Storys & Aberfoyle Creek Water Quality Monitoring

November 2016

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A Report to Mineral Resources Tasmania

♦♦♦*Technical Advice on Water*♦♦♦

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PREPARED BY:	Lois Koehnken, Technical Advice on Water Daniel Ray, Aquatic Science	V1.1: 6 January 2016
DISTRIBUTED TO:	Michael Reid	Electronic .doc

Executive Summary

Water quality and flow monitoring was completed in Storys Creek on 22 November 2016 at the same sites as monitored in 2003 – 2006. Water levels in Storys Creek were low at the mine site, but increased downstream owing to a recent (10 days prior) high rainfall event.

The geomorphology of Storys Creek has not changed during the intervening 10 years, with the river choked with gravels, cobbles and boulders. Infrastructure associated with the mine site remediation were observed and require maintenance. The flow system associated with the Anoxic Limestone Drain is not functioning properly, and the outflow from the Precipitate Dam is flowing through the rock wall.

Water quality results were largely consistent with the 2003 – 2006 results, with Storys Creek upstream of the mine site, Aberfoyle Creek and Nisbet Creek having low concentrations of sulphate and metals and being unaffected by mining inflows. The sites associated with historic mining inputs, the Precipitate Dam outflow, Storys above Side Creek (diffuse inputs from mine site), Side Creek and Eastern Adit, continue to have the highest concentrations of sulphate and metals. Cadmium, copper, nickel, manganese and zinc are the metals of environmental concern that continue to be elevated at these sites. pH values in 2016 at many sites were ~5.5, which is lower than previously determined, but consistent with rainwater and likely reflect the extremely high rainfall occurring in the catchment during the previous winter. EC values were also towards the low end of the previously determined values, consistent with high rainfall flushing dissolved constituents from the soils.

Metal and sulphate fluxes at the Storys Creek monitoring sites were within the previous range documented, and were generally above median values for sulphate, cadmium and nickel and below the previous medians for zinc. Fluxes continued to increase downstream of the site, reflecting inputs from the ongoing oxidation and weathering of material in the river bed.

Zinc concentrations in the lower catchment at the Storys above Aberfoyle (218 μg/L) and Aberfoyle above Storys (222 μg/L) sites were similar which contrasts with the historical results that consistently (with one exception) documented considerably lower concentrations at the Aberfoyle above Storys site. Due to the higher flow in Storys Creek, the zinc load in the two creeks was 10.11 kg/day in Storys Creek, as compared to 6.2 kg/day in Aberfoyle Creek.

Recommendations include maintenance of the ALD and Precipitate Dam outflow, and re-evaluation of remediation options at Aberfoyle Mine site (e.g. removal of tailings). Ongoing water quality monitoring at Storys Creek is not recommended due to the difficulties in flow monitoring affecting the accuracy of the flux results and limiting the ability to discern small changes relative to the previous monitoring, and the likelihood that any additional remediation actions at Storys Creek Mine would be costly, and unlikely to address the widespread diffuse sources.

1 Introduction

The Storys Creek mine, located in the Storys Creek catchment, produced tin and wolfram from the late 1800s to the 1980s. The mining operations left an environmental legacy of acid drainage and contaminated tailings in the river valley, and remediation activities were implemented by Mineral Resources Tasmania in the 1990s and 2000s. Between 2003 and 2006, quarterly water quality monitoring was completed to document the concentrations and loads of metals and sulphate in Storys Creek, and to evaluate the effectiveness of the remediation measures.

In November 2016, a survey of water quality in Storys Creek was completed, with measurements and samples collected at the same locations as during the 2003 - 2006 surveys. The aims of the monitoring include:

- Identifying and quantifying large-scale changes to water quality over the past 10-years;
- Establishing whether any of the remediation works require maintenance or upgrading; and,
- Evaluate the potential value and likelihood of identifying and quantifying changes in water quality through additional water quality monitoring.

2 Methods

2.1 Water quality sampling and *in situ* measurements

Monitoring was completed at 17 locations (Figure 2.1 and Figure 2.2) on 22 November 2016 by Lois Koehnken (Technical Advice on Water) and Daniel Ray (Aquatic Science). Sixteen of the monitoring sites were the same as those included in the 2003 – 2006 monitoring campaign. One additional site, Aberfoyle at Highway (upstream of the Aberfoyle mine site) was added to the 2016 monitoring schedule to provide a comparison with the Aberfoyle above Storys River site. Coordinates and photographs of the monitoring locations and are provided in Appendix 1. At each location, the pH, electrical conductivity and temperature of the water was determined using a WTW pH and electrical conductivity meter. Water quality samples were collected in pre-washed bottles provided by the laboratory completing the water quality analyses (Analytical Services Tasmania (AST)).

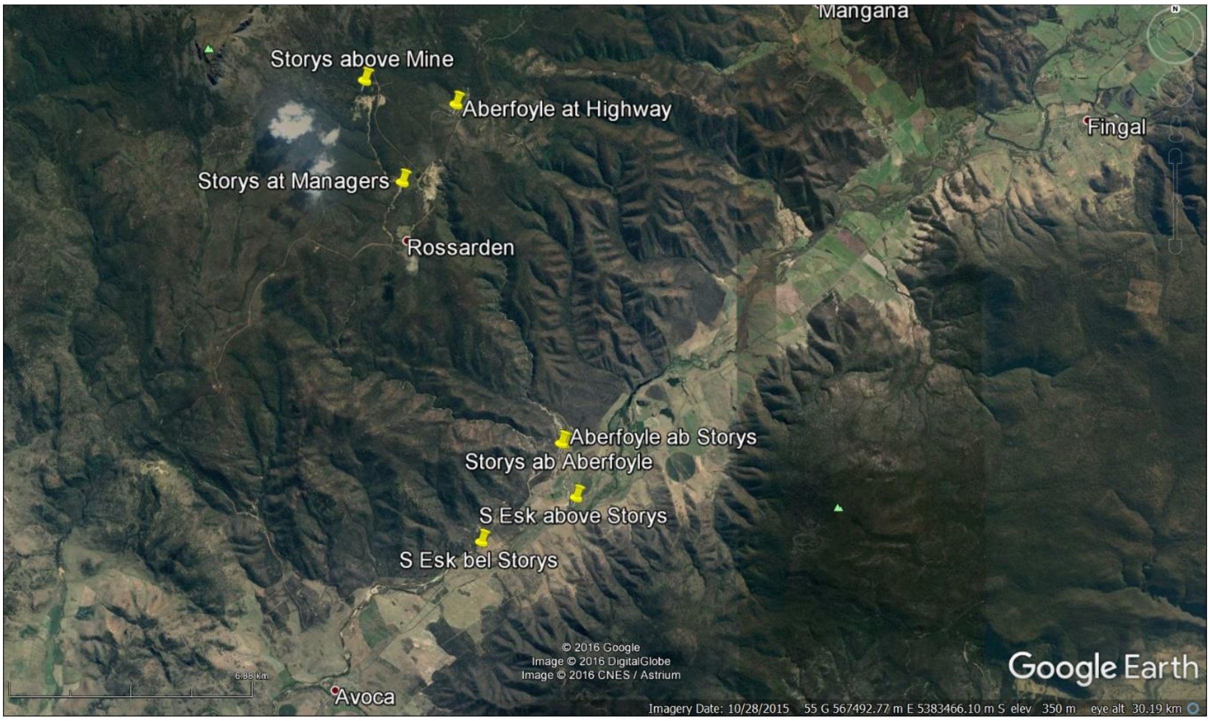

Figure 2.1. Google Earth image showing water quality monitoring locations upstream and downstream of the Storys Creek and Aberfoyle mine sites.

