McIntyre Road	2006	June, September
		Freeway	2006	September
2	One Nairne Creek sample with relatively many taxa, some common taxa missing and some uncommon taxa present	Nairne Creek	2006	March
3	Most downstream sites	Balyarta	2002	June-December
			2006	June
		Freeway	2002	September
			2006	June
4	Some uncommon taxa present	Brukunga	2002	June
			2006	March, June
		McIntyre Road	2002	June
			2006	December
		Balyarta	2006	September
5	Sites receiving AMD	Brukunga	2002	March, September, December
		McIntyre Road	2002	March, September, December

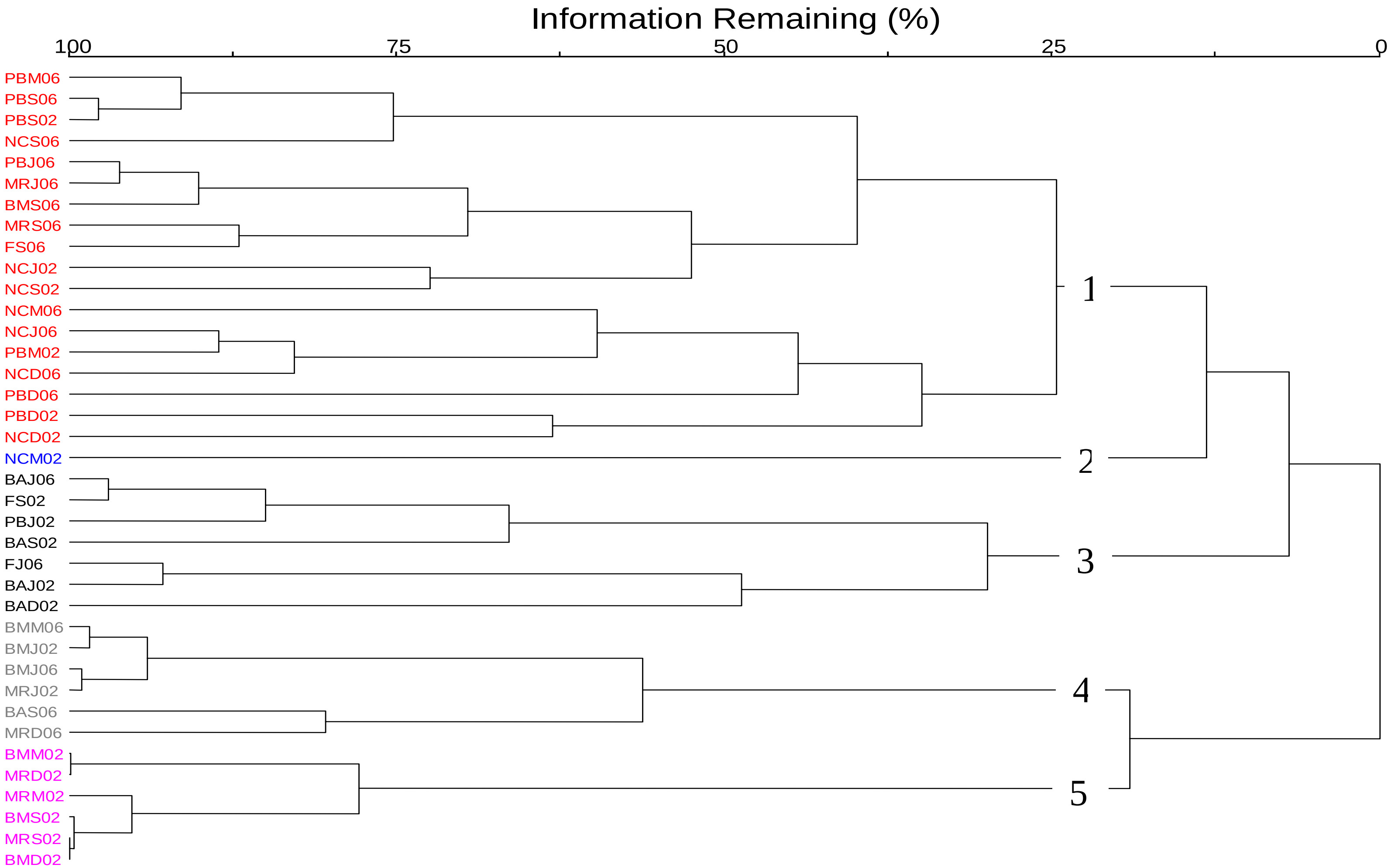

Figure 13. **Dendrogram of 2002 and 2006 edge samples. (First two letters designate site. PB = Peggy Buxton Road, BM = D/S Brukunga, MR = McIntyre Road, BA = Balyarta, F = Freeway, NC = Nairne Creek. Third letter designates month, M = March, J = June, S = September and D = December. Digits indicate year of collection). Interpretation of Groups 1-5 is provided in Table 3.**

Ordination 2002, 2006

The NMS ordination in 3 dimensions did not confirm all of the cluster groupings to be clearly defined. Groups 1, 3 and 4 all shared boundaries and the single-sample Group 2 represented an outlier only (Figure 14). However, Group 5 was clearly defined in the ordination space (Figure 14).

The same ordination data are presented with each site and year labelled in Figure 15. Samples from local reference sites occupy the upper left quadrant of the plot (Figure 15). Most distant from the local reference sites along axis 1 are 2002 samples from Brukunga Mine and McIntyre Road; and in the direction of axis 2 the least similar samples are Balyarta and Freeway samples in 2002 (Figure 15). Of the 2006 samples from sites that have been exposed to AMD, those from McIntyre Road and Brukunga Mine were positioned close to the cluster of local reference site samples and were at a marked distance along axis 1 from samples from those sites in 2002 (Figure 15). This suggests that between 2002 and 2006, the macroinvertebrate species at McIntyre Road and Brukunga Mine had changed and become more similar to that at local reference sites that have not been exposed to AMD.

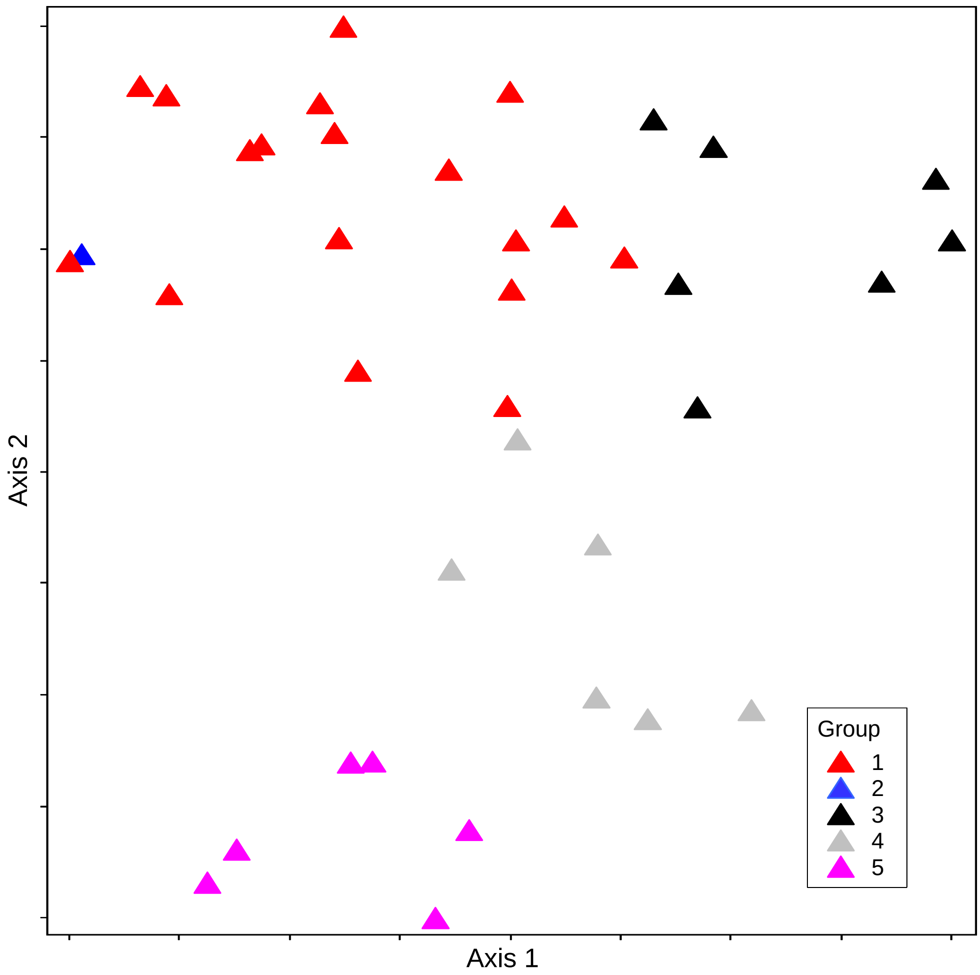

***Figure 14.* SSH Ordination of 2002 and 2006 edge samples.** Group numbers are those from the cluster analysis.

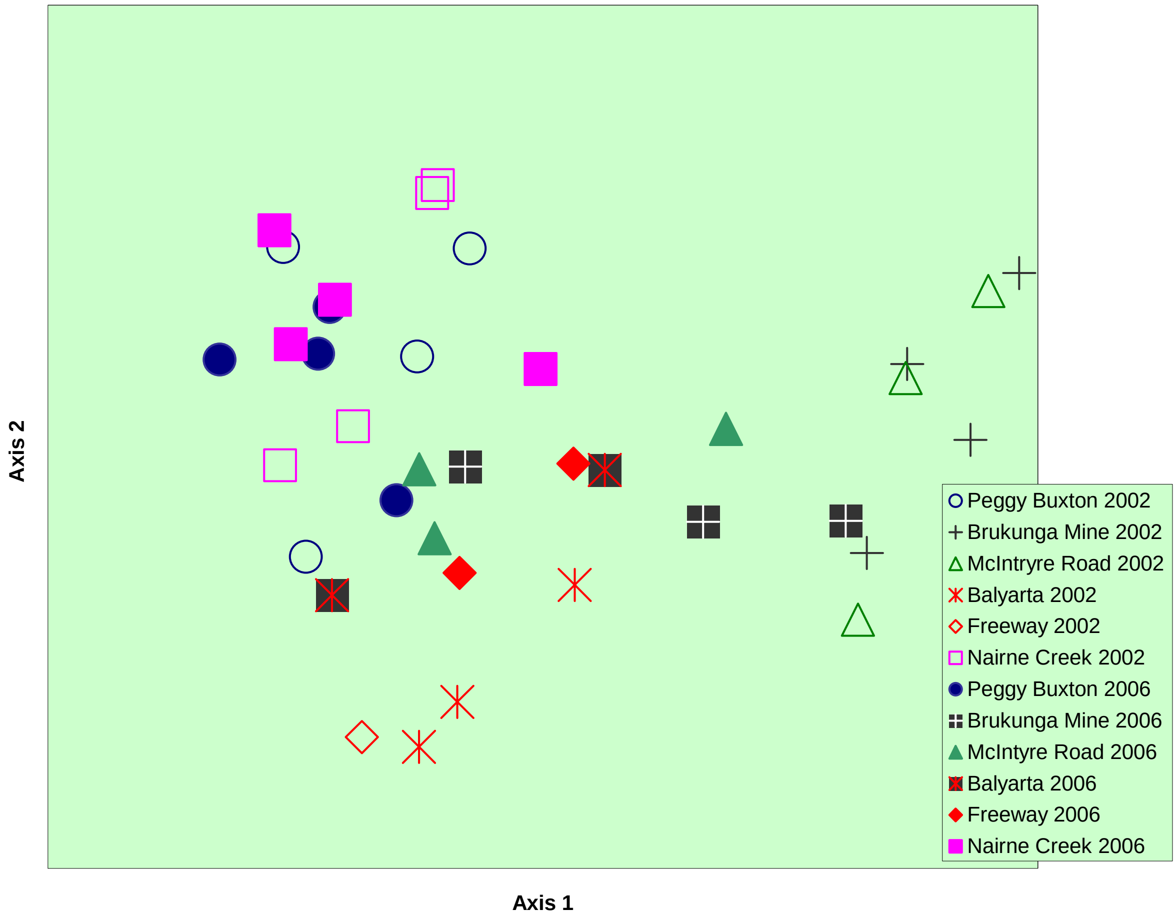

Figure 15. **SSH Ordination of 2002 and 2006 samples.** Samples from the same site have the same symbol shape; 2002 samples have unshaded symbols and 2006 samples have solid symbols.

