Review of Storys Creek Water Quality & Future Monitoring Strategy

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A Report to Mineral Resources Tasmania

L. Koehnken
Technical Advice on Water

Review of Storys Creek Water Quality and Future Monitoring Strategy

1 Introduction

Over the past 5-years, Mineral Resources Tasmania (MRT) has implemented remediation strategies in historic mine workings and tailings deposits in Storys Creek, a tributary of the South Esk River in north east Tasmania. The works have included the relocation of a precipitation dam, sealing of a mine adit, construction of an anoxic limestone drain, *in situ* limestone sand addition to the river on a yearly basis and the relocation of large volumes of jig tailings.

MRT will implement 3-year water quality monitoring program to document water quality trends in Storys Creek and assess the effectiveness of the remediation works.

The aim of this report is to review available water quality information and design a water quality monitoring program that will achieve the objectives by establishing the fluxes and concentrations of pollutants, namely zinc, copper aluminium in the waterways.

This water quality review and monitoring plan focuses primarily on Storys Creek, as this is the catchment where all of the remediation works have been completed. The downstream impact of Storys Creek water quality on Aberfoyle Creek and the South Esk will also be considered, but are not a major focus of the monitoring.

Background information of the remediation works and a summary of available water quality data are summarised in JMP (2000).

2 Review of Water Quality data

2.1 Setting

Storys Creek is a ~25 km long tributary of the South Esk River, with its headwaters originating on the Ben Lomond plateau. The creek flows steeply off the dolerite plateau over scree slopes, entering Ordovician sediments and Devonian granites, which underlie the majority of the catchment. The river transects the South Esk floodplain for about 1 km before flowing into the South Esk. The catchment downstream of the Ben Lomond plateau is shown in Figure 2.1. Mining in the catchment occurred between the 1880s and 1970s upstream of Rossarden with tin and tungsten recovered.

Remediation works began in 1998 with the addition of limetsone to exposed jig tailings deposits in the river. In the summer of 2000, slimes from a precipiatate dam were relocated to a secure landfill. Recently, in 2002 – 2003, 71,000 m^3 of jig tailings were removed from the west bank of the river and disposed of in the same landfill as the slimes. The details of the works undertaken are described in JMP (2000) and JMP (2003)

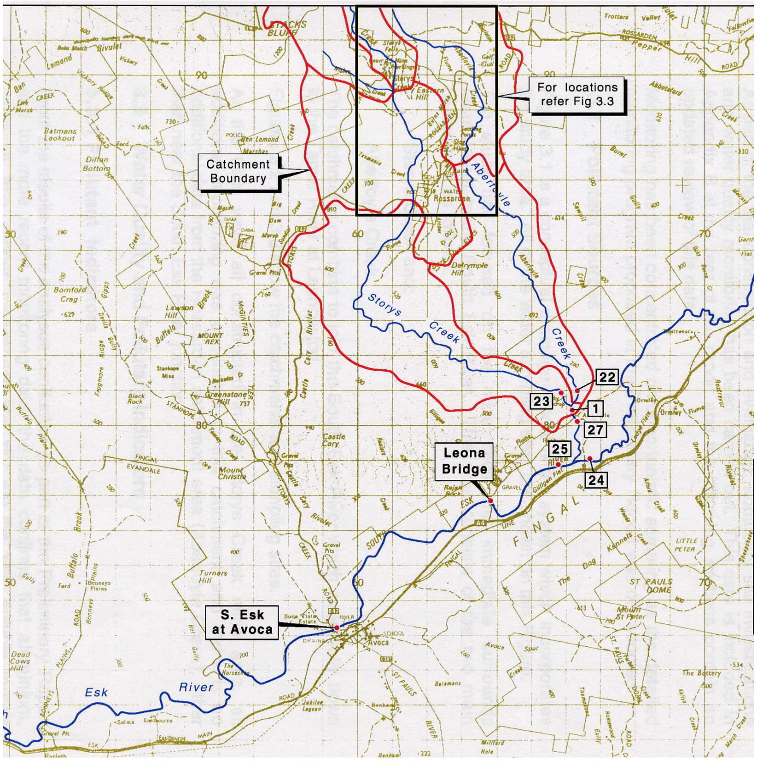


Figure 2.1. Area map of Storys Creek. From JMP, 2000.