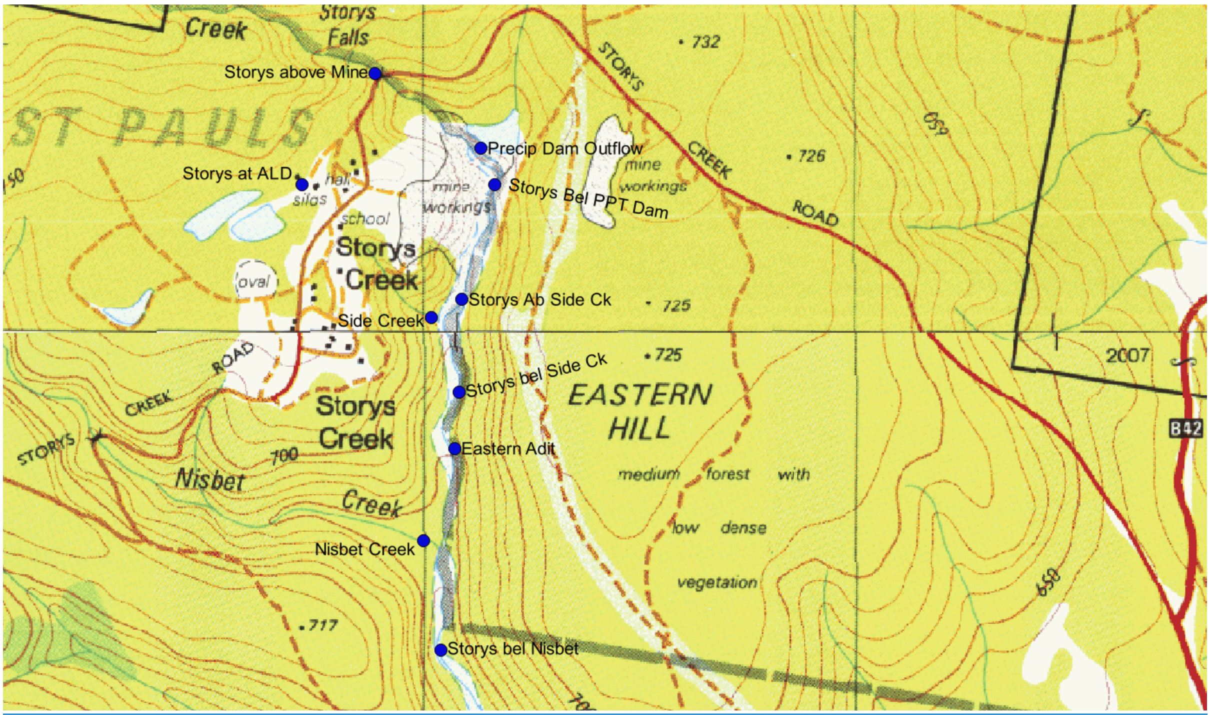

Figure 2.2. Topographic map showing water quality monitoring locations within the Storys Creek mine site. Storys at Managers is located approximately 1.75 km downstream of Storys bel Nisbet.

2.2 Determination of flow

Estimates of flow were made so that metal and sulphate fluxes (loadings) could be calculated. Due to the large volumes of rock present in the river and the braided nature of the river channel, there are only a limited number of locations where flow is contained in one channel and able to be measured. At these six sites, flow measurements were completed using a Sontek Flowtracker. At the remaining sites, flow was either estimated based on observation, calculated from the measurements, or the measurement from the closest site was used if there were no major inflows occurred in the intervening river section.

Table 1. Summary of methods used to derive flow for metal and sulphate flux estimates.

Monitoring Site	Flow for Flux Estimates	Flow (L/s)
Anoxic Limestone Drain	Estimated	0.05
Storys Above Mine	Used Storys bel Precip Dam	63.8
Precip Dam Outflow	Estimated	1
Storys Bel Precip	Measured	63.8
Storys Ab Side Creek	Used Storys bel Precip Dam	63.8
Side Creek	Measured	3
Storys Bel Side Cr	Side Cr + Storys Bel Precip Dam	67
Storys Bel Nisbet	Measured	197
Storys at Managers	Measured	218
Storys Ab Aber	Measured	537
Aber Ab Storys	Measured	323
Storys Bel Aber	Storys ab Aber + Aber ab Storys	860

Monitoring Site	Flow for Flux Estimates	Flow (L/s)
S. Esk Ab Storys	No estimate made	
S. Esk Bel Storys	No estimate made	
Eastern Adit	<0.5 l/s	
Nisbet Creek	No estimate made	
Aberfoyle at Hwy	No estimate made	

3 Results

3.1 Rainfall prior to monitoring

The long-term Bureau of Meteorology rainfall site at Mathinna (1889 – 2016) is located approximately 20 km northeast of the Storys Creek mine site and 15 km northeast of the Aberfoyle mine site. Comparing the long-term monthly rainfall results with the recorded rainfall in December 2015 – 2016 (Figure 3.1) shows that the first six months were dry and the last six months were wet, with more than four-times the average monthly rainfall recorded in June 2016. Rainfall totals for the twelve months prior (Dec 2016 – Nov 2016) were 1398 mm compared to the long-term average of 843 mm. In the three weeks prior to monitoring, 134 mm of rain fell at Mathinna, with 122 mm falling between November of the total recorded on November 11th and 14th.

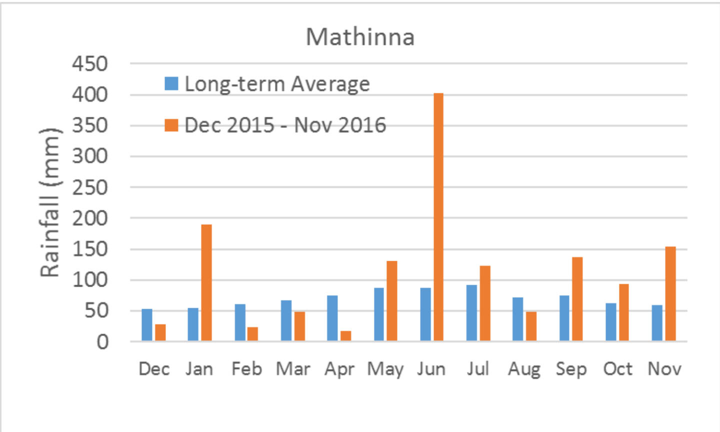

Figure 3.1. Comparison of long-term rainfall averages at Mathinna Tasmania (1889 – 2015) with rainfall in the twelve months prior to water quality sampling on November 22, 2016. Mathinna is located approximately 20 km northeast of the Storys Creek mine site.

3.2 Field observations

- Safe access to Aberfoyle Creek at the mine site remains difficult, and prevented the collection of a water quality sample at the mine site;
- The water management infrastructure of the ALD is not functioning. There is a leak in the feeder pipe from the upper pond to the drain. There was extensive ponding of water on the surface of the drain on the monitoring day which may be related to the broken pipe and / or the recent high rainfall

	*Figure 3.2. Leak in feeder pipe to ALD.*
	*Figure 3.3. Ponded water in pipe feeding the underground workings due to deposition and vegetation in the channel.*

- The Precipitate Dam is discharging through rocks without a clear discharge point.

Figure 3.4. Precipitate Dam showing low water level with discharge point through the wall in far part of dam, November 2016.

Figure 3.5. View upstream in Storys Creek where Precipitate Dam outflow is entering through the rocks. No flow was discernible from the creek. November 2016.

- The historic tailings deposits remain largely unvegetated, although vegetation is increasing in other areas around the mine site

Figure 3.6. Historic tailings at Storys Creek mine site, November 2016.

- Storys Creek remains choked with gravels, cobbles and boulders. Flow in the river typically occurs within several channels making the collection of water samples difficult. There is also water flowing under the rocks, so except for the few places where bedrock outcrops in the channel, it is difficult to obtain flow measurements or water quality samples that reflect the entire flow of the river (Figure 3.7);

Figure 3.7. Comparison of river channel downstream of the mine site in 2003 (left) and 2016 (right).

- Localised erosion continues in Storys Creek, with numerous recent tree falls (leaves still intact) observed during the field visit. The side channel associated with Eastern Adit has eroded as shown in Figure 3.8.

Figure 3.8. Erosion in Storys Creek near Eastern Adit. Photo on the left from Dec 06, photos below obtained in November 2016. The angle of 2006 and 2016 photos are slightly different.