4. Discussion and Recommendations

During this monitoring program, the water in Dawesley Creek has altered from an acidic state that was unsuitable as habitat for most macroinvertebrates to an environment that more frequently resembles reference condition. The construction of the diversion around the mine site in 2003 was intended to isolate the mine and prevent much of the contamination (Randall and Cox, 2003). The indications from the 2006 monitoring is that Dawesley Creek is improving compared to the conditions prior to the diversion. The driest winter on record however has contributed independently of AMD to a decline in stream health, taxonomic richness and AusRivAS scores from those recorded in 2004 and 2005.

The occurrence of surface water at the monitoring sites was less frequent than average in 2006 and the most similar year of flow during the duration of monitoring was considered to be 2002. Macroinvertebrate richness at sites downstream of Brukunga Mine resembled levels at the local reference sites on most occasions. Although the degree of variation has been large, the average richness at Dawesley Creek sites downstream of Brukunga Mine since 2003 remains higher than values from the 1996 to 2002 data.

Peggy Buxton received AusRivAS results equal to reference condition in March and December; and slightly impaired ecological health in June and September. This site receives treated waste water (WW) from the Bird in Hand waste water treatment plant. During the drier months of March and December the treated WW would usually be the only reason the site has surface water present, providing a refuge for macroinvertebrates, even in the presence of the often eutrophic conditions. It is this presence of surface water during the drier months that has lead to equal to reference site macroinvertebrate assemblage. Peggy Buxton, during June and September, would usually have the largest proportion of its flow contributed from natural rainfall runoff which improves habitat, making it more favourable to a wider assemblage of macroinvertebrates. The dry conditions during 2006 have altered the percentage of WW in the flows and hence impacted the usual flow regime. This could be the reason for the slightly impaired ecological health ratings for this site in June and September.

In general the AMD influenced sites on Dawesley Creek had AusRivAS results indicating slight impairment to ecological health. These sites also endured periods of dry conditions which would have resulted in less invertebrate drift, reducing the chances of re-colonisation of macroinvertebrate in the AMD influenced reaches of Dawesley Creek.

For all survey's the AusRivAS results for Nairne Creek were favourable, it seems strange that during our driest year and winter on record that Nairne Creek continued to flow; it was mentioned in the 2005 report that it was our belief from a comment made by the land owner adjacent the Nairne Creek site that the Chapman's factory contributed significant water to Nairne Creek year round from condensation from many fridges and since the closing of the site the creek has become temporally dry for the first time she could remember. A visit to the old Chapman's factory site on the 13/3/2007 revealed some abattoir activity at the site. A meeting with the site manager occurred and he explained that all internal runoff from abattoir activity is captured by grease traps and flows to a filter plant where greasy residue is filtered and the remaining water pumped to effluent ponds. They are required by law to allow no internal runoff from operations to enter Nairne Creek or leave the site. Runoff from building roofs and outside concreted areas is allowed to flow into Nairne Creek. From this new information the flow in Nairne Creek is most likely from a new or recharged spring contributing water to the Nairne Creek catchment upstream of the site.

MVA indicated that the macroinvertebrate samples from the local reference sites were similar to each other, even for data collected in different years. Grouped with this collection of most of the reference site samples were four samples collected in 2006 from the Dawesley Creek sites downstream of the mine. In 2002, the compostion of macroinvertebrate samples from sites known to receive AMD had little resemblance to that at the local reference sites. In 2006, macroinvertebrates in at least one sample from each of these sites were more similar to those at the local reference sites than they were to 2002 samples from the same site.

Macroinvertebrates from the Class Crustacea and the Phylum Mollusca are particularly sensitive to water of low pH. Low pH water affects the ability of these organisms to secrete the calcareous material which makes up their exoskeleton. Macroinvertebrates from these groups are usually recorded in Dawesley Creek at Peggy Buxton Road and Nairne Creek, however records of them in the past from AMD affected regions in Dawesley Creek are very rare. It has now been four years since the diversion around the mine site; spot pH recordings indicate waters of neutral pH; so why have the crustaceans and molluscs not returned to the AMD affected waters of Dawesley Creek? Close attention for the return of these macroinvertebrates will be given to determine if conditions in Daweseley Creek are approaching reference condition. Unlike many of the macroinvertebrates in the stream that recolonise/repopulate streams via the air (as flying adults), crustaceans and molluscs migrate through the water either through drift or active movement up or down the stream.

In previous years records for molluscs from AMD affected waters have been from Dawesley Creek at the mine and at Balyarta, both these sites are close to a population source from where these molluscs could have migrated or drifted from. In 2006 no molluscs were recorded from AMD affected waters; this is most likely due to the drought reducing flows within Dawesley Creek, thus causing poor recruitment from population sources in non AMD affected waters. The Crustaceans *Partya australiensis* (freshwater shrimp) and *Austrochiltonia australis* (scud) were recorded from Dawesley Creek at Balyarta in June and September and September only respectively. Many shrimps were recorded from Peggy Buxton and many scuds were recorded from Peggy Buxton and Nairne Creek. There does not appear to be any populations of these Crustaceans in AMD affected waters; their presence in low numbers at Balyarta is most likely due to invertebrate drift and temporary colonisation. Close attention to the distribution of Molluscs and Crustaceans is still required in Dawesley Creek to ascertain if the ecological health of the creek is approaching those of the reference sites in the study.

The sampling of riffles for the first time in the study has proven they are a long way from being near reference site condition, however a positive is that black fly larvae were found in June and September at Balyarta giving an indication that a true riffle specialist has returned to the AMD influenced sections of Dawesley Creek. Close attention should be paid to the riffle macroinvertebrates marked in blue in Table 3, to determine if the ecological health of the AMD influenced regions of Dawesley Creek are approaching, or equal, to the condition of reference sites.

Recommendations

It is recommended that riffle habitat continue to be sampled during June and September at Peggy Buxton, Brukunga downstream mine, Balyarta and Nairne Creek and for taxonomic richness graphs at these riffles to be constructed for comparisons between years.

As part of a further investigation the highly predicted taxa in edge samples from the AusRivAS model could be isolated, to determine what type of taxa may be contributing to the impairment of ecological health in the study area. The habitat requirements of the missing highly predicted taxa could be identified and possible reasons for their absence in the AMD influenced sites proposed.

Invertebrate drift could be monitored at the outfall of the diversion pipe and downstream of the Nairne Creek site, to determine which macroinvertebrates are moving from the Peggy Buxton Rd site into the downstream mine site and from Nairne Creek into the Balyarta site. The macroinvertebrate assemblages at the two receiving water sites could be compared to the invertebrate drift, to determine what proportion of the macroinvertebrate assemblage at the downstream mine and Balyarta site is from macroinvertebrates moving into the site from upstream or have established populations at the site.

5. References

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APPENDIX C

METAL CONCENTRATION WITHIN THE ZONE OF IMPACT

Nairne Creek water, upsteam of the ford at Diatadapeel

Grab Sampling Location AWQC 1953

< indicates below analysis detection level

DATE	pH units	TDS by EC total mg/l	CONDUCTIVITY uS/cm	SULPHATE total mg/l	ALUMINIUM total mg/l	CADMIUM total mg/l	CHROMIUM total mg/l	COPPER total mg/l	IRON total mg/l	LEAD total mg/l	MANGANESE total mg/l	NICKEL total mg/l	ZINC total mg/l
20-Jan-2004	7.6	710	1300	118	0.090	<0.0005	<0.003	0.002	0.495	0.0007	0.0689	0.0052	0.006
17-Feb-2004		no flow											
10-Mar-2004		no flow											
15-Apr-2004		no flow											
19-May-2004		no flow											
18-Jun-2004	7.6	460	830	106	2.160	<0.0005	0.007	0.009	2.26	0.0029	0.0656	0.0073	0.069
14-Jul-2004	7.7	700	1280	114	0.441	<0.0005	<0.003	0.007	0.637	<0.0005	0.0102	0.0077	0.049
19-Aug-2004	7.9	1000	1820	123	0.667	<0.0005	<0.003	0.007	1.02	0.0006	0.0531	0.0062	0.046
15-Sep-2004	7.9	1100	2024	138	0.150	<0.0005	<0.003	<0.001	0.54	<0.0005	0.0783	0.0069	0.029
19-Oct-2004	9	1700	3120	268	0.031	<0.0005	0.004	0.004	0.438	<0.0005	0.0861	0.0072	0.008
9-Nov-2004	8	1000	1850	117	0.234	<0.0005	0.005	0.004	0.554	<0.0005	0.0321	0.0058	0.019
15-Dec-2004	8	720	1310	99	0.063	0.0006	<0.003	0.005	0.552	<0.0005	0.0249	0.006	0.014
12-Jan-2005		no flow											
11-Feb-2005		no flow											
7-Mar-2005		no flow											
13-Apr-2005		no flow											
02-May-2005	7.4	770	1390	160	0.255	<0.0005	<0.003	0.011	0.503	<0.0005	0.0186	0.0047	0.031
15-Jun-2005	7.7	630	1150	122	0.694	<0.0005	<0.003	0.013	1.21	0.0019	0.1095	0.0009	0.036
13-Jul-2005	7.6	870	1570	105	0.198	<0.0005	<0.003	0.005	0.239	<0.0005	0.0085	0.0022	0.033
23-Aug-2005	8.1	580	1050	71.8	0.439	<0.0005	<0.003	0.004	0.523	0.0006	0.0075	<0.0005	0.016
05-Sep-2005	8.3	860	1550	115	0.170	<0.0005	0.004	0.005	0.334	<0.0005	0.0095	0.0024	0.021
18-Oct-2005	7.9	930	1690	107	0.112	<0.0005	<0.003	0.006	0.287	<0.0005	0.0204	0.0071	0.022
21-Nov-2005	7.8	871	1580	99	0.124	<0.0005	<0.003	0.0053	0.366	<0.0005	0.0236	0.0056	0.016
15-Dec-2005	8.2	799	1450	83.1	0.035	<0.0005	<0.003	0.0043	0.124	<0.0005	0.0041	0.0069	0.009
11-Jan-2006	7.6	816	1480	84.3	0.082	<0.0005	<0.003	0.0036	0.108	<0.0005	0.0343	0.0053	0.006
14-Feb-2006		no flow											
14-Mar-2006	8.2	594	1080	81	0.125	<0.0005	<0.003	0.0034	0.206	<0.0005	0.003	0.0046	0.008
17-Apr-2006	7.9	572	1040	60.6	0.055	<0.0005	<0.003	0.0029	0.17	<0.0005	0.005	0.0029	0.007
22-May-2006	7.5	567	1030	63.9	0.180	<0.0005	0.006	0.0032	0.43	<0.0005	0.0174	0.0035	0.012
13-Jun-2006	7.8	572	1040	45.9	0.028	<0.0005	0.003	0.0014	0.134	<0.0005	0.0062	0.0024	0.006
17-Jul-2006	7.5	760	1380	69.9	0.137	<0.0005	<0.003	0.0038	0.409	0.0006	0.0242	0.0033	0.023
15-Aug-2006	7.6	720	1300	66	0.079	<0.0005	0.005	0.0035	0.369	<0.0005	0.0133	0.0029	0.014
12-Sep-2006	7.9	570	1040	45.9	0.041	<0.0005	<0.003	0.0025	0.183	<0.0005	0.0062	0.0023	0.006
12-Oct-2006	7.4	690	1260	72.3	0.047	<0.0005	<0.003	0.0027	0.246	<0.0005	0.007	0.0033	0.01
15-Nov-2006	7.5	650	1180	63.6	0.038	<0.0005	<0.003	0.0038	0.148	<0.0005	0.0045	0.0027	0.007
13-Dec-2006	7.5	780	1420	66.6	0.032	<0.0005	<0.003	0.0017	0.231	<0.0005	0.0355	0.0042	0.009

1992 ANZECC GUIDELINES FOR WATER QUALITY **(highlighted value indicates the recorded value exceeds the recommended guideline)**

For Aquatic		1,000	**for pH<6.5**	no value	0.005	0.0002	0.01	0.002	1.0	0.001	no value	0.015	0.005
Ecosystems	6.5 - 9.0	1,000	**for pH>6.5**	no value	0.1	0.002	0.01	0.005	1.0	0.005	no value	0.15	0.05
Irrigation	4.5 - 9.0	3,500		no value	5	0.01	1.00	0.2	1.0	0.2	2	0.2	2
Livestock	no value	3,000		1,000	5	0.01	1.00	0.5	no value	0.1	no value	1	20

Fig C-1. Nairne Creek (control, not influenced by mine drainage)