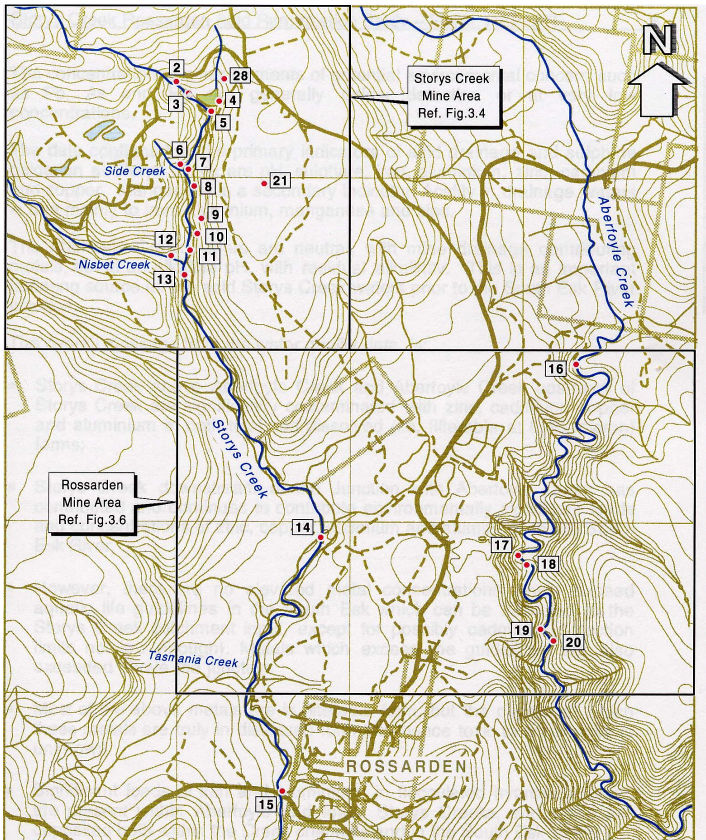


Figure 2.2. Monitoring sites in Storys Creek, from JMP, 2000.

2.2 Available data and approach

MRT initiated systematic water quality monitoring in the Storys Creek catchment in 1997, when the remediation program began. Suites of samples were collected 1 – 3 times per year between 1997 and 2003, over a range of flow conditions at the sites shown in Figure 2.2. The monitoring identified zinc, copper aluminium and cadmium as the pollutants of greatest concern in the catchment.

Flow data are only consistently available for Site 14, Storys Creek below the Pumphouse where a river level recorder was installed.

The lack of flow data and limited sampling runs completed prior to the initiation of remediation works makes it difficult to establish historic pollutant concentrations or flux ranges. To overcome these limitations, the following approach has been adopted for interpreting the available data, and designing a monitoring program:

- Establish parameter vs parameter relationships between pollutants to determine whether there are common processes controlling pollutants of concern;
- Establish concentration vs flow relationships to identify the flow regimes with the greatest environmental impact and identify pre- and post- remediation trends.
- Based on flow data from Site 14, divide data set into low, medium and high flows, and look at downstream changes in water quality under each flow regime
- Using flow data from Site 14, establish which flow regimes are delivering the greatest pollutant loads to the downstream environment and identify pre- and post-remediation trends;
- Interpret water quality results and trends with respect to proposed Protected Environmental Values for the Storys Creek and South Esk River catchments
- Develop on going water quality monitoring program based on findings.

The following sections discuss each of these steps in detail.

3 Water quality results

3.1 Parameter vs parameter correlations

A good correlation between parameters does not necessarily imply a common source, but does indicate that similar processes are likely to be responsible for the liberation and transport of the pollutant in a river system. Good correlation between parameters also provides a way of simplifying monitoring by allowing the determination and interpretation of fewer parameters. Additionally, it allows continuous monitoring data collected for one parameter, such as electrical conductivity (EC) to be extrapolated to other parameters.