3.3 Overview of November 2016 monitoring results

The 22nd of November, 2016 analytical and field monitoring results are summarised in Table 2, along with the reporting limits for each analyte. The final column in Table 2 shows the ANZECC (2000) 95th percentile trigger values for freshwater. Highlighted values in the November 2016 data set exceed these trigger values. The results show the following characteristics:

- The water quality results for three of the waterways, Aberfoyle at Highway, Storys above Mine and Nisbet Creek show low concentrations of all metals and sulphate and reflect rivers that are unimpacted by the mining works;
- Alkalinity values are low in all samples except the outflow from the ALD (62 mg/L) and in the Eastern Adit (42 mg/L). The ALD values suggest some alkalinity continues to be generated by the drain, despite the water management issues. The alkalinity in the Eastern Adit is somewhat surprising, and probably reflects acidic water contacting limestone within the old mine workings;
- Acidity values are generally low except for Side Creek, with the acidity attributable to the high concentration of iron in the creek;

- Many samples have elevated levels of aluminium, including the ‘clean’ waterways. This is common in Tasmania and aluminium concentrations up to ~80 μg/L are usually associated with the complexation of aluminium by dissolved organic acids;
- Arsenic, cobalt chromium and lead levels are generally at or below the limit of reporting at most sites. An exception is arsenic in Side Creek and the Eastern Adit. These trends are consistent with previous monitoring results;
- The sites with the highest metal and sulphate concentrations are directly linked to the historic mining operations and include the Precipitate Dam, Side Creek, and Eastern Adit. Concentrations also increase between the Storys below Precipitation Dam and Storys above Side Creek sites suggesting that diffuse drainage from the hill slope contributes to the load. This is consistent with EC measurements across the channel that found higher EC values on the bank closest to the mine;
- Cadmium, copper, nickel, manganese and zinc are the metals showing the most substantial increases compared to the ‘clean’ waterways, which is consistent with previous monitoring results;
- The inputs from these mining ‘sources’ increase metal and sulphate concentrations between Storys below the Precipitation Dam and Storys below Side Creek. The inflow of Nisbet Creek provides dilution that reduces concentrations at Storys below Nisbet Creek. Concentrations reduce with distance downstream of Nisbet Creek (despite some flux increase, see next section).

Table 2. Analytical and field monitoring results from November 22, 2016.

	LOR & Units	Storys Ab Mine	Precip Dam Outflow	Storys Bel Precip	Storys Ab Side Cr	Side Creek	Storys Bel Side Cr	Eastern Adit	Nisbet Creek	Storys Bel Nisbet	Storys at Manager	Storys Ab Aber	Aber Ab Storys	Storys bel Aber
Date		22 Nov 16	22 Nov 16	22 Nov 16	22 Nov 16	22 Nov 16	22 Nov 16	22 Nov 16	22 Nov 16	22 Nov 16	22 Nov 16	22 Nov 16	22 Nov 16	22 Nov 16
Alkalinity Total	2 mg/l CaCO3	8	3	8	6	1	4	42	11	5	2	2	17	8
Acidity	3 mg/l CaCO3	1.5	18	1.5	1.5	88	6	37	1.5	3	1.5	1.5	1.5	1.5
Fluoride	0.05 mg/l	0.025	0.5	0.025	0.15	9.73	0.4	2.63	0.025	0.16	0.09	0.23	0.78	0.45
Sulphate	0.1 mg/l	0.4	104	7.6	9.7	179	19.4	72.7	0.7	14.6	12.2	7.3	30.4	16.5
Al Dis	1 µg/l	8	174	16	95	5320	115	130	24	44	64	117	27	71
Al Total	1 µg/l	28	380	41	146	5450	455	563	84	112	121	381	238	333
As Dis	1 µg/l	0.5	0.5	0.5	0.5	3	0.5	7	0.5	0.5	0.5	0.5	1	0.5
As Total	1 µg/l	0.5	0.5	0.5	0.5	16	0.5	48	0.5	0.5	0.5	0.5	2	1
Cd Dis	0.1 µg/l	0.05	201	12.7	17.1	212	29.1	20.8	0.05	14.8	14.5	8.1	6.8	7.5
Cd Total	0.1 µg/l	0.05	202	12.8	17.1	216	29.1	23.1	0.05	14.9	14.7	8.3	7.1	7.8
Co Dis	0.5 µg/l	0.25	36.5	0.25	0.25	33.3	2.1	17.1	0.25	0.25	0.25	0.25	0.25	0.25
Co Total	0.5 µg/l	0.25	37.1	0.5	0.25	34	2.2	17.1	0.25	0.25	0.25	0.25	0.25	0.25
Cr Dis	1 µg/l	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Cr Total	1 µg/l	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Cu Dis	1 µg/l	0.5	8	1	32	184	38	0.5	0.5	17	18	17	20	19
Cu Total	1 µg/l	0.5	11	1	35	194	49	0.5	0.5	20	19	20	28	23
Fe Dis	µg/l	10	10	10	23	9280	83	9060	33	10	52	70	66	67

	LOR & Units	Storys Ab Mine	Precip Dam Outflow	Storys Bel Precip	Storys Ab Side Cr	Side Creek	Storys Bel Side Cr	Eastern Adit	Nisbet Creek	Storys Bel Nisbet	Storys at Manager	Storys Ab Aber	Aber Ab Storys	Storys bel Aber
Fe Total	20 µg/l	10	31	10	37	26200	263	17400	69	41	91	230	304	259
Mn Dis	1 µg/l	0.5	2520	45	30	2660	179	1480	2	42	13	5	9	6
Mn Total	1 µg/l	0.5	2540	46	31	2760	179	1500	3	42	14	6	13	8
Ni Dis	0.5 µg/l	0.25	36.9	2.1	1.6	73.3	4.6	33.5	0.25	2	1.4	0.8	1.8	1.2
Ni Total	0.5 µg/l	0.25	37.7	2.1	1.6	75.8	4.7	33.6	0.25	2	1.4	0.9	2.1	1.3
Pb Dis	0.5 µg/l	0.25	0.25	0.25	0.25	1.4	0.25	0.25	0.25	0.25	0.25	0.25	0.7	0.5
Pb Total	0.5 µg/l	0.25	0.25	0.25	0.25	3.3	0.9	0.25	0.25	0.25	0.25	0.9	2.5	1.5
Zn Dis	2 µg/l	1	8260	556	501	10900	983	1480	1	465	387	208	206	199
Zn Total	2 µg/l	1	8300	556	505	11100	986	1570	1	468	393	218	222	219
TSS	2 mg/l	1	1	1	1	36*	2	22*	1	1	1	1	2	3
Flow	L/s		1	63.8		3				197	218	537	323	
pH	pH unit	6.22	5.67	5.89	5.79	3.4	5.51	6.07	6.06	5.87	5.51	5.96	6.6	6.48
EC	µS/cm	25	237	51	47	434	65	266	34	58	51	50	133	84
Temp	°C	11	16.3	11	11.5	12.8	11.8	11	9.3	11.9	14.9	17.5	18.2	17.7

**Elevated TSS associated with the precipitation of iron after collection.*

		ALD Outflow	Aberfoyle @ Hwy	S. Esk Ab Storys	S. Esk Bel Storys	ANZECC 95th percentile triggers*
Date		**22 Nov 16**	**22 Nov 16**	**22 Nov 16**	**22 Nov 16**	
Alkalinity Total	mg/l CaCO3	62	11	14	14	
Acidity	mg/l CaCO3	15	1.5	1.5	1.5	
Fluoride	mg/l	0.14	0.025	0.025	0.025	
Sulphate	mg/l	0.6	0.7	1.9	2.7	
Al Dis	µg/l	12	24	51	53	55
Al Total	µg/l	542	84	324	337	55
As Dis	µg/l	0.5	0.5	0.5	0.5	1
As Total	µg/l	1	0.5	0.5	0.5	1
Cd Dis	µg/l	4.6	0.05	0.05	0.5	0.2
Cd Total	µg/l	6.5	0.05	0.05	0.6	0.2
Co Dis	µg/l	0.25	0.25	0.5	0.25	No trigger
Co Total	µg/l	0.25	0.25	0.5	0.25	No triger
Cr Dis	µg/l	0.5	0.5	0.5	0.5	1 (Cr VI)
Cr Total	µg/l	0.5	0.5	0.5	0.5	1 (Cr VI)
Cu Dis	µg/l	11	0.5	0.5	2	1.4
Cu Total	µg/l	29	0.5	1	3	1.4
Fe Dis	µg/l	24	96	200	195	
Fe Total	µg/l	583	160	507	509	