Peggy Buxton Road, Dawesley Creek water upstream of the Mine Site

Grab Sampling Location AWQC 4728

< indicates below analysis detection level

DATE	pH units	TDS by EC total mg/l	CONDUCTIVITY uS/cm	SULPHATE total mg/l	ALUMINIUM total mg/l	CADMIUM total mg/l	CHROMIUM total mg/l	COPPER total mg/l	IRON total mg/l	LEAD total mg/l	MANGANESE total mg/l	NICKEL total mg/l	ZINC total mg/l
20-Jan-2004	7.7	970	1760	88.7	0.570	<0.0005	<0.003	0.002	0.921	0.0013	0.0423	0.007	0.008
17-Feb-2004	7.7	1,000	1870	62.7	0.510	<0.0005	0.005	0.005	0.815	0.0010	0.0706	0.0059	0.01
10-Mar-2004	7.7	1,100	1940	64.2	0.338	<0.0005	<0.003	<0.001	0.727	0.0006	0.0605	0.0042	<0.003
15-Apr-2004	7.8	1,000	1830	135.0	0.319	<0.0005	<0.003	0.001	0.446	<0.0005	0.0209	0.0036	0.003
19-May-2004	7.7	1,300	2380	153.0	0.373	<0.0005	0.008	0.004	0.569	0.0006	0.0389	0.0049	0.018
18-Jun-2004	7.7	970	1760	101.0	1.050	<0.0005	0.004	0.003	1.46	0.0007	0.0435	0.0049	0.012
14-Jul-2004	7.6	790	1430	78.0	0.649	<0.0005	0.005	0.014	1.31	0.001	0.0385	0.0058	0.019
19-Aug-2004	7.3	950	1720	85.1	0.421	<0.0005	<0.003	0.004	1.11	0.0007	0.0874	0.0037	0.024
15-Sep-2004	7.5	940	1700	81.7	0.440	<0.0005	<0.003	0.003	1.2	0.0009	0.0661	0.0059	0.012
19-Oct-2004	8.0	1,200	2100	104.0	0.273	<0.0005	0.004	0.004	0.792	0.0007	0.1003	0.0052	0.013
09-Nov-2004	7.8	870	1580	63.8	0.848	<0.0005	0.006	0.004	1.59	0.0011	0.0642	0.0045	0.013
15-Dec-2004	7.7	840	1530	54.6	0.827	<0.0005	<0.003	0.002	1.01	<0.0005	0.0328	0.004	0.005
12-Jan-2005		no flow											
11-Feb-2005	7.5	930	1680	114.0	0.336	<0.0005	<0.003	0.004	1.77	0.0012	0.1829	0.0067	0.015
22-Mar-2005	7.6	910	1650	111.0	0.307	<0.0005	<0.003	0.003	2.11	0.0009	1.342	0.009	0.011
14-Apr-2005	7.6	950	1720	116.0	0.532	<0.0005	<0.003	0.004	1.65	0.0009	0.663	0.0036	0.012
02-May-2005	8.6	970	1760	140.0	0.187	<0.0005	0.004	0.002	0.484	<0.0005	0.1953	0.0030	0.007
15-Jun-2005	7.6	860	1550	99.9	2.720	<0.0005	0.01	0.007	3.42	0.0022	0.2992	0.003	0.015
13-Jul-2005	7.4	820	1490	62.6	0.460	<0.0005	<0.003	0.003	0.77	<0.0005	0.1406	0.0021	0.008
23-Aug-2005	7.3	880	1600	73.9	0.556	<0.0005	0.003	0.006	0.937	0.0007	0.1063	0.0142	0.028
05-Sep-2005	7.4	900	1640	82.5	0.353	<0.0005	0.005	0.003	1.04	<0.0005	0.2021	0.001	0.009
18-Oct-2005	7.5	1,000	1810	89.4	0.373	<0.0005	<0.003	0.003	1.10	0.0007	0.2176	0.0049	0.009
21-Nov-2005	7.5	1,020	1850	71.7	0.455	<0.0005	0.004	0.0048	1.01	0.0006	0.1076	0.004	0.014
15-Dec-2005	7.7	1,510	832	45.3	0.455	<0.0005	<0.003	0.0016	1.13	0.0007	0.0645	0.0069	0.027
11-Jan-2006		no flow											
14-Feb-2006													
14-Mar-2006		no flow											
17-Apr-2006	7.8	1,130	2050	64.2	0.322	<0.0005	0.003	0.003	1.44	0.0008	0.1756	0.0063	0.014
22-May-2006	7.5	810	1470	44.4	0.356	<0.0005	0.006	0.0026	0.594	<0.0005	0.0262	0.0035	0.009
13-Jun-2006	7.6	849	1540	65.4	0.238	<0.0005	0.004	0.0016	0.519	<0.0005	0.0372	0.004	0.007
17-Jul-2006	7.5	980	1780	59.7	0.149	<0.0005	0.004	0.0031	0.79	0.0005	0.2101	0.0043	0.01
15-Aug-2006	7.4	1,100	1950	81.9	0.341	<0.0005	0.004	0.0014	0.94	<0.0005	0.2892	0.0033	0.005
12-Sep-2006	7.7	850	1540	43.2	0.327	<0.0005	0.004	0.0047	0.805	0.0094	0.0203	0.0032	0.015
12-Oct-2006	7.8	910	1650	52.8	0.457	<0.0005	<0.003	0.0017	0.928	0.0006	0.0281	0.0028	0.007
15-Nov-2006	7.8	1,000	1820	27.9	0.372	<0.0005	0.003	0.0026	1	0.0005	0.0681	0.003	0.007
13-Dec-2006	7.9	1,400	2530	22.2	1.890	<0.0005	0.004	0.003	3.73	0.0017	0.1127	0.0039	0.017

ANZECC GUIDELINES FOR WATER QUALITY **(highlighted value indicates the recorded value exceeds the recommended guideline)**

For Aquatic		1,000	**for pH<6.5**	no value	0.005	0.0002	0.01	0.002	1.0	0.001	no value	0.015	0.005
Ecosystems	6.5 - 9.0	1,000	**for pH>6.5**	no value	0.100	0.0020	0.01	0.005	1.0	0.005	no value	0.15	0.05
Irrigation	4.5 - 9.0	3,500		no value	5	0.01	1.00	0.2	1.0	0.2	2	0.2	2
Livestock	no value	3,000		1,000	5	0.01	1.00	0.5	no value	0.1	no value	1	20

Fig C-2. Dawesley Creek upstream of the mine site

Dawesley Creek water - downstream of the Brukunga Mine Site

Grab Sampling Location AWQC 3158

< indicates below analysis detection level

DATE	pH units	TDS by EC total mg/l	CONDUCTIVITY uS/cm	SULPHATE total mg/l	ALUMINIUM total mg/l	CADMIUM total mg/l	CHROMIUM total mg/l	COPPER total mg/l	IRON total mg/l	LEAD total mg/l	MANGANESE total mg/l	NICKEL total mg/l	ZINC total mg/l
20-Jan-2004	7	1100	2,040	277	1.2	0.002	<0.003	0.005	1.34	<0.0005	0.56	0.0327	0.133
17-Feb-2004	6.9	1300	2310	423	1.0	0.003	<0.003	0.005	2.06	<0.0005	1.20	0.0462	0.308
10-Mar-2004	6.3	1800	3,230	774	1.2	0.002	<0.003	0.002	1.12	<0.0005	1.05	0.0288	0.154
15-Apr-2004	7.2	1300	2,360	564	1.2	0.002	<0.003	0.003	0.97	<0.0005	0.70	0.024	0.110
19-May-2004	6.2	2000	3550	1930	2.3	0.005	0.006	0.003	2.54	<0.0005	1.83	0.0352	0.733
18-Jun-2004	4	1300	2430	1710	129.0	0.016	0.008	0.090	7.19	0.0022	8.63	0.3819	9.820
14-Jul-2004	7	1300	2280	806	2.5	0.003	<0.003	0.008	1.30	<0.0005	1.24	0.0415	0.209
19-Aug-2004	6.4	1300	2350	662	3.3	0.008	<0.003	0.011	1.96	<0.0005	3.57	0.0388	0.705
15-Sep-2004	7	1300	2330	574	5.2	0.004	<0.003	<0.001	2.01	<0.0005	0.86	0.0269	0.278
19-Oct-2004	6.8	1600	2910	956	2.9	0.008	<0.003	0.010	1.60	<0.0005	2.92	0.045	0.566
9-Nov-2004	7.4	1200	2160	535	1.3	0.002	0.004	0.007	0.68	<0.0005	1.60	0.0223	0.097
15-Dec-2004	7.3	960	1740	217	0.6	0.001	<0.003	0.006	0.49	<0.0005	0.49	0.0293	0.039
12-Jan-2005		no flow											
11-Feb-2005	7.2	1400	2440	692	1.5	0.002	<0.003	0.005	11.00	0.001	8.77	0.0298	0.187
22-Mar-2005	7.5	970	1760	211	2.6	0.001	<0.003	0.006	6.12	0.0012	1.02	0.027	0.214
13-Apr-2005	7.3	1600	2870	1220	2.0	0.001	<0.003	0.005	3.02	0.0006	4.35	0.014	0.158
18-May-2005	8.8	1200	2130	528	1.7	0.001	<0.003	0.003	2.11	<0.0005	2.41	0.0359	0.146
15-Jun-2005	4.2	1200	2150	1090	87.1	0.025	0.004	0.034	11.60	0.0007	6.79	0.1473	4.846
13-Jul-2005	6.4	1200	2180	660	24.1	0.008	<0.003	0.015	8.46	0.0015	1.31	0.0355	1.205
23-Aug-2005	7.1	1100	2020	382	8.5	0.004	<0.003	0.010	4.35	0.0016	0.72	0.0181	0.393
5-Sep-2005	6.7	1300	2410	766	3.0	0.004	0.003	0.011	2.25	<0.0005	2.59	0.0383	0.284
18-Oct-2005	6.6	1700	2990	1240	5.2	0.007	<0.003	0.150	2.26	<0.0005	4.09	0.0373	0.398
21-Nov-2005	4.4	1480	2680	969	2.9	0.036	<0.003	0.015	17.80	<0.0005	15.88	0.2282	4.070
15-Dec-2005	7.4	1060	1920	405	4.3	0.005	<0.003	0.012	4.00	0.0006	1.38	0.0346	0.886
11-Jan-2006	7	1210	2190	342	1.6	0.007	<0.003	0.018	3.49	<0.0005	1.81	0.0616	0.333
14-Feb-2006		No Flow											
14-Mar-2006		no flow											
17-Apr-2006	7.5	1130	2050	279	3.1	0.003	<0.003	0.007	3.74	0.0005	1.32	0.0243	0.237
22-May-2006	7.4	844	1530	97.5	28.9	0.009	0.006	0.012	20.50	0.0039	1.08	0.0212	1.350
13-Jun-2006	7.4	899	1630	125	3.5	0.001	0.004	0.003	2.30	<0.0005	0.39	0.0158	0.167
17-Jul-2006	6.4	1300	2420	747	9.9	0.007	0.004	0.013	9.81	0.0007	1.68	0.0492	0.875
15-Aug-2006	7.4	1100	1960	1550	4.1	0.009	<0.003	0.010	1.94	<0.0005	7.71	0.0573	1.250
12-Sep-2006	7.4	1100	1940	369	1.7	0.002	0.004	0.005	0.76	0.0176	1.91	0.0201	0.103
12-Oct-2006	6.9	1800	3260	1440	1.4	0.004	<0.003	0.003	0.94	<0.0005	<0.0005	0.0437	0.328
15-Nov-2006	7	1500	2740	804	1.3	0.002	<0.003	0.004	1.15	<0.0005	6.16	0.0358	0.199
13-Dec-2006		dry											

1992 ANZECC GUIDELINES FOR WATER QUALITY **(highlighted value indicates the recorded value exceeds the recommended guideline)**

For Aquatic		1,000	**for pH<6.5**	no value	0.005	0.0002	0.01	0.002	1.0	0.001	no value	0.015	0.005
Ecosystems	6.5 - 9.0	1,000	**for pH>6.5**	no value	0.1	0.002	0.01	0.005	1.0	0.005	no value	0.15	0.050
Irrigation	4.5 - 9.0	3,500		no value	5	0.01	1.00	0.20	1.0	0.2	2	0.2	2
Livestock	no value	3,000		1,000	5	0.01	1.00	0.5	no value	0.1	no value	1	20