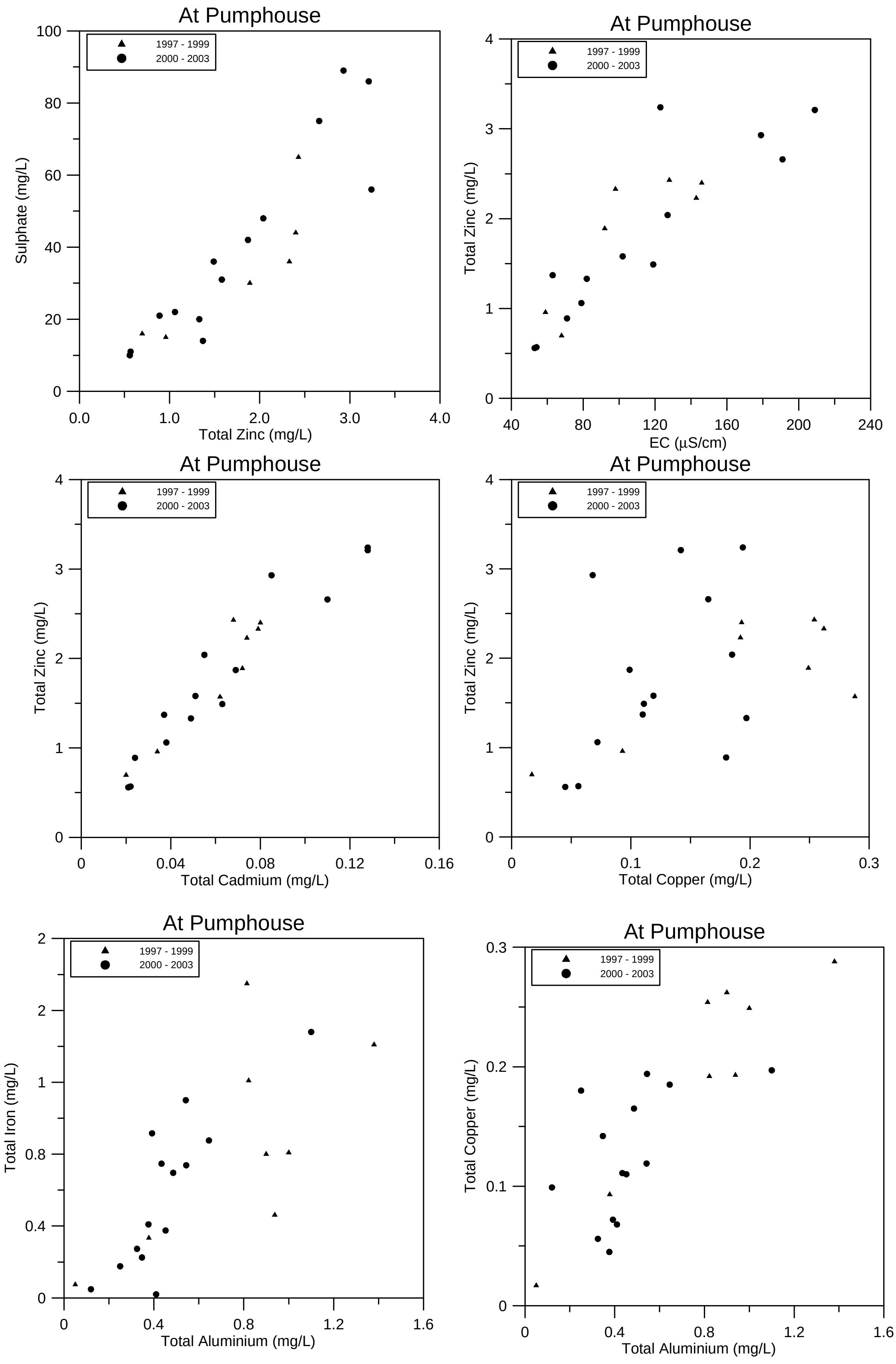


Figure 3.1. Parameter vs parameter graphs for Site 14, Storys Creek below Pumphouse.

To establish the correlation between parameters within Storys Creek, the water quality monitoring data from Site 14 was used, as it reflects all major inputs and has the most complete monitoring record, including flow information. The data set has been divided into pre- and post- 2000 components, as this was the time when the precipitate dam was relocated. This division would also reflect limestone placement on the riverbanks for ~1 year.