		ALD Outflow	Aberfoyle @ Hwy	S. Esk Ab Storys	S. Esk Bel Storys	ANZECC 95th percentile triggers*
Mn Dis	µg/l	1	16	10	13	1900
Mn Total	µg/l	46	17	19	19	1900
Ni Dis	µg/l	1.3	0.25	<0.5	<0.5	11
Ni Total	µg/l	2.5	0.25	0.8	0.8	11
Pb Dis	µg/l	0.25	0.25	0.25	0.25	3.4
Pb Total	µg/l	1.6	0.25	0.25	0.25	3.4
Zn Dis	µg/l	170	1	1	13	8
Zn Total	µg/l	12	1	2	17	8
TSS	mg/l	25	1	4	4	
Flow	L/s	0.05				
pH	pH unit	5.65	6.10	6.42	6.27	
EC	µS/cm	131	32	77	79	
Temp	°C	13.5	11	17.7	17.8	

*ANZECC 95th percentile triggers are applicable to slightly – moderately disturbed systems, and are levels that denote additional investigation may be warranted to understand potential impacts on water quality and the ecosystem.

3.4 Comparison of Nov 2016 concentrations with previous monitoring results

The November 2016 monitoring results are compared with the 2003 – 2006 monitoring results in Figure 3.9 to Figure 3.20.

In each graph, the 2003 – 2006 results are presented as box and whisker plots, with the 'box' encompassing the 25th to 75th percentile values for the parameter at each site, and the 'whiskers' indicating the minimum and maximum values in the data set. The November 2016 results are displayed as points on the same plots. Note that results are plotted against log scales to accommodate the large range of values. The pH results are not plotted on a log scale as this measurement is already on a log scale. The comparisons show the following:

- The flows in November 2016 were within the 25th to 75th percentile values of the previous monitoring results overall, but rankings increased with distance downstream. Flow at the Storys below the Precipitation Dam site was equivalent to the 36th percentile flow of the historic data set, and classed in the upper end of the 'low flows' range (<250 L/s). Further downstream, where more runoff from the recent rains enters the forested catchment enters the stream, the flow rankings were close to the median of historic flow results and the maximum 'low flows' recorded. The potential for errors in the flow results due to water flowing under the rock fill in the river channel needs to be recognised;

Table 3. Ranking of flows in November 2016 compared to the historic data set.

	Flow L/s	**Flow percentile of all monitoring runs**	**Flow percentile of 'low flows' (<250 L/s at Storys bel Precip dam)**
Storys bel Precipitation Dam	63.8	36	80
Storys at Managers	218	53	Max
Storys above Aberfoyle	538	61	Max

- pH values recorded in November were consistently between pH 5.5 and 6.0 in Storys Creek. This likely reflects the very wet year and dilute nature of groundwater due to recent rainfall, as pH of rain is generally ~5.5. It is also possible that the pH probe was reading low, although it was successfully calibrated. Similar to previous results Side Creek had the lowest pH;

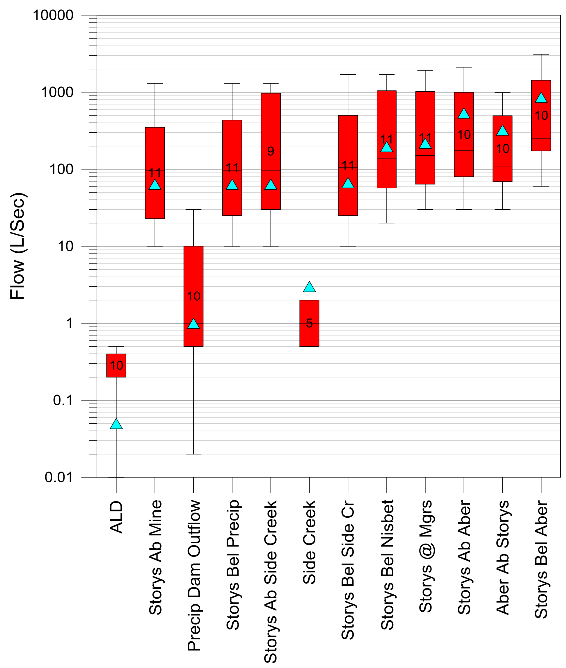

Figure 3.9. Flow in November 2016 compared with flow measured during the 2003 -2006 monitoring period. Number in each box indicates the number of samples included in the analysis.

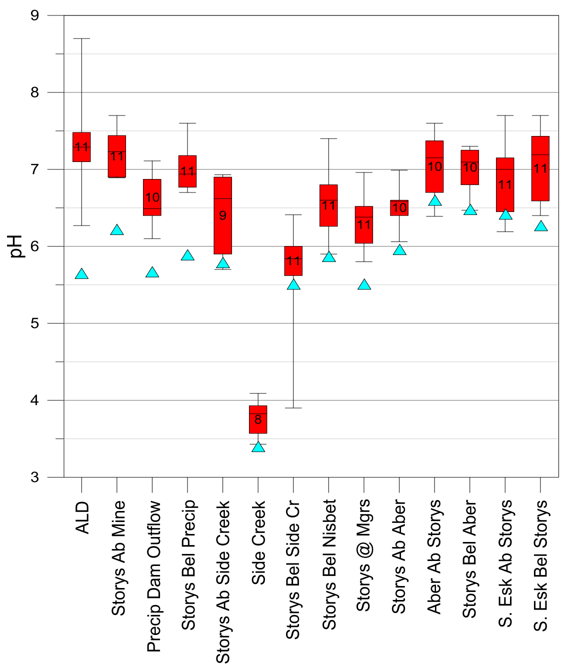

Figure 3.10. pH in November 2016 compared with the values obtained during the 2003 -2006 monitoring period. Number in each box indicates the number of samples included in the analysis.

- The Electrical Conductivity values (Figure 3.11) in November were within the historic range, but towards the lower end of the scale. This is likely attributable to the preceding wet year and recent high flow events 'flushing' dissolved constituents from the groundwater. The highest EC values were recorded in Side Creek;
- Alkalinity values were similar to previous results (Figure 3.12) with the exception of the Precipitate Dam. This reduction may be linked to the high volumes of rainfall over the previous weeks and months flushing available alkalinity from the impoundment faster than it can be generated;
- The alkalinity concentration (Figure 3.12) and alkalinity flux (Figure 3.13) in the Anoxic Limestone Drain were low, and are likely due to the poor state of the infrastructure of the drain. The overall higher concentration in the ALD compared to the other sites suggests that the ALD continues to produce alkalinity;

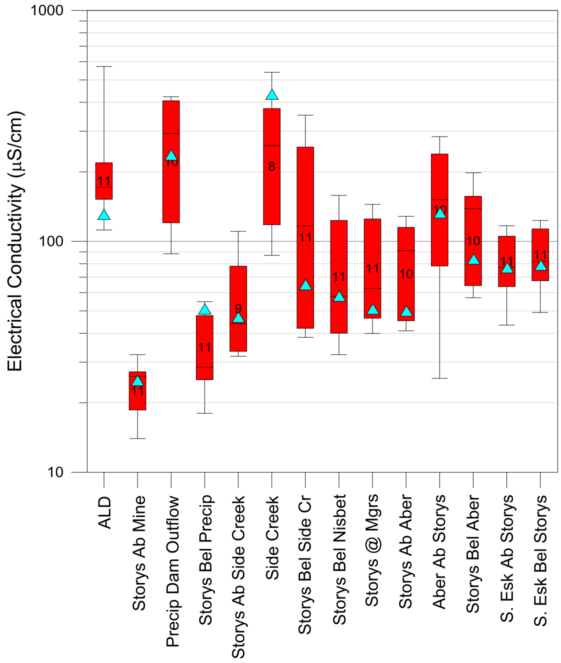

Figure 3.11. Electrical Conductivity in November 2016 compared with flow measured during the 2003 -2006 monitoring period. The number in each box indicates the number of samples included in the analysis.