Fig C-3. Dawesley Creek leaving the Brukunga mine site

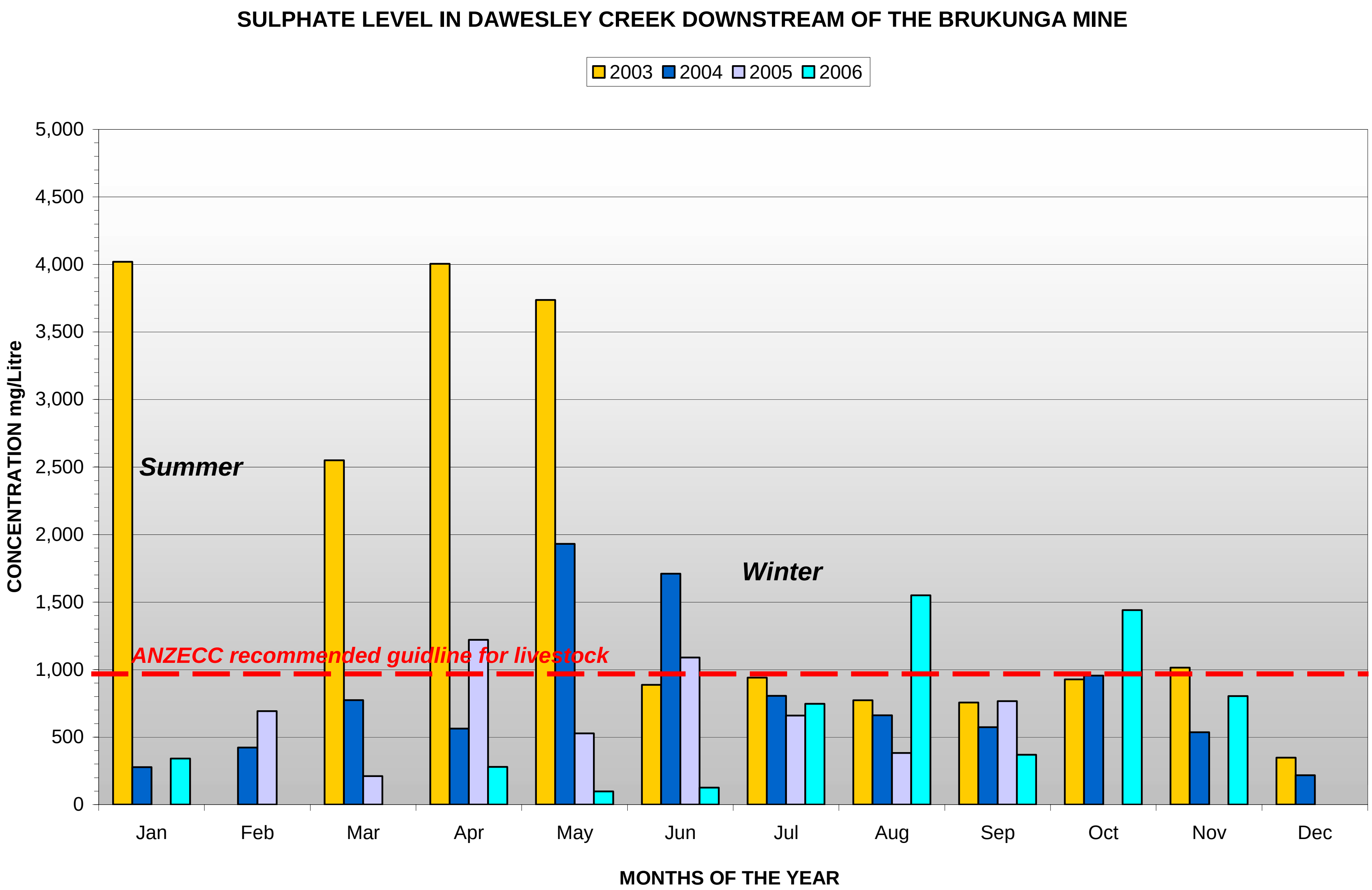

Fig C-4.Sulphate in Dawesley Creek leaving the mine site

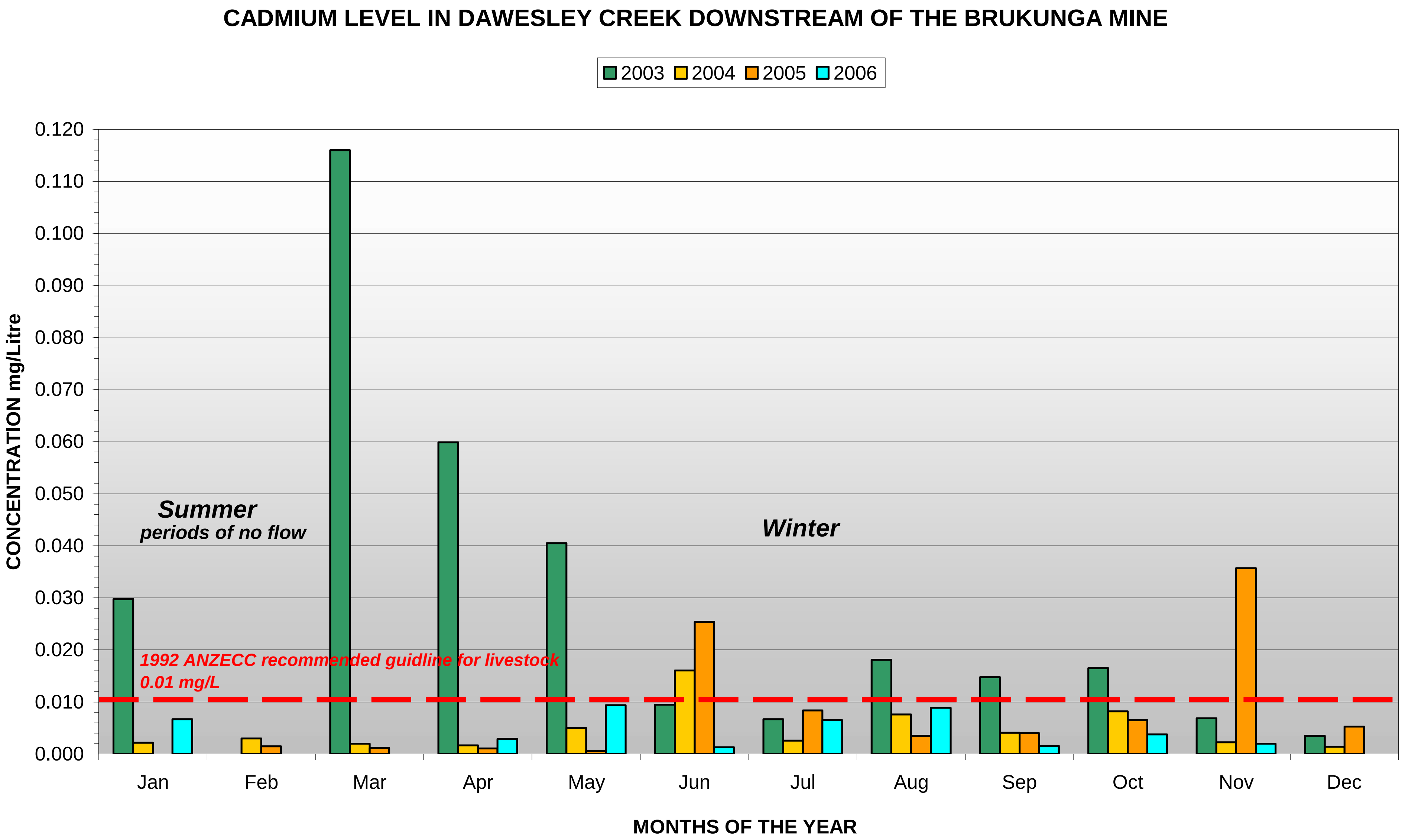

Fig C-5. Cadmium in Dawesley Creek leaving the mine site

Dawesley Creek water - at McIntyre Road (Old Melbourne Bridge)

Grab Sampling Location AWQC 1951

< indicates below analysis detection level

DATE	pH units	TDS by EC total mg/l	CONDUCTIVITY uS/cm	SULPHATE total mg/l	ALUMINIUM total mg/l	CADMIUM total mg/l	CHROMIUM total mg/l	COPPER total mg/l	IRON total mg/l	LEAD total mg/l	MANGANESE total mg/l	NICKEL total mg/l	ZINC total mg/l
20-Jan-2004	5.2	1,400	2440	614	1.08	0.0010	<0.003	0.003	4.74	<0.0005	2.19	0.034	0.16
17-Feb-2004	4.2	1,900	3350	896	2.01	0.0010	<0.003	0.002	5.50	<0.0005	3.37	0.0351	0.17
10-Mar-2004		No Flow											
15-Apr-2004	6.1	1500	2710	710	0.139	0.0006	<0.003	<0.001	0.588	<0.0005	1.3840	0.0239	0.111
19-May-2004	4.4	1,500	2790	766	0.68	0.0011	0.007	0.002	0.54	<0.0005	1.94	0.041	0.37
18-Jun-2004	6	1,400	2530	822	0.30	0.0031	<0.003	0.002	0.21	<0.0005	1.39	0.043	0.45
14-Jul-2004	7.1	1,300	2310	769	0.46	0.0016	<0.003	0.009	0.52	<0.0005	1.64	0.037	0.13
19-Aug-2004	6.9	1,100	2050	508	1.53	0.0059	<0.003	0.006	1.64	<0.0005	2.72	0.033	0.42
19-Sep-2004	7.3	1,200	2210	469	0.82	0.0019	<0.003	<0.001	1.15	<0.0005	1.01	0.030	0.13
19-Oct-2004	6.2	1,600	2900	854	0.22	0.0031	<0.003	0.004	2.73	<0.0005	2.16	0.057	0.42
9-Nov-2004	7.3	1,100	2030	327	0.60	0.0009	0.005	0.005	1.43	<0.0005	0.86	0.024	0.07
16-Dec-2004	7.2	1,200	2100	544	0.45	0.0009	<0.003	0.004	1.02	<0.0005	0.92	0.035	0.08
12-Jan-2005		no flow											
11-Feb-2005	6.9	1,100	2050	479	0.95	0.0014	<0.003	0.006	4.37	<0.0005	2.88	0.029	0.11
22-Mar-2005	7.1	1,200	2240	576	0.12	<0.0005	<0.003	0.003	1.66	<0.0005	0.29	0.017	0.02
13-Apr-2005	7	1,400	2500	725	0.18	<0.0005	<0.003	0.002	1.73	<0.0005	0.05	0.013	0.02
18-May-2005	7.4	1,200	2190	449	0.26	<0.0005	<0.003	0.002	0.81	<0.0005	3.44	0.011	0.01
15-Jun-2005	6.9	900	1630	542	3.11	0.0016	<0.003	0.005	2.32	<0.0005	2.66	<0.0005	0.40
13-Jul-2005	6.1	1,200	2220	585	2.42	0.0071	<0.003	0.009	1.55	<0.0005	2.04	0.059	0.95
23-Aug-2005	7.4	1,000	1860	293	3.43	0.0018	<0.003	0.006	3.00	0.0006	0.68	0.016	0.19
05-Sep-2005	7.3	1,300	2310	652	1.06	0.0031	<0.003	0.006	1.90	<0.0005	3.64	0.042	0.16
18-Oct-2005	6.5	1,600	2870	1200	0.47	0.0100	<0.003	0.007	1.21	<0.0005	4.04	0.080	1.15
21-Nov-05	6.6	1,360	2450	666	0.18	0.0087	<0.003	0.004	1.08	<0.0005	8.00	0.090	0.68
15-Dec-05	7.5	1,090	1980	441	0.36	0.0011	<0.003	0.007	1.39	<0.0005	1.99	0.036	0.20
11-Jan-06	7.3	1,240	2250	417	0.23	<0.0005	<0.003	0.003	3.76	<0.0005	2.23	0.019	0.10
14-Feb-06		No Flow											
14-Mar-06		Dry											
17-Apr-06	7.5	1,180	2140	282	1.25	0.0021	<0.003	0.006	4.31	<0.0005	1.07	0.018	0.13
22-May-06	7.5	988	1790	237	1.07	0.0013	0.005	0.003	2.23	<0.0005	0.65	0.019	0.12
13-Jun-06	7.4	1,210	2190	519	4.39	0.0013	0.003	0.003	1.44	<0.0005	1.12	0.023	0.14
17-Jul-06	7.2	1,300	2410	678	0.47	0.0035	0.003	0.004	1.08	<0.0005	1.95	0.043	0.28
15-Aug-06	6.9	1,500	2720	903	0.07	0.0042	0.004	0.003	0.37	<0.0005	2.58	0.045	0.43
12-Sep-06	7.7	1,000	1900	289	0.34	0.0005	<0.003	0.004	0.75	<0.0005	0.40	0.018	0.05
12-Oct-06	7.1	1,400	2580	792	0.13	0.0008	<0.003	0.002	0.58	<0.0005	0.85	0.014	0.06
15-Nov-06	7.4	1,100	2050	282	0.10	<0.0005	<0.003	0.003	0.86	<0.0005	0.20	0.010	0.01
13-Dec-06	7.5	1,500	2690	537	0.05	<0.0005	<0.003	<0.0010	0.42	<0.0005	<0.0005	0.010	0.02