In Storys Creek, there is good correlation between zinc, sulphate, electrical conductivity (EC), and cadmium. These parameters are not greatly affected by the pH range present in Storys Creek, and therefore are not readily removed from the water column once present. The trends are similar for both pre- and post- remediation data sets, suggesting the ratios of metals in the system has not greatly changed. There may be a shift towards lower zinc values for equivalent sulphate values in the post 2000 data set (Figure 3.1). Dilution is likely to be the main process affecting concentrations of these parameters once present in the river.

The good correlation between EC and zinc indicates that a continuous recording EC probe linked to a water level recorder could be used to estimate the on going disharge of pollutants from the area.

There are poorer correlations between zinc and copper, zinc and aluminium (not shown) or zinc and iron (not shown). The pH range present in Storys Creek affects the speciation of copper, aluminium and iron, and removal would be expected to occur under some conditions. The correlation between these parameters is relatively good, as shown in the final 2 graphs of Figure 3.1.

Figure 3.2 shows the relationship between zinc and alkalinity at Site 14, and demonstrates that the highest zinc concentrations occur when alkalinity is at or below 1 mg/L. All but one of the >1 mg/L alkalinity values were recorded after remediation works began, and suggests that the liming of river bed and banks has increased alkalinity values in the river under some conditions.

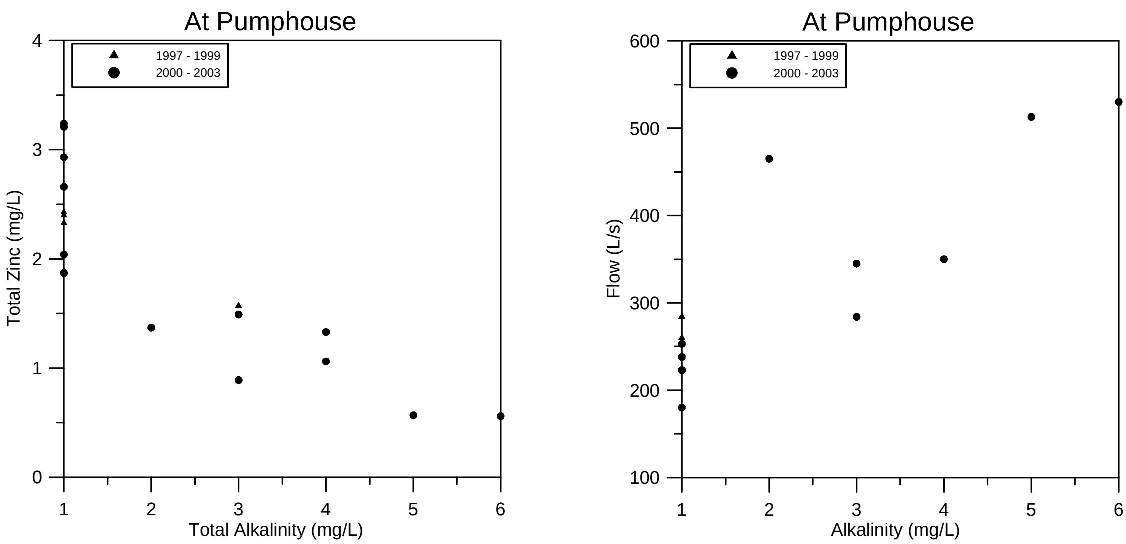


Figure 3.2. (Left) Graph of alkalinity vs zinc for Storys Creek below Pumphouse

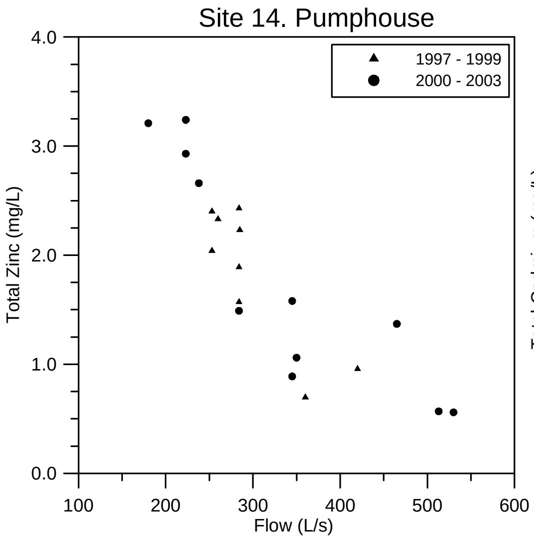
Figure 3.3. (Right) Graph of alkalinity vs River flow for Storys Creek below Pumphouse