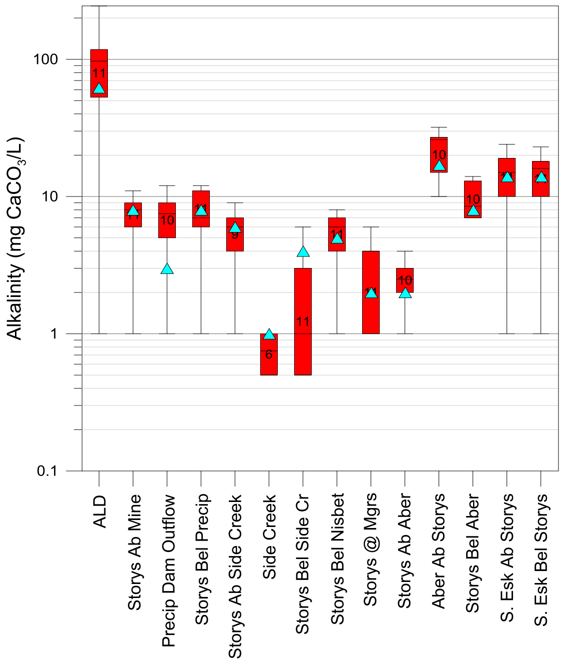

Figure 3.12 Alkalinity concentrations in November 2016 compared with the values obtained during the 2003 -2006 monitoring period. The number in each box indicates the number of samples included in the analysis.

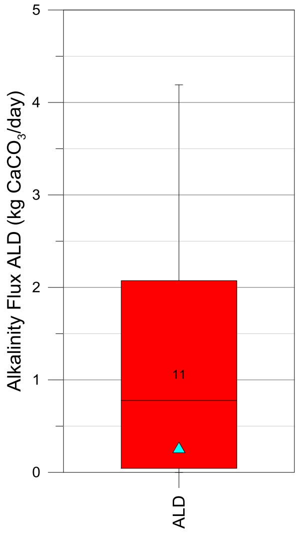

Figure 3.13 Alkalinity flux in the ALD in November 2016 compared with the flux values obtained during the 2003 – 2006 monitoring period. The number in box indicates the number of samples included in the analysis.

- The 2016 results for sulphate, fluoride and concentrations of cadmium, copper, nickel, manganese and zinc show similar patterns, with the concentrations recorded at sites in Storys Creek below the median values of the historic results. In the case of cadmium and manganese, many of the 2016 values are below the range of previously recorded results. This may reflect the high rainfall over the previous year and month 'flushing' metals and sulphate out of the system faster than they can are being generated. In addition, high rainfall several days prior to sampling would generate greater dilution at the downstream sites. In contrast, the concentrations at Side Creek tended to be elevated compared to previous values. This could be due to the high rainfall totals increasing groundwater levels and 'reserves' of metals that are generally not subjected to flushing being mobilised.

- The metal concentrations in the ALD are relatively high compared to previous results, and might be associated with the greater overland flow, or dissolution of cadmium, zinc and nickel bearing carbonates;
- Zinc concentrations in the outflow from the Precipitate Dam were similar to the median values of the historic data set. This input resulted in a large increase in concentration in Storys Creek below the Precipitate Dam as compared to the creek upstream of the mine site. Historically, concentrations increased between the Storys below Precipitate Dam and Storys above Side Creek sites, reflecting diffuse inflow from the mine site, but in 2016, the concentrations remained similar. This is also consistent with high rainfall 'flushing' zinc from the workings at a faster rate than the zinc is being generated;
- Zinc concentrations in Side Creek were above previously recorded values, also consistent with the theory that elevated ground water levels increased metal inputs from the workings. In spite of the increase in Side Creek, concentrations downstream of Side Creek were low compared to historic results, including the lowest recorded at the Storys above Aberfoyle monitoring point;
- The sulphate, fluoride and metal concentrations in Aberfoyle Creek above Storys Creek were generally within the 25 to 50th percentile levels of the historic data set. Exceptions include cadmium which was lower than previously recorded and copper which was near the maximum value of the previously recorded concentrations;
- Zinc concentrations at the Storys above Aberfoyle (218 μg/L) and Aberfoyle above Storys (222 μg/L) sites were similar which is in contrast to the historic results that consistently (with one exception) documented considerably lower concentrations at the Aberfoyle above Storys site (Figure 3.21);
- Eastern Adit is very difficult to monitor due to the very low flow and extensive presence of iron precipitates in the waterway. The waterway was sampled in November 2016 (Table 2) but no results from 2003 – 2006 are available for comparison. The outflow from the adit shows elevated values of most metals, although not as high as the concentrations present in Side Creek. The low concentrations of copper in the outflow are consistent with the pH of 6.07, which would limit mobilisation. The relatively elevated pH is also consistent with the ubiquitous presence of precipitated iron hydroxides that choke the adit and downstream creek. The high pH is accompanied by substantial levels of alkalinity, suggesting the neutral acid drainage is being generated by or near carbonate bearing rock. The pH and EC values collected in 2016 are very close to the median values collected in 2003 – 2006 (Figure 3.22

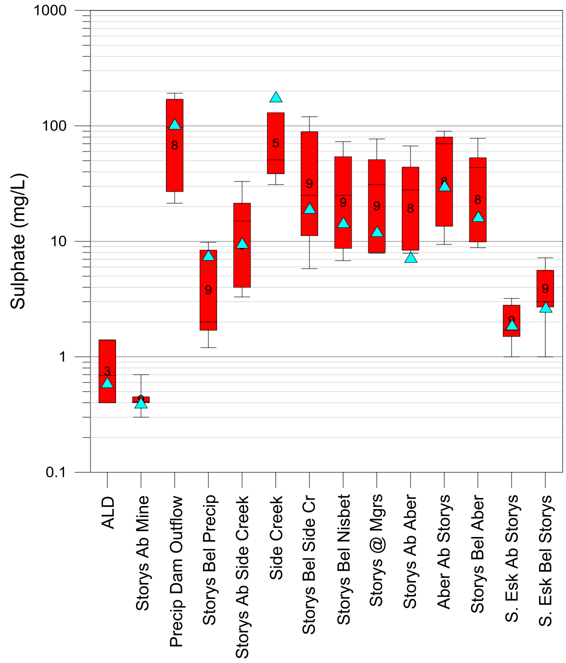

Figure 3.14. Sulphate concentrations in November 2016 compared with the values obtained during the 2003 -2006 monitoring period. The number in each box indicates the number of samples included in the analysis.

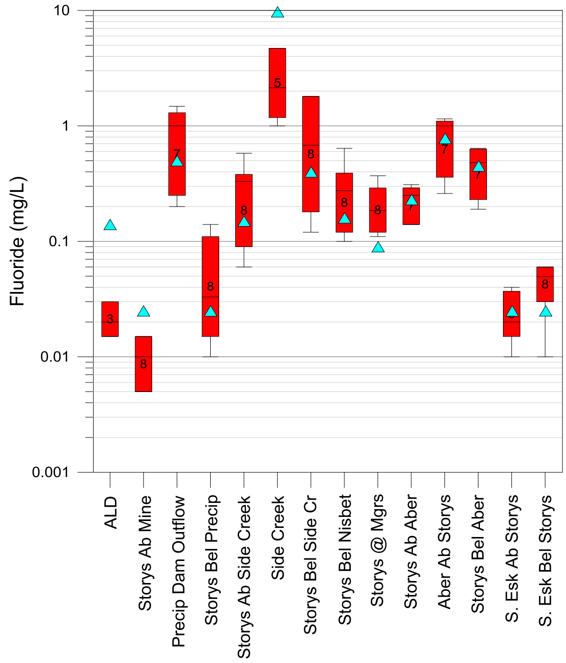

Figure 3.15 Fluoride concentrations in November 2016 compared with the values obtained during the 2003 -2006 monitoring period. The number in each box indicates the number of samples included in the analysis.