1992 ANZECC GUIDELINES FOR WATER QUALITY **(highlighted value indicates the recorded value exceeds the recommended guideline)**

For Aquatic		1,000	**for pH<6.5**	no value	0.005	0.0002	0.01	0.002	1.0	0.001	no value	0.015	0.005
Ecosystems	6.5 - 9.0	1,000	**for pH>6.5**	no value	0.1	0.002	0.01	0.005	1.0	0.005	no value	0.15	0.05
Irrigation	4.5 - 9.0	3,500		no value	5	0.01	1.00	0.2	1.0	0.2	2	0.2	2
Livestock	no value	3,000		1,000	5	0.01	1.00	0.5	no value	0.1	no value	1	20

Fig C-6. Dawesley Creek downstream at Melbourne Bridge

Dawesley Creek water, downstream Nairne Creek (Bremer SVY LOC 5A)

Grab Sampling Location AWQC 1822

< indicates below analysis detection level

DATE	pH units	TDS by EC total mg/l	CONDUCTIVITY uS/cm	SULPHATE total mg/l	ALUMINIUM total mg/l	CADMIUM total mg/l	CHROMIUM total mg/l	COPPER total mg/l	IRON total mg/l	LEAD total mg/l	MANGANESE total mg/l	NICKEL total mg/l	ZINC total mg/l
20-Jan-2004		No Flow											
17-Feb-2004		No Flow											
10-Mar-2004		No Flow											
15-Apr-2004		No Flow											
19-May-2004		No Flow											
18-Jun-2004	7	790	1430	266	1.73	0.0041	0.004	0.009	1.68	0.0017	0.3913	0.0168	0.256
14-Jul-2004	5.4	1300	2370	730	1.63	0.0222	<0.003	0.009	0.146	<0.0005	2.281	0.0843	1.889
19-Aug-2004	6.1	1100	1900	368	2.01	0.0154	<0.003	0.017	0.492	<0.0005	1.713	0.0884	1.554
19-Sep-2004	7.4	1300	2360	394	0.289	0.0045	<0.003	<0.001	0.304	<0.0005	1.141	0.0379	0.361
19-Oct-2004	6.7	1600	2830	546	0.113	0.0024	<0.003	0.006	0.513	<0.0005	1.075	0.0353	0.294
9-Nov-2004	7.2	1700	3000	527	0.349	0.0018	0.005	0.006	0.672	<0.0005	0.6175	0.0226	0.114
15-Dec-2004	7	1600	2880	665	0.258	0.0014	<0.003	0.003	0.557	<0.0005	0.1818	0.0272	0.087
12-Jan-2005		no flow											
11-Feb-2005		no flow											
22-Mar-2005	6.6	1700	3120	770	0.194	<0.0005	<0.003	0.003	0.691	<0.0005	3.032	0.017	0.036
13-Apr-2005		no flow											
02-May-2005		no flow											
15-Jun-2005	7	1600	2920	675	0.394	0.0058	<0.003	0.006	0.298	<0.0005	1.673	0.0266	0.445
13-Jul-2005	5.6	1500	2750	775	1.2	0.0087	<0.003	0.009	0.293	<0.0005	4.100	0.0674	1.271
23-Aug-2005	7.5	1000	1900	376	0.507	0.0019	<0.003	0.005	0.452	<0.0005	1.74	0.0237	0.112
05-Sep-2005	7.3	1200	2170	486	0.331	0.0016	<0.003	0.005	0.722	<0.0005	1.62	0.0276	0.141
18-Oct-2005	7.2	1100	2080	386	0.319	0.002	<0.003	0.005	0.455	<0.0005	0.92	0.0247	0.114
21-Nov-2005	7	1140	2060	426	0.317	0.0021	<0.003	0.0034	0.719	<0.0005	1.879	0.0298	0.203
15-Dec-2005	6.9	1380	2490	552	0.181	0.0006	<0.003	0.0011	0.688	<0.0005	1.892	0.0311	0.095
11-Jan-2006		no flow											
14-Feb-2006		no flow											
14-Mar-2006		no flow											
17-Apr-2006	7.5	1430	2590	444	0.041	0.0011	<0.003	0.004	0.143	<0.0005	0.2529	0.0097	0.055
22-May-2006	7	1610	2900	783	0.711	0.003	0.007	0.0033	1.18	0.0006	1.648	0.0259	0.284
13-Jun-2006	7.6	1070	1930	360	0.063	<0.0005	<0.003	0.0022	0.241	<0.0005	0.044	0.008	0.034
17-Jul-2006	5.4	1100	1980	474	2.12	0.0107	<0.003	0.0087	0.191	<0.0005	2.585	0.065	1.18
15-Aug-2006	7.4	1300	2320	570	0.081	0.001	0.003	0.0025	0.241	<0.0005	0.6463	0.0169	0.075
12-Sep-2006	7.5	1100	1940	408	0.098	<0.0005	<0.003	0.0032	0.221	<0.0005	0.1097	0.0087	0.025
12-Oct-2006	7.2	1300	2390	507	0.224	0.0005	<0.003	0.0019	0.475	0.0008	<0.0005	0.0075	0.044
15-Nov-2006		no flow											
13-Dec-2006		dry											

1992 ANZECC GUIDELINES FOR WATER QUALITY **(highlighted value indicates the recorded value exceeds the recommended guideline)**

For Aquatic		1,000	**for pH<6.5**	no value	0.005	0.0002	0.01	0.002	1.0	0.001	no value	0.015	0.005
Ecosystems	6.5 - 9.0	1,000	**for pH>6.5**	no value	0.1	0.002	0.01	0.005	1.0	0.005	no value	0.15	0.05
Irrigation	4.5 - 9.0	3,500		no value	5	0.01	1.00	0.2	1.0	0.2	2	0.2	2
Livestock	no value	3,000		1,000	5	0.01	1.00	0.5	no value	0.1	no value	1	20

Fig C-7. Dawesley Creek upstream of the mine site

Dawesley Creek water, under the SE Freeway

Grab Sampling Location AWQC 1952

< indicates below analysis detection level

DATE	pH units	TDS by EC total mg/l	CONDUCTIVITY uS/cm	SULPHATE total mg/l	ALUMINIUM total mg/l	CADMIUM total mg/l	CHROMIUM total mg/l	COPPER total mg/l	IRON total mg/l	LEAD total mg/l	MANGANESE total mg/l	NICKEL total mg/l	ZINC total mg/l
20-Jan-2004		No Flow											
17-Feb-2004		No Flow											
10-Mar-2004		No Flow											
15-Apr-2004		No Flow											
19-May-2004		No Flow											
18-Jun-2004		No Flow											
14-Jul-2004	6.5	1300	2290	603	0.078	0.0175	<0.003	0.007	0.038	<0.0005	1.408	0.0794	1.108
19-Aug-2004	6.1	1000	1830	352	0.689	0.0134	<0.003	0.003	0.249	<0.0005	1.522	0.0178	1.327
19-Sep-2004	6.9	1300	2280	439	0.216	0.007	<0.003	<0.001	0.175	<0.0005	1.768	0.0576	0.759
19-Oct-2004	6.3	1500	2780	543	0.068	0.0014	<0.003	0.005	0.326	<0.0005	1.383	0.0238	0.222
9-Nov-2004	6.4	1700	3080	584	0.269	0.0044	0.004	0.006	0.195	<0.0005	1.06	0.0291	0.319
15-Dec-2004	6.9	1400	2570	506	0.185	0.0015	0.003	0.005	0.744	<0.0005	0.3632	0.0224	0.107
12-Jan-2005		no flow											
11-Feb-2005		no flow											
7-Mar-2005		no flow											
13-Apr-2005		no flow											
02-May-2005		no flow											
15-Jun-2005		no flow											
13-Jul-2005	8.1	2700	4830	225	0.558	<0.0005	<0.003	0.005	0.946	<0.0005	0.0431	<0.0005	0.008
23-Aug-2005	6.8	1100	2080	458	0.328	0.0042	<0.003	0.006	0.147	0.0007	1.8614	0.0354	0.408
05-Sep-2005	7.1	1200	2140	475	0.228	0.0026	<0.003	0.005	0.476	<0.0005	1.47	0.029	0.202
18-Oct-2005	6.7	1100	1960	332	0.243	0.002	<0.003	0.006	0.207	<0.0005	0.473	0.0258	0.152
21-Nov-2005	6.8	1100	2000	411	0.085	0.002	<0.003	0.0044	0.211	<0.0005	1.497	0.0231	0.178
15-Dec-2005	7.1	1180	2140	426	0.113	0.005	<0.003	0.0026	0.562	<0.0005	0.6377	0.0157	0.083
11-Jan-2006		no flow											
11-Feb-2006													
14-Mar-2006		no flow											
17-Apr-2006		no flow											
22-May-2006	7	1330	2400	456	0.051	0.001	0.005	0.0052	0.126	<0.0005	0.0264	0.0065	0.049
13-Jun-2006	7.3	1240	2250	531	0.189	0.001	<0.003	0.0047	0.368	<0.0005	0.0847	0.0082	0.078
17-Jul-2006	6.1	980	1780	441	0.387	0.0082	<0.003	0.0055	0.052	<0.0005	1.974	0.0521	0.94
15-Aug-2006	6.8	1200	2220	534	0.037	0.0027	<0.003	0.0048	0.073	<0.0005	0.6577	0.0159	0.169
12-Sep-2006	7.4	1200	2090	453	0.064	0.0005	<0.003	0.0039	0.169	<0.0005	0.0709	0.0086	0.032
12-Oct-2006	6.9	1200	2160	450	0.025	0.0008	<0.003	0.0032	0.152	<0.0005	0.3395	0.0051	0.047
25-Nov-2006		no flow											
13-Dec-2006		dry											

1992 ANZECC GUIDELINES FOR WATER QUALITY **(highlighted value indicates the recorded value exceeds the recommended guideline)**

For Aquatic		1,000	**for pH<6.5**	no value	0.005	0.0002	0.01	0.002	1.0	0.001	no value	0.015	0.005
Ecosystems	6.5 - 9.0	1,000	**for pH>6.5**	no value	0.1	0.002	0.01	0.005	1.0	0.005	no value	0.15	0.05
Irrigation	4.5 - 9.0	3,500		no value	5	0.01	1.00	0.2	1.0	0.2	2	0.2	2
Livestock	no value	3,000		1,000	5	0.01	1.00	0.5	no value	0.1	no value	1	20

Fig C-8. Dawesley Creek d/s at Sth East Freeway (~ 22 km)

Bremer River water, at Jaensch Road ford (Loc 8)