In Figure 3.3, alkalinity levels are plotted against river flow and shows that higher alkalinity values correspond with periods of high flow. This indicates that the water entering the river system during rain events has higher alkalinity levels than the baseflow (groundwater?) entering the creek during low flow. Based on the flow / alkalinity relationship, the decreasing zinc trend present in Figure 3.2 is at least partially attributable to dilution.

In summary, there are good correlations between the pollutants of concern, suggesting they are controlled by common processes. Once in the waterway, dilution appears to be the major process affecting contaminant concentrations, with pH affecting aluminium, iron and copper. Alkalinity levels increase with increasing flow, due to influent waters being more alkaline than baseflow. Based on the relationships, a continuous recording EC record could be used to provide a continuous estimate of the pollutant load in Storys Creek.

3.2 Concentration vs flows

There is a consistent trend between decreasing pollutant concentrations and increasing flow in Storys Creek as shown in Figure 3.4 and Figure 3.5 for zinc and cadmium at Site 14. The plots suggest that dilution is the major factor controlling contaminant concentrations both before and after remediation works were completed on site.



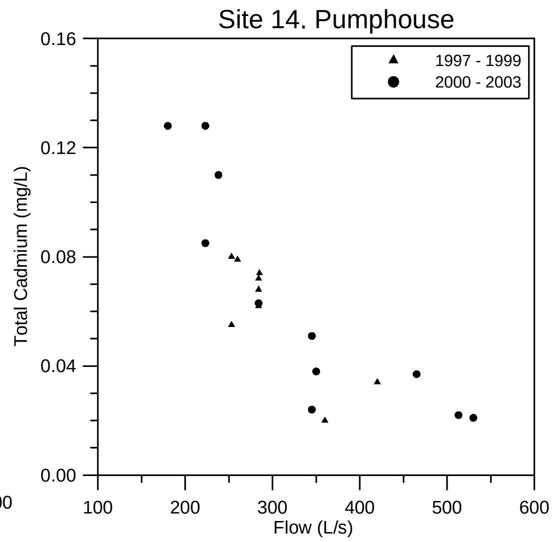


Figure 3.4. (Left) Flow vs total zinc at Site 14.

Figure 3.5. (Right) Flow vs total cadmium at Site 14.

The flow data from Site 14 was used to categorise water quality data at other monitoring sites into low, medium and high flows. The bar graphs in Figure 3.6 show zinc concentrations as a function of these flow categories, with the data arranged in order of increasing flow (based on the flow data at Site 14). The bar colours indicate flow regime, with the dark blue bars denoting samples collected prior to removal of the precipitation dam in the summer of 2000. The data displayed in the bar graph for

Site 14 in Figure 3.6 is the same data as presented in Figure 3.4. Note that data are not available for all sites on all dates.