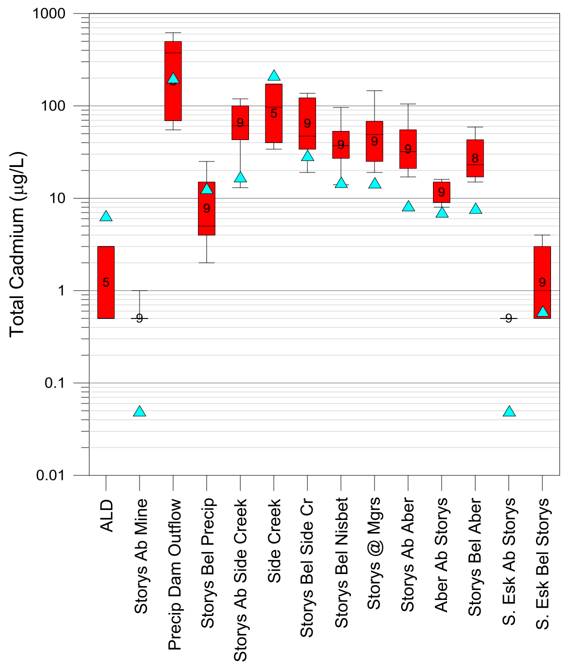

Figure 3.16. Total cadmium concentrations in November 2016 compared with the values obtained during the 2003 - 2006 monitoring period. The number in each box indicates the number of samples included in the analysis.

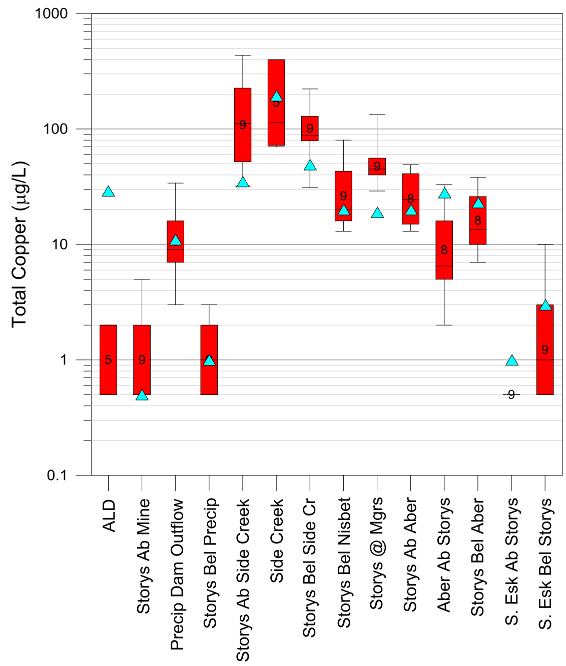

Figure 3.17. Total copper concentrations in November 2016 compared with the values obtained during the 2003 -2006 monitoring period. The number in each box indicates the number of samples included in the analysis.

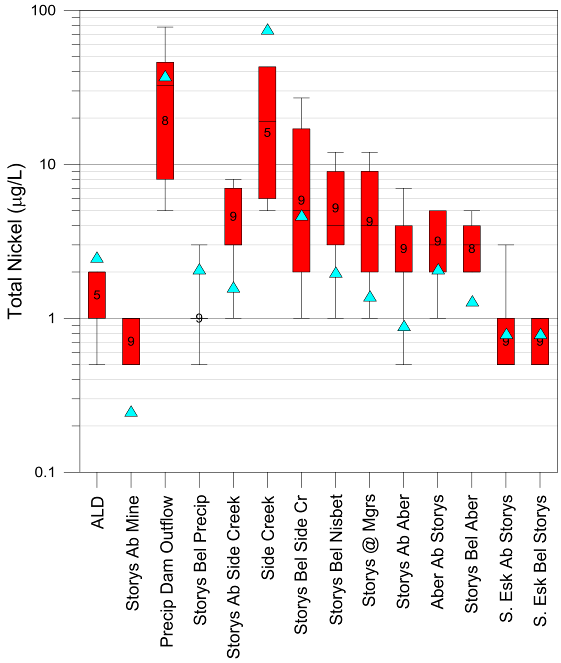

Figure 3.18. Total nickel concentrations in November 2016 compared with the values measured during the 2003 -2006 monitoring period. The number in each box indicates the number of samples included in the analysis.

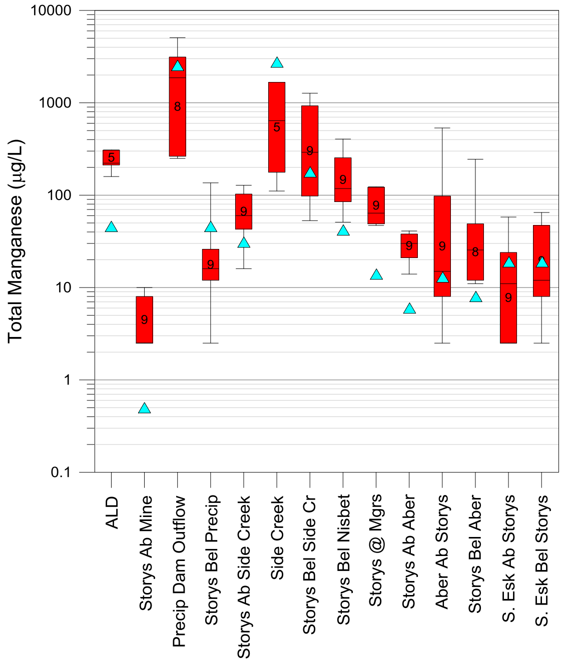

Figure 3.19. Total manganese concentrations in November 2016 compared with the values obtained during the 2003 - 2006 monitoring period. The number in each box indicates the number of samples included in the analysis.

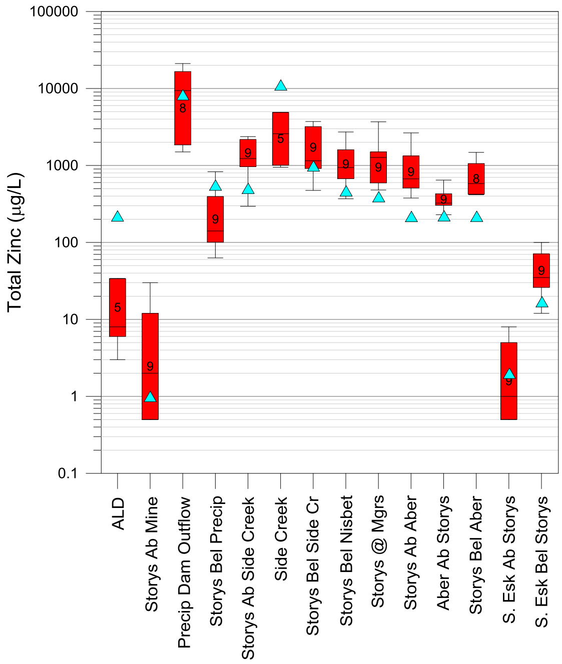

Figure 3.20. Total zinc concentrations in November 2016 compared with the values obtained during the 2003 -2006 monitoring period. The number in each box indicates the number of samples included in the analysis.