Grab Sampling Location AWQC 1824

< indicates below analysis detection level

DATE	pH units	TDS by EC total mg/l	CONDUCTIVITY uS/cm	SULPHATE total mg/l	ALUMINIUM total mg/l	CADMIUM total mg/l	CHROMIUM total mg/l	COPPER total mg/l	IRON total mg/l	LEAD total mg/l	MANGANESE total mg/l	NICKEL total mg/l	ZINC total mg/l
20-Jan-2004		No Flow											
17-Feb-2004		No Flow											
10-Mar-2004	8.0	2400	4360	188	0.131	<0.0005	<0.003	<0.001	0.193	<0.0005	0.3195	0.0052	0.009
15-Apr-2004		No Flow											
19-May-2004		No Flow											
18-Jun-2004	7.5	570	1040	78	1.540	<0.0005	0.005	0.004	1.73	0.0023	0.054	0.0048	0.049
14-Jul-2004	7.6	1100	2020	196	0.414	<0.0005	0.003	0.008	0.427	0.0006	0.065	0.0064	0.047
19-Aug-2004	7.6	1100	1970	178	0.869	0.002	<0.003	0.006	0.393	0.0009	0.3072	0.0183	0.259
19-Sep-2004	7.8	1300	2340	210	0.232	0.0008	<0.003	0.003	0.285	<0.0005	0.1735	0.0104	0.052
19-Oct-2004	8.0	1700	3010	229	0.100	<0.0005	<0.003	0.003	0.174	<0.0005	0.2855	0.0057	0.017
9-Nov-2004	7.9	1500	2680	160	0.030	0.0006	0.005	0.003	0.168	<0.0005	0.0836	0.0057	0.015
15-Dec-2004	7.8	1200	2140	114	0.257	0.0008	0.005	0.003	0.311	<0.0005	0.2663	0.0065	0.014
12-Jan-2005		no flow											
11-Feb-2005		no flow											
22-Mar-2005	8	2600	4570	179	0.182	<0.0005	<0.003	0.002	0.238	<0.0005	0.2711	0.0047	0.013
13-Apr-2005		no flow											
02-May-2005		no flow											
15-Jun-2005	8	2500	4410	322	0.426	0.0006	<0.003	0.004	0.22	<0.0005	0.0717	0.0029	0.035
13-Jul-2005	7.8	1900	3450	287	0.189	0.0015	<0.003	0.004	0.239	<0.0005	0.1632	0.011	0.14
23-Aug-2005	7.9	1500	2710	192	0.212	<0.0005	<0.003	0.003	0.238	<0.0005	0.0499	0.0043	0.032
5/09/2005	7.8	1300	2290	199	0.356	<0.0005	0.004	0.003	0.557	0.0006	0.1397	0.0048	0.029
18-Oct-2005	7.8	1100	2040	142	0.27	<0.0005	<0.003	0.003	0.137	<0.0005	0.1459	0.0071	0.021
21-Nov-2005	7.6	1150	2090	154	2.19	0.0012	0.007	0.0078	3.22	0.0043	0.6598	0.0168	0.124
15-Dec-2005	8	1280	2320	172	0.24	<0.0005	<0.003	0.0014	0.346	<0.0005	0.3475	0.0072	0.074
11-Jan-2006		No Flow											
11-Feb-2006		No Flow											
14-Mar-2006	8	2400	4300	152	0.142	<0.0005	<0.003	<0.0010	0.222	<0.0005	0.5902	0.0025	0.006
17-Apr-2006		no flow											
22-May-2006	7.5	844	1530	117	2.271	0.0006	0.009	0.005	2.41	0.0025	0.406	0.0062	0.094
13-Jun-2006	7.6	1270	2300	300	0.186	<0.0005	<0.003	<0.0010	0.206	<0.0005	0.1324	0.0029	0.011
17-Jul-2006	7.4	1500	2770	235	0.183	<0.0005	0.005	0.0027	0.308	0.0006	0.1387	0.0058	0.046
15-Aug-2006	8	1500	2680	205	0.093	<0.0005	0.004	0.0023	0.185	<0.0005	0.0942	0.003	0.018
12-Sep-2006	7.8	1400	2560	194	0.551	<0.0005	<0.003	0.0049	0.732	0.0012	0.084	0.004	0.037
12-Oct-2006	8.8	1200	2230	174	0.101	<0.0005	<0.003	0.0013	0.174	<0.0005	0.1485	0.0021	0.011
15-Nov-2006		No Flow											
13-Dec-2006	8.1	2100	3840	148	0.042	<0.0005	0.003	<0.0010	0.101	<0.0005	0.1978	0.0018	0.005

1992 ANZECC GUIDELINES FOR WATER QUALITY **(highlighted value indicates the recorded value exceeds the recommended guideline)**

For Aquatic		1,000	**for pH<6.5**	no value	0.005	0.0002	0.01	0.002	1.0	0.001	no value	0.015	0.005
Ecosystems	6.5 - 9.0	1,000	**for pH>6.5**	no value	0.1	0.002	0.01	0.005	1.0	0.005	no value	0.15	0.05
Irrigation	4.5 - 9.0	3,500		no value	5	0.01	1.00	0.2	1.0	0.2	2	0.2	2
Livestock	no value	3,000		1,000	5	0.01	1.00	0.5	no value	0.1	no value	1	20

Fig C-9. Mt Barker Creek

Bremer River water, at Jaensch Road ford (Loc 8)

Grab Sampling Location AWQC 1824

< indicates below analysis detection level

DATE	pH units	TDS by EC total mg/l	CONDUCTIVITY uS/cm	SULPHATE total mg/l	ALUMINIUM total mg/l	CADMIUM total mg/l	CHROMIUM total mg/l	COPPER total mg/l	IRON total mg/l	LEAD total mg/l	MANGANESE total mg/l	NICKEL total mg/l	ZINC total mg/l
20-Jan-2004		No Flow											
17-Feb-2004		No Flow											
10-Mar-2004	8.0	2400	4360	188	0.131	<0.0005	<0.003	<0.001	0.193	<0.0005	0.3195	0.0052	0.009
15-Apr-2004		No Flow											
19-May-2004		No Flow											
18-Jun-2004	7.5	570	1040	78	1.540	<0.0005	0.005	0.004	1.73	0.0023	0.054	0.0048	0.049
14-Jul-2004	7.6	1100	2020	196	0.414	<0.0005	0.003	0.008	0.427	0.0006	0.065	0.0064	0.047
19-Aug-2004	7.6	1100	1970	178	0.869	0.002	<0.003	0.006	0.393	0.0009	0.3072	0.0183	0.259
19-Sep-2004	7.8	1300	2340	210	0.232	0.0008	<0.003	0.003	0.285	<0.0005	0.1735	0.0104	0.052
19-Oct-2004	8.0	1700	3010	229	0.100	<0.0005	<0.003	0.003	0.174	<0.0005	0.2855	0.0057	0.017
9-Nov-2004	7.9	1500	2680	160	0.030	0.0006	0.005	0.003	0.168	<0.0005	0.0836	0.0057	0.015
15-Dec-2004	7.8	1200	2140	114	0.257	0.0008	0.005	0.003	0.311	<0.0005	0.2663	0.0065	0.014
12-Jan-2005		no flow											
11-Feb-2005		no flow											
22-Mar-2005	8	2600	4570	179	0.182	<0.0005	<0.003	0.002	0.238	<0.0005	0.2711	0.0047	0.013
13-Apr-2005		no flow											
02-May-2005		no flow											
15-Jun-2005	8	2500	4410	322	0.426	0.0006	<0.003	0.004	0.22	<0.0005	0.0717	0.0029	0.035
13-Jul-2005	7.8	1900	3450	287	0.189	0.0015	<0.003	0.004	0.239	<0.0005	0.1632	0.011	0.14
23-Aug-2005	7.9	1500	2710	192	0.212	<0.0005	<0.003	0.003	0.238	<0.0005	0.0499	0.0043	0.032
5/09/2005	7.8	1300	2290	199	0.356	<0.0005	0.004	0.003	0.557	0.0006	0.1397	0.0048	0.029
18-Oct-2005	7.8	1100	2040	142	0.27	<0.0005	<0.003	0.003	0.137	<0.0005	0.1459	0.0071	0.021
21-Nov-2005	7.6	1150	2090	154	2.19	0.0012	0.007	0.0078	3.22	0.0043	0.6598	0.0168	0.124
15-Dec-2005	8	1280	2320	172	0.24	<0.0005	<0.003	0.0014	0.346	<0.0005	0.3475	0.0072	0.074
11-Jan-2006		No Flow											
11-Feb-2006		No Flow											
14-Mar-2006	8	2400	4300	152	0.142	<0.0005	<0.003	<0.0010	0.222	<0.0005	0.5902	0.0025	0.006
17-Apr-2006		no flow											
22-May-2006	7.5	844	1530	117	2.271	0.0006	0.009	0.005	2.41	0.0025	0.406	0.0062	0.094
13-Jun-2006	7.6	1270	2300	300	0.186	<0.0005	<0.003	<0.0010	0.206	<0.0005	0.1324	0.0029	0.011
17-Jul-2006	7.4	1500	2770	235	0.183	<0.0005	0.005	0.0027	0.308	0.0006	0.1387	0.0058	0.046
15-Aug-2006	8	1500	2680	205	0.093	<0.0005	0.004	0.0023	0.185	<0.0005	0.0942	0.003	0.018
12-Sep-2006	7.8	1400	2560	194	0.551	<0.0005	<0.003	0.0049	0.732	0.0012	0.084	0.004	0.037
12-Oct-2006	8.8	1200	2230	174	0.101	<0.0005	<0.003	0.0013	0.174	<0.0005	0.1485	0.0021	0.011
15-Nov-2006		No Flow											
13-Dec-2006	8.1	2100	3840	148	0.042	<0.0005	0.003	<0.0010	0.101	<0.0005	0.1978	0.0018	0.005

1992 ANZECC GUIDELINES FOR WATER QUALITY (highlighted value indicates the recorded value exceeds the recommended guideline)

For Aquatic		1,000	**for pH<6.5**	no value	0.005	0.0002	0.01	0.002	1.0	0.001	no value	0.015	0.005
Ecosystems	6.5 - 9.0	1,000	**for pH>6.5**	no value	0.1	0.002	0.01	0.005	1.0	0.005	no value	0.15	0.05
Irrigation	4.5 - 9.0	3,500		no value	5	0.01	1.00	0.2	1.0	0.2	2	0.2	2
Livestock	no value	3,000		1,000	5	0.01	1.00	0.5	no value	0.1	no value	1	20

Fig C-10. Bremer River at Jaensch ford

ALUMINIUM DISPERSED ALONG THE WATERCOURSE 2004 - 2006

Date 2004	U/S Brukunga Site 4728	D/S Brukunga Site 3158	Old Melb. Bridge Site 1951	D/S Nairne Ck Site 1822	SE Freeway Site 1952	Mt Barker Creek Site 1807	Bremer River Site 1824	O/S Nairne Ck Site 1953
20-Jan-2004	0.570	1.230	1.080					0.090
17-Feb-2004	0.510	1.000	2.010					
10-Mar-2004	0.338	1.240				0.096	0.131	
15-Apr-2004	0.319	1.150	0.139					
19-May-2004	0.373	2.250	0.679					
18-Jun-2004	1.050	129.000	0.303	1.730		1.290	1.540	2.160
14-Jul-2004	0.649	2.500	0.460	1.630	0.078	0.058	0.414	0.441
19-Aug-2004	0.421	3.340	1.530	2.010	0.689	0.063	0.869	0.667
15-Sep-2004	0.440	5.210	0.816	0.289	0.216	0.116	0.232	0.150
19-Oct-2004	0.273	2.910	0.222	0.113	0.068	0.063	0.100	0.031
09-Nov-2004	0.848	1.250	0.603	0.349	0.269	<0.020	0.030	0.234
15-Dec-2004	0.827	0.602	0.453	0.258	0.185	0.163	0.257	0.063
Max	1.050	129.000	2.010	2.010	0.689	1.290	1.540	2.160
Min	0.273	0.602	0.139	0.113	0.068	0.058	0.030	0.031
Median	**0.475**	**1.750**	**0.603**	**0.349**	**0.201**	**0.096**	**0.245**	**0.192**
2005								
12-Jan-2005								
11-Feb-2005	0.336	1.520	0.945					
22-Mar-2005	0.307	2.580	0.118	0.194		0.241	0.182	
14-Apr-2005	0.532	2.030	0.179					
02-May-2005	0.187	1.700	0.260					0.255
15-Jun-2005	2.720	87.100	3.110	0.394		0.223	0.426	0.694
13-Jul-2005	0.460	24.100	2.420	1.200	0.558	0.081	0.189	0.198
23-Aug-2005	0.556	8.540	3.430	0.507	0.328	0.139	0.212	0.439
05-Sep-2005	0.353	2.960	1.060	0.331	0.228	0.190	0.356	0.170
18-Oct-2005	0.373	5.240	0.466	0.319	0.243	0.138	0.270	0.112
21-Nov-2005	0.455	2.870	0.176	0.317	0.085	0.488	2.190	0.124
15-Dec-2005	0.455	4.250	0.360	0.181	0.113	0.297	0.240	0.035
Max	2.72	87.1	3.43	1.2	0.558	0.488	2.19	0.694
Min	0.187	1.52	0.118	0.181	0.085	0.081	0.182	0.035
Median	**0.455**	**2.960**	**0.466**	**0.325**	**0.236**	**0.207**	**0.255**	**0.184**
2006								
11-Jan-2006		1.550	0.233					0.082
14-Feb-2006								
14-Mar-2006						0.174	0.142	0.125
17-Apr-2006	0.322	3.066	1.247	0.041				0.055
22-May-2006	0.356	28.900	1.066	0.711	0.051	0.182	2.271	0.180
13-Jun-2006	0.238	3.456	4.389	0.063	0.189	0.088	0.186	0.028
17-Jul-2006	0.149	9.890	0.470	2.120	0.387	0.143	0.183	0.137
15-Aug-2006	0.341	4.060	0.068	0.081	0.037	0.057	0.093	0.079
12-Sep-2006	0.327	1.700	0.344	0.098	0.064	0.091	0.551	0.041
12-Oct-2006	0.457	1.350	0.128	0.224	0.025	0.268	0.101	0.047
15-Nov-2006	0.372	1.270	0.095					0.038
13-Dec-2006	1.890		0.047			0.084	0.042	0.032
Max	1.89	28.9	4.389	2.12	0.387	0.268	2.271	0.18
Min	0.149	1.27	0.047	0.041	0.025	0.057	0.042	0.028
Median	**0.341**	**3.066**	**0.289**	**0.098**	**0.058**	**0.117**	**0.163**	**0.055**