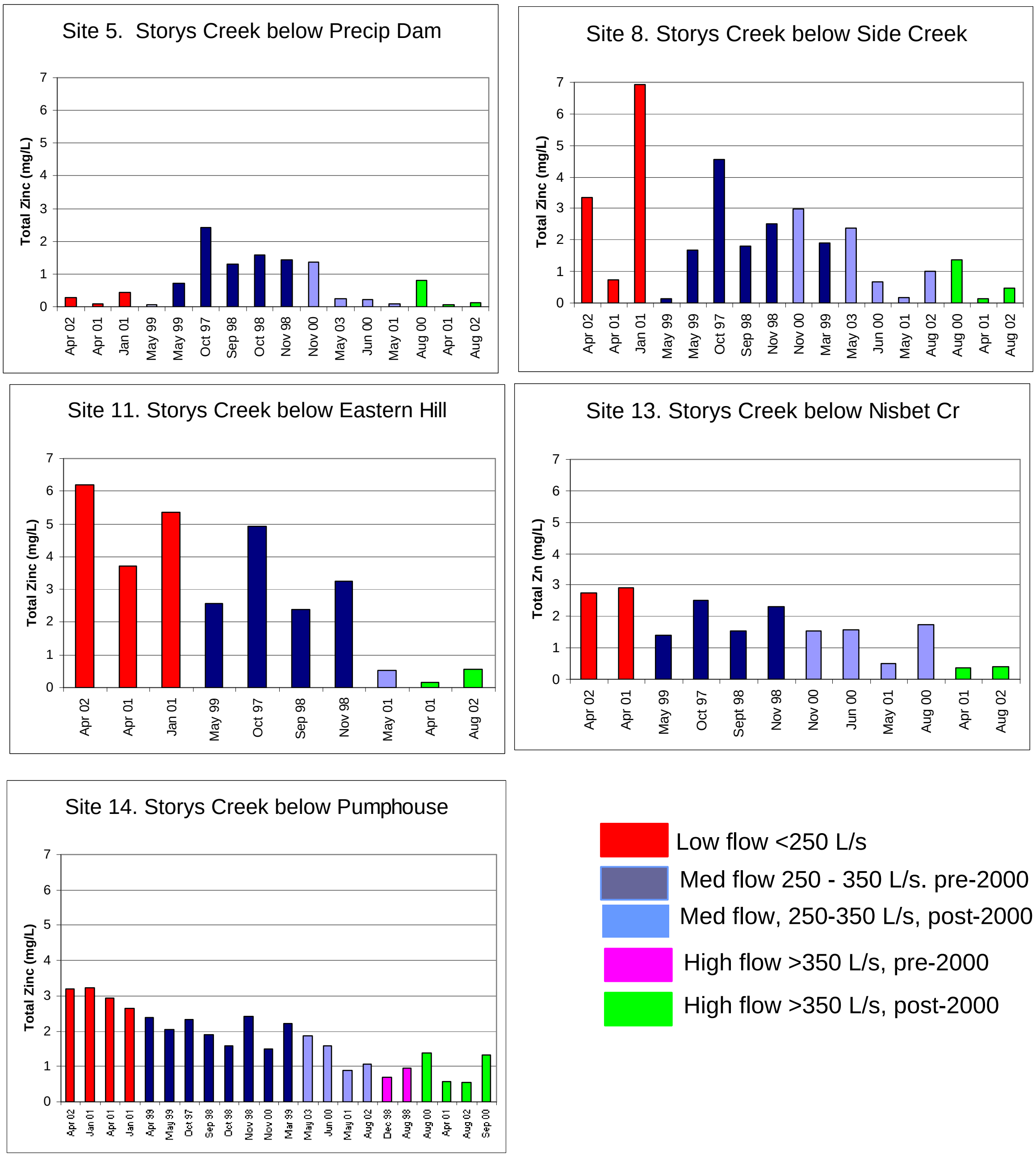


Figure 3.6. Total zinc concentrations at five sites in Storys Creek. Red bars indicate low flow conditions (<250 L/s); dark and light blue bars indicate medium flow conditions (250 - 350 L/s), and green and pink bars indicate high flow conditions (>350 L/s). Removal of the Precipitation Dam was completed in summer 2000.

The distribution of the dark blue bars in Figure 3.6, denoting pre-remediation monitoring, shows that only medium flow levels were monitored prior to works being completed, with the exception of two 'high' flows at Site 14. This makes it difficult to identify pre- and post- remediation trends for low or high flows.

The Site 5-'Storys Cr below the Precipitation Dam' graph suggests a decrease in zinc concentrations since remediation of the dam during medium sized flow events. No direct comparison can be made for the low or high flows, however, this site does not follow the catchment trend of higher concentrations at low flows, suggesting that groundwater is not constantly delivering zinc to the river at this site.

The Site 8-'Storys Creek below Side Creek' graph and Site 11 – 'Storys Creek below Eastern Hill graph show there is a large increase in zinc concentrations in Storeys Creek as compared to Site 5 below the precipitation dam, and the concentrations are highest during low flows. This is the area where jig tailings are believed to have the greatest contribution to contaminant loads. The data supports the hypothesis that the majority of pollutants are delivered via base flow, and diluted by higher flows. The Site 8 graph also demonstrates that prior to remediation of the precipitation dam, inputs from Side Creek were greater than inputs from the dam, with concentrations more than doubling in the pre-2000 data sets.