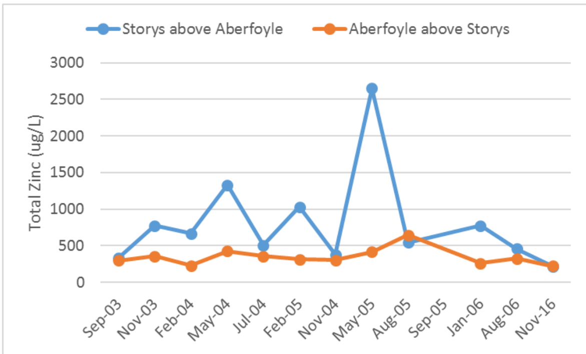

Figure 3.21. Comparison of total zinc values at Storys above Aberfoyle and Aberfoyle above Storys Creek monitoring sites.

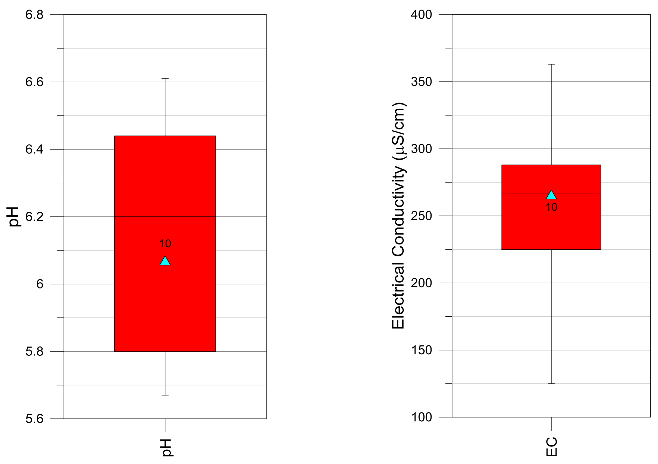

Figure 3.22. pH and EC results in November 2016 from Eastern Adit compared to historical values. The number in each box indicates the number of samples included in the analysis.

3.5 November 2016 fluxes compared to previous monitoring results

Fluxes of sulphate cadmium, nickel and zinc based on the flow and concentrations in the November 2016 samples have been calculated and are compared with previous results in Figure 3.23 to Figure 3.26.

The calculated fluxes are within the previously determined range, and are generally above median values for sulphate, cadmium and nickel, and below the previous medians for zinc. The fluxes show similar patterns of increasing loads as Storys Creek flows through mine site, and continued increases between Storys below Nisbet and Storys above Aberfolye. It is likely that the increases in loads downstream of the mine site are associated with the continued weathering and oxidation of metal bearing material in the river channel.

In Aberfoyle above Storys Creek, the loads fall within the 50th to 75th percentile range of previous results for all four of the parameters.

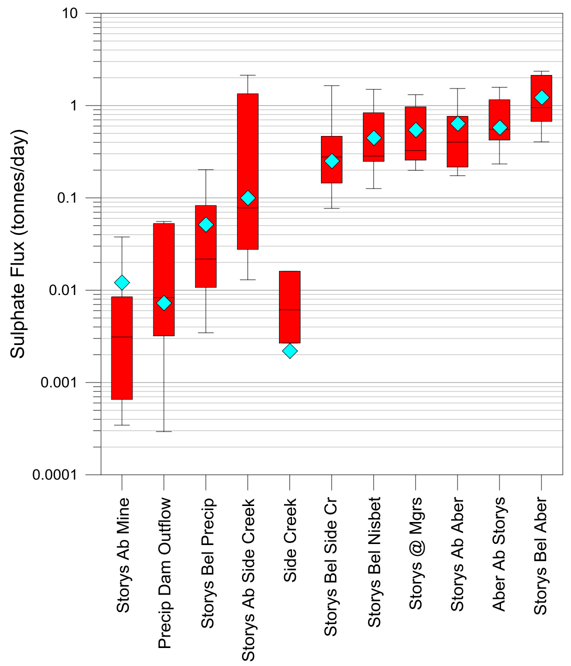

Figure 3.23. Sulphate fluxes (tonnes/day) in November 2016 compared with fluxes determined from the 2003 -2006 monitoring results. The number in each box indicates the number of samples included in the analysis.

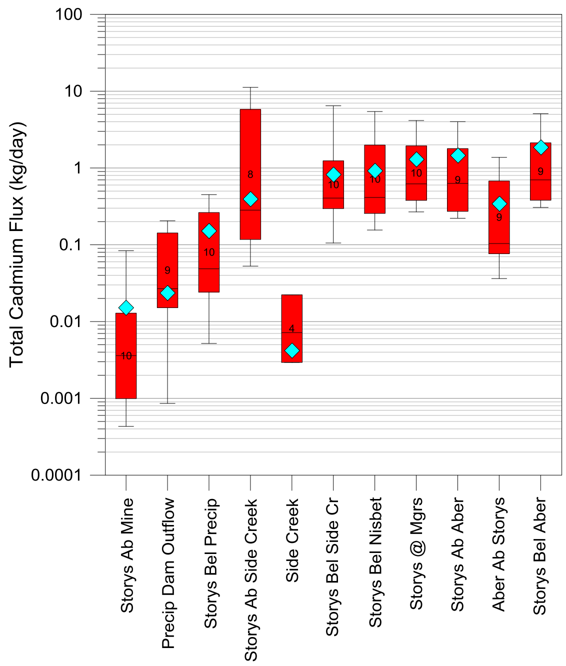

Figure 3.24 Total cadmium fluxes (tonnes/day) in November 2016 compared with fluxes determined from the 2003 -2006 monitoring results. The number in each box indicates the number of samples included in the analysis.

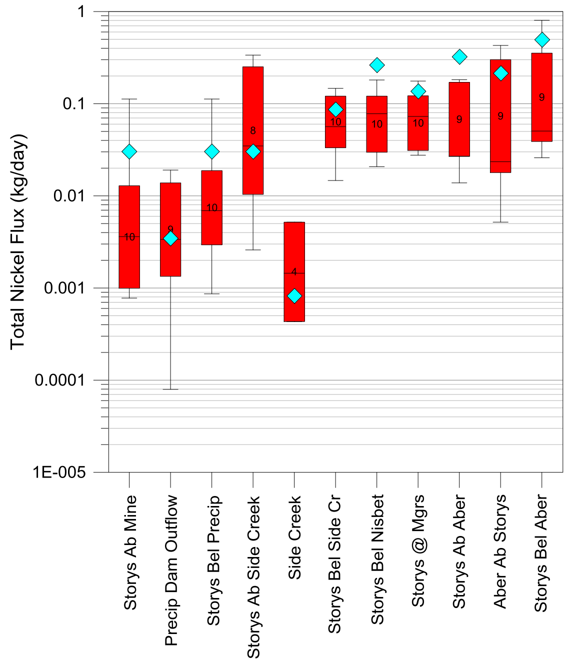

Figure 3.25 Total nickel fluxes (tonnes/day) in November 2016 compared with fluxes determined from the 2003 -2006 monitoring results. The number in each box indicates the number of samples included in the analysis.

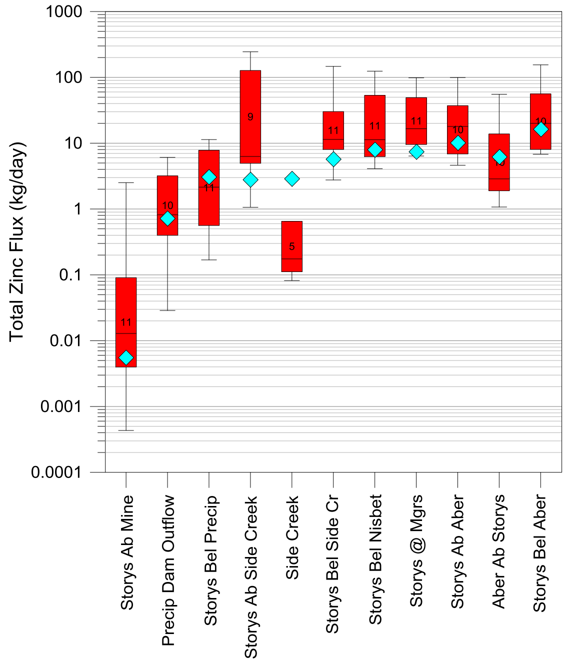

Figure 3.26 Total zinc fluxes (tonnes/day) in November 2016 compared with fluxes determined from the 2003 - 2006 monitoring results. The number in each box indicates the number of samples included in the analysis.