Fig C-11. Aluminium dispersion in watercourses 2004 to 2006

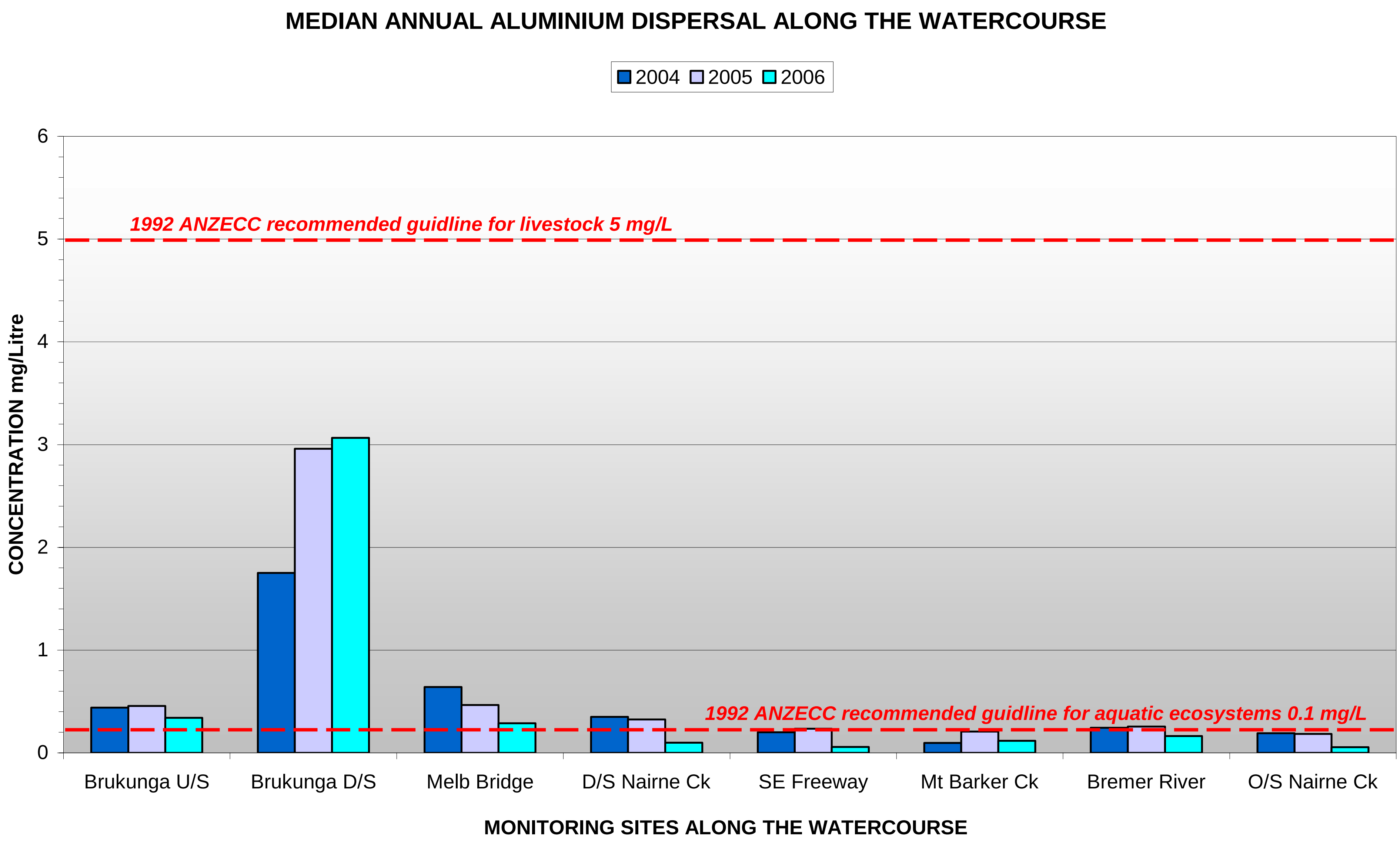

Fig C-12 Plot of median Aluminium dispersion in watercourses 2004 to 2006

CADMIUM DISPERSED ALONG THE WATERCOURSE 2004 - 2006

Date	U/S Brukunga Site 4728	D/S Brukunga Site 3158	Old Melb. Bridge Site 1951	D/S Nairne Ck Site 1822	SE Freeway Site 1952	Mt Barker Creek Site 1807	Bremer River Site 1824	O/S Nairne Ck Site 1953
2004								
20-Jan-2004	<0.0005	0.002	0.001					<0.0005
17-Feb-2004	<0.0005	0.003	0.001					
10-Mar-2004	<0.0005	0.002				<0.0005	<0.0005	
15-Apr-2004	<0.0005	0.002	0.001					
19-May-2004	<0.0005	0.005	0.001					
18-Jun-2004	<0.0005	0.016	0.003	0.004		0.0006	<0.0005	<0.0005
14-Jul-2004	<0.0005	0.003	0.002	0.022	0.018	<0.0005	<0.0005	<0.0005
19-Aug-2004	<0.0005	0.008	0.006	0.015	0.013	<0.0005	0.002	<0.0005
15-Sep-2004	<0.0005	0.004	0.002	0.005	0.007	0.0015	0.0008	<0.0005
19-Oct-2004	<0.0005	0.008	0.003	0.002	0.001	<0.0005	<0.0005	<0.0005
09-Nov-2004	<0.0005	0.002	0.001	0.002	0.004	0.001	0.0006	<0.0005
15-Dec-2004	<0.0005	0.001	0.001	0.001	0.002	0.0008	0.0008	0.0006
Max	0.000	0.016	0.006	0.022	0.018	0.002	0.002	0.001
Min	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Median	**0.000**	**0.003**	**0.001**	**0.004**	**0.006**	**0.001**	**0.001**	**0.001**
2005								
12-Jan-2005								
11-Feb-2005	<0.0005	0.002	0.001					
22-Mar-2005	<0.0005	0.001	<0.0005	<0.0005		<0.0005	<0.0005	
14-Apr-2005	<0.0005	0.001	<0.0005					
02-May-2005	<0.0005	0.001	<0.0005					<0.0005
15-Jun-2005	<0.0005	0.025	0.002	0.006		<0.0005	0.0006	<0.0005
13-Jul-2005	<0.0005	0.008	0.007	0.009	<0.0005	<0.0005	0.0015	<0.0005
23-Aug-2005	<0.0005	0.004	0.002	0.002	0.004	<0.0005	<0.0005	<0.0005
05-Sep-2005	<0.0005	0.004	0.003	0.002	0.003	<0.0005	<0.0005	<0.0005
18-Oct-2005	<0.0005	0.007	0.010	0.002	0.002	<0.0005	<0.0005	<0.0005
21-Nov-2005	<0.0005	0.036	0.009	0.002	0.002	<0.0005	0.0012	<0.0005
15-Dec-2005	<0.0005	0.005	0.001	0.001	0.005	<0.0005	<0.0005	<0.0005
Max	0.000	0.036	0.010	0.009	0.005	0.000	0.002	0.000
Min	0.000	0.001	0.001	0.001	0.002	0.000	0.001	0.000
Median	**0.000**	**0.004**	**0.002**	**0.002**	**0.003**	**0.000**	**0.001**	**0.000**
2006								
11-Jan-2006		0.007	<0.0005					<0.0005
14-Feb-2006								
14-Mar-2006						<0.0005	<0.0005	<0.0005
17-Apr-2006	<0.0005	0.003	0.002	0.0011				<0.0005
22-May-2006	<0.0005	0.009	0.001	0.003	0.001	0.0007	0.0006	<0.0005
13-Jun-2006	<0.0005	0.001	0.001	<0.0005	0.001	<0.0005	<0.0005	<0.0005
17-Jul-2006	<0.0005	0.007	0.004	0.0107	0.0082	<0.0005	<0.0005	<0.0005
15-Aug-2006	<0.0005	0.009	0.004	0.001	0.0027	<0.0005	<0.0005	<0.0005
12-Sep-2006	<0.0005	0.002	0.001	<0.0005	0.0005	<0.0005	<0.0005	<0.0005
12-Oct-2006	<0.0005	0.004	0.001	0.0005	0.0008	<0.0005	<0.0005	<0.0005
15-Nov-2006	<0.0005	0.002	<0.0005					<0.0005
13-Dec-2006	<0.0005		<0.0005			<0.0005	<0.0005	<0.0005
Max	0.000	0.009	0.004	0.011	0.008	0.001	0.001	0.000
Min	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.000
Median	**0.000**	**0.004**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.000**