Comparing the post-2000 monitoring results from Storys below Nisbet Creek (Site 13) with Site 11 shows the entrance of the creek dilutes zinc concentrations during low flow, but does not alter zinc values associated with medium or high flow zinc appreciatively. This may indicate that during higher flows, additional zinc enters this section of the river via the flushing of tailings deposits in the river.

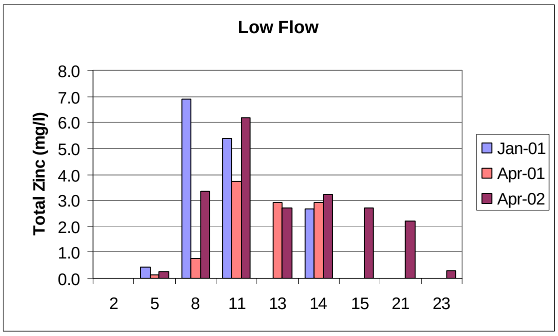
Overall, the monitoring results indicate that since remediation of the precipitation dam, the majority of pollutants enter the river between the Precipitation Dam and Eastern Hill, with concentrations decreasing downstream. The highest concentrations occur during periods of low flow, indicative of a groundwater pollutant input, with higher flows reducing values through dilution.

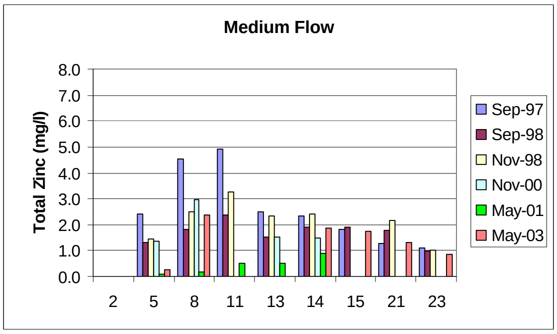
3.3 Downstream Pollutant trends in Storys Creek

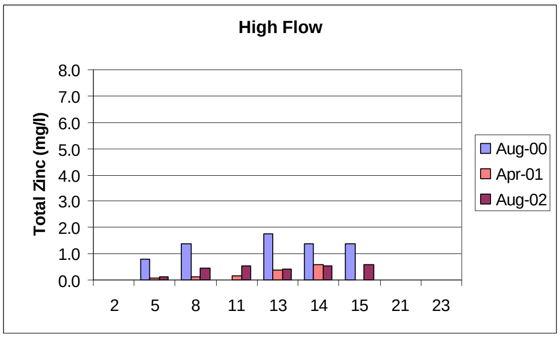
The behaviour of zinc along the length of Storys Creek is shown in Figure 3.7 where data are again divided into high, medium and low flow groupings. The large reduction in zinc concentrations following remediation of the precipitation dam is evident in the 'Medium' flow graph, and the sizeable inputs entering Storys Creek from Side Creek are evident in the 'Low' and 'Medium' graphs.

Based on the limited data sets, zinc concentrations decrease slowly downstream of Site 14 under low and medium flow conditions, with the greatest decrease occurring below the confluence of Storys and Aberfoyle Creek due to the lower (although still elevated) zinc values in Aberfoyle Creek. Similar trends occur for other metals (cadmium, copper) where the concentrations in Aberfolye Creek are lower than in Storys Creek. For parameters such as sulphate and alkalinity, which are higher in Aberfoyle Creek as compared to Storys, concentrations increase in Storys Creek below the confluence, as expected (eg. sulphate, Figure 3.8).

No high flow data sets are available for the sites downstream of the Pumphouse, although it is expected the trends would be the same as for the low and medium flow regimes.







Site	Location
2	Storys above Precip dam
5	Storys below Precip dam
8	Storys below Side Cr
11	Storys below Eastern Hill
13	Storys below Nisbet Creek
14	Storsy below Pumphouse
15	Storys at Rossarden
21	Storys above Aberfoyle Creek
23	Storys below Aberfoyle Creek

Figure 3.7. Zinc concentrations at monitoring sites along Storys Creek.

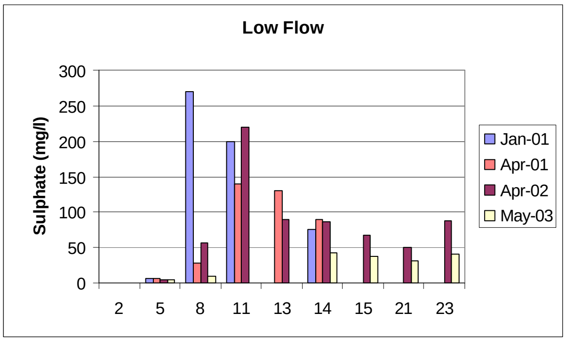
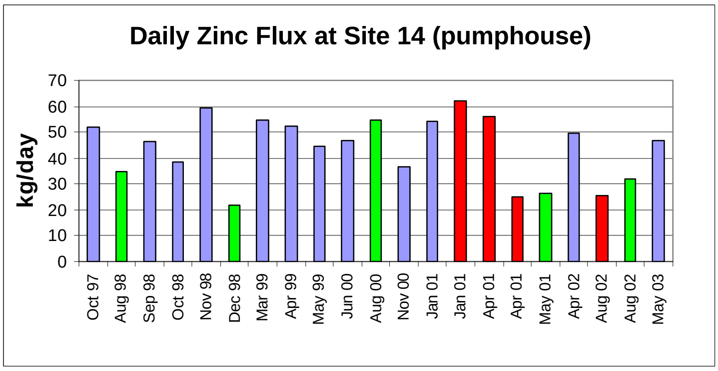


Figure 3.8. Sulphate concentrations at monitoring sites along Storys Creek.

3.4 Fluxes vs flows

The bar graphs in Figure 3.9 show calculated zinc and sulphate fluxes for Site 14. The data is presented in chronological order, with the bar colour indicative of flow regime (red = high, blue = medium, green = high). Figure 3.9 shows that zinc fluxes range from 25 to 50 kg/day and sulphate ranges from 500 to ~1500 kg/day. These are relatively small ranges, and suggest that the pollutants are being released at relatively slow rate and removed downstream under even very low flow regimes. There is no indication that pollutants are 'building up' in the deposits, and then being flushed out during a high flow event.



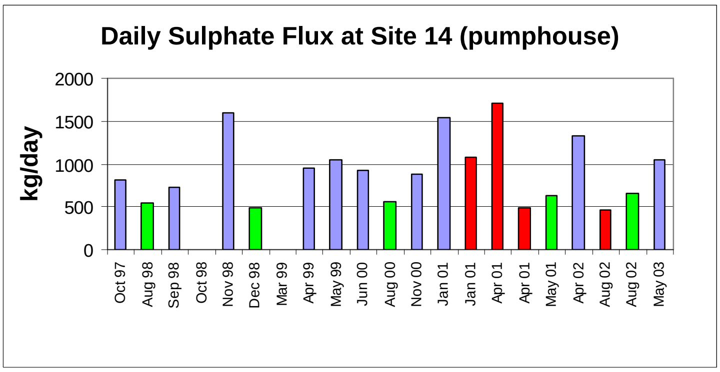


Figure 3.9. Zinc and sulphate fluxes at Site 14 in chronological order. Colour coding indicates flow regime, red= <250 L/s; blue = 250 – 350 L/s; green = > 350 L/s.

Table 1 summarises average and median zinc and sulphate fluxes at Site 14 for data collected prior to removal of the precipitation dam (pre-2000) and after dam removal and limestone dosing (post-2000). The average and median zinc values indicate there has been little change pre- and post 2000. The average and median sulphate values, however, indicate there has been a substantial (~25%) increase in the sulphate flux since the remediation works.

Because sulphate is an anion that is not affected by changes in pH, the results suggest that the generation of pollutants near Storys Creek has increased since 2000 relative to the earlier monitoring data. This may be related to the extended drought experienced in the Midlands over the past few years, which has prolonged the exposure of acid generating material to oxygen due to reduced water levels. This is supported by the higher zinc fluxes being associated with the lowest flows in recent years.

The fact zinc levels have remained essentially constant during