The flux estimates for sulphate, zinc and cadmium have been divided into low (<250 L/s, red) medium (250-350 L/s, blue) and high flows (>350 L/s, green) as measured at the Storys at Managers site. The low flow November 2016 fluxes are compared to previous estimates, including those obtained prior to the 2003-2006 monitoring program (Figure 3.27 to Figure 3.29). The 2016 fluxes are well within the previous range of low flow results

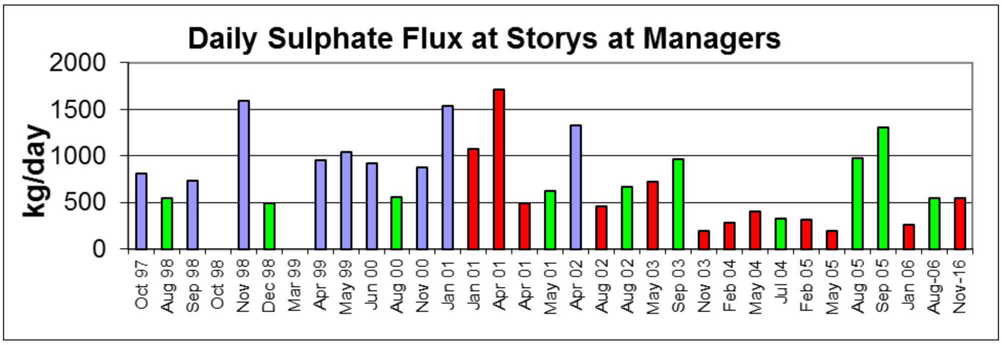

Figure 3.27. Daily sulphate flux at Storys at Managers monitoring site. Red bars indicate low flow at mine site (<250 L/s), blue bars indicated medium flow (250-350 L/s) and green bars indicate high flow (>350 L/s)

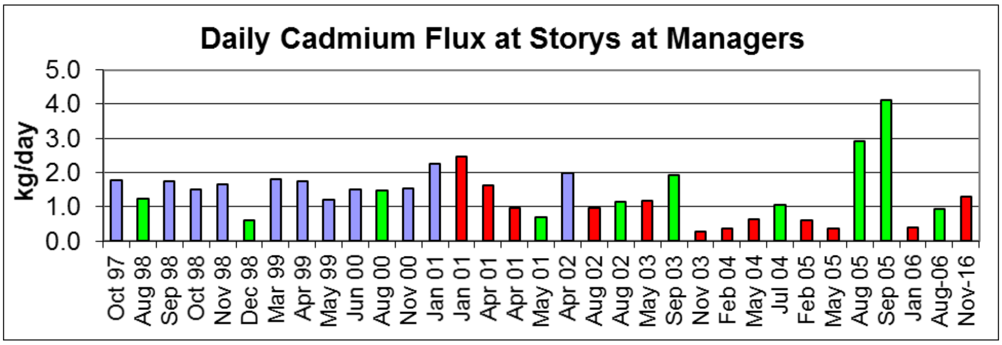

Figure 3.28. Daily cadmium flux at Storys at Managers monitoring site. Red bars indicate low flow at mine site (<250 L/s), blue bars indicated medium flow (250-350 L/s) and green bars indicate high flow (>350 L/s)

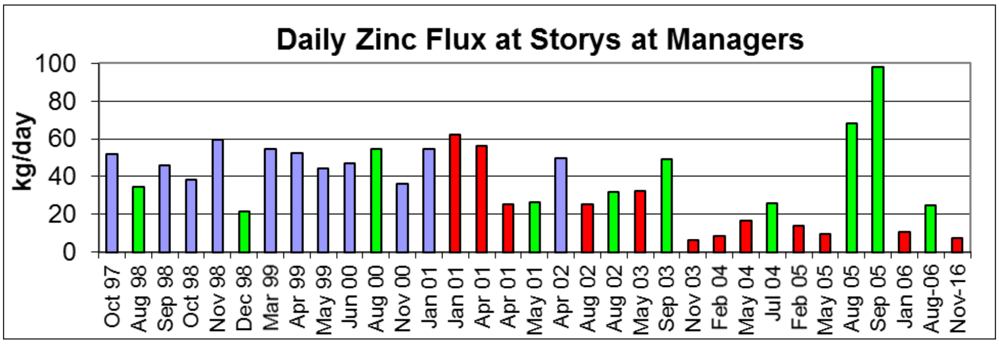

Figure 3.29. Daily zinc flux at Storys at Managers monitoring site. Red bars indicate low flow (<250 L/s), blue bars indicated medium flow (250-350 L/s) and green bars indicate high flow (>350 L/s)

4 Recommendations

Recommendations arising from the water quality monitoring include the following:

- Fix the water delivery system at the ALD, and clean out the drain so that more alkalinity-rich water enters the underground workings;
- Review the outflow system at the Precipitate Dam and upgrade if required;
- Possibly re-investigate remediation options at the Aberfoyle Mine. The large volumes of tailings and waste material on the site are undoubtedly contributing to the metal and sulphate loads in the river, and removal and disposal of this material would be logistically easier than addressing the underground acid drainage sources at Storys Creek. However, the relative contributions of the surface material compared to underground inputs at Aberfoyle would need to be assessed, and issues associated with the use of the surface tailings as building material would need to be addressed before a decision could be made. Additional monitoring in Aberfoyle Creek upstream, through and downstream of the mine site, including establishing the flux of contaminants from accessible mine adits, would increase the understanding of the sources and assist with deliberations. Additional monitoring in Aberfoyle would also determine whether the elevated copper concentration recorded in November 2016 was a unique event or indicative of a longer term trend;
- Routine, additional monitoring in Storys Creek over 12 or more months is not recommended. This recommendation assumes that major additional mine site remediation works at Storys Creek are unlikely due to prohibitive costs associated with addressing the groundwater inputs and widespread diffuse sources entering the waterway from the material in the creek bed, so

the primary aim of ongoing monitoring would be to document the long-term recovery of the system. Within this context, the present water quality monitoring results are consistent with previous results, and do not indicate substantial changes as compared to the 2003 – 2006 monitoring period. Due to the consistency of the recent and historic results, the inherent variability in the system linked to rainfall patterns, the relatively low number of previous monitoring results, and difficulty in accurately monitoring flow, it would be statistically difficult to identify definite changes within the system. There might be value in completing one additional monitoring run following a period of extended dry conditions to provide an indication of ground water inputs from the mine. This approach could be repeated every 5 to 10 years to provide a 'monitored recovery' of the system. It is also suggested by the investigators that in the context of historic acid drainage issues in Tasmania, Storys Creek is a moderate issue, and greater environmental outcomes could probably be gained by investment in other areas of the State.

Appendix 1: Photos of monitoring sites in November 2016

Monitoring Site	Easting	Northing
Aberfoyle at Highway	563442	5390182
Storys above Mine	560996	5390778
Storys at ALD	560827	5390521
Precip Dam Outflow	561242	5390605
Storys Bel PPT Dam	561275	5390521
Storys Ab Side Ck	561198	5390255
Side Creek	561128	5390214
Storys bel Side Ck	561192	5390040
Nisbet Creek	561109	5389697
Eastern Adit	561181	5389910
Storys bel Nisbet	561149	5389443
Storys at Managers	561948	5388044
Storys ab Aberfoyle	566243	5380759
Aberfoyle ab Storys	566304	5380751
S Esk above Storys	566647	5379225
S Esk bel Storys	563947	5377992

Aberfoyle at Highway

Storys ab Mine (at Falls)

Storys at ALD into mine

Precipitate Dam (sample collected at outlet near arrow)

Storys below Precipitation Dam

Storys above Side Creek

Side Creek

Storys below Side Creek

Eastern Adit

Nisbet Creek

Storys below Nisbet

Storys at Managers

Storys above Aberfoyle

Aberfoyle above Storys

Storys below Aberfoyle