Fig C-13. Cadmium dispersion in watercourses 2004 to 2006

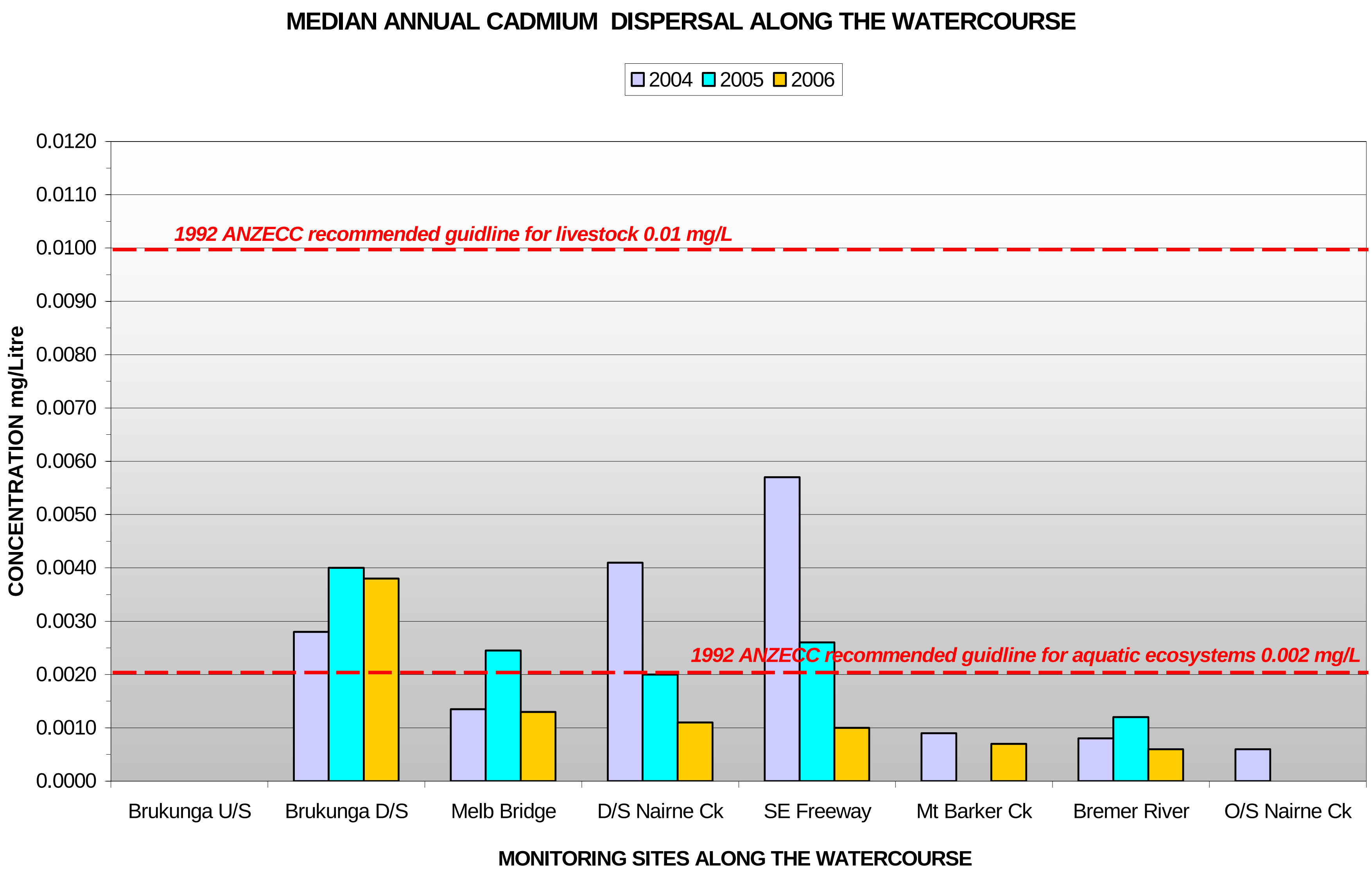

Fig C-14. plot of median Cadmium dispersion in watercourses 2004 to 2006

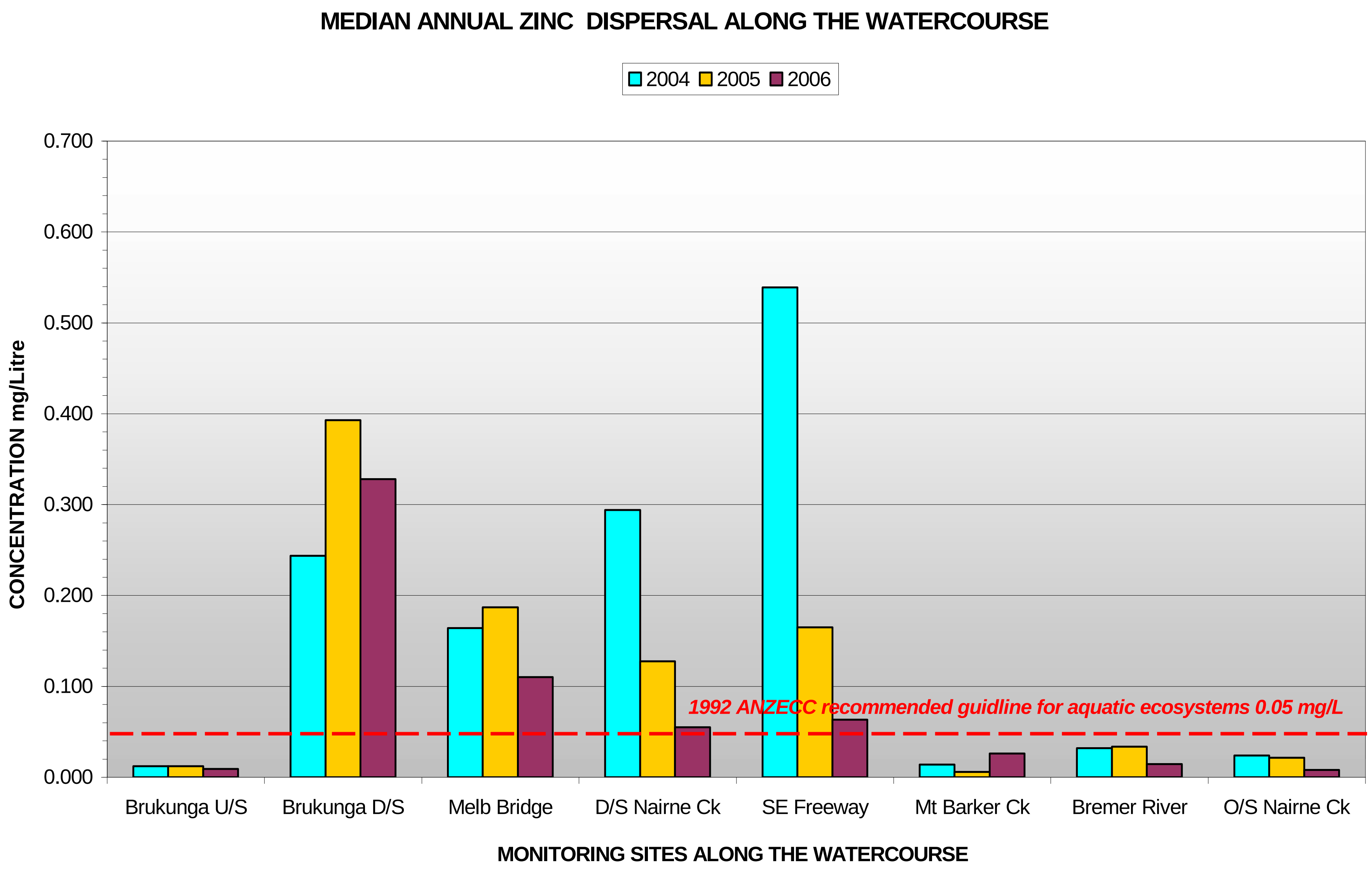

Fig C-15. Plot of median Zinc dispersion in watercourses 2004 to 2006

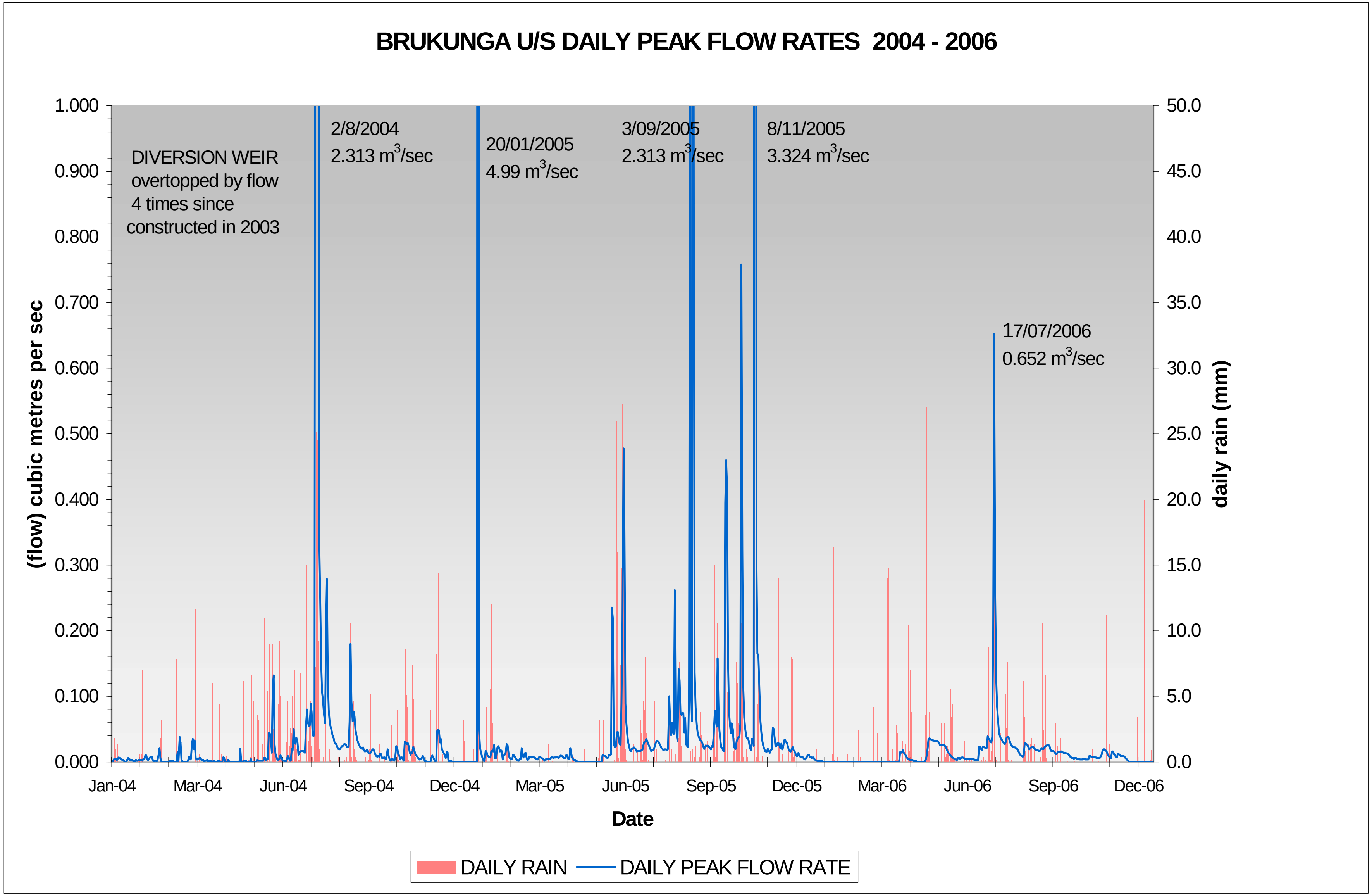

Fig C-16. Brukunga U/S Daily Peak Flow rates in Dawesley Creek 2004 – 2006

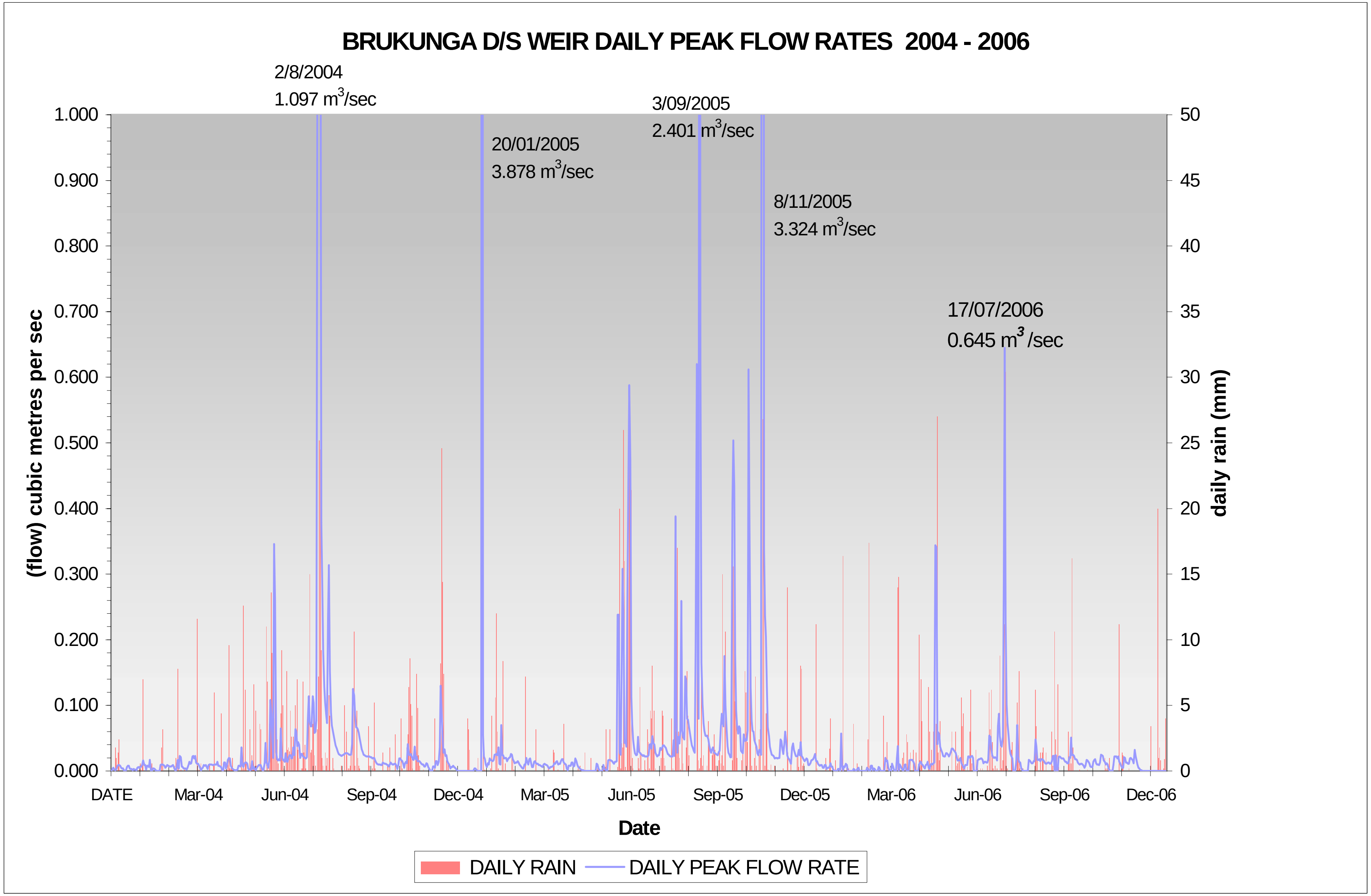

Fig C-17. Brukunga D/S Daily Peak Flow rates in Dawesley Creek 2004 - 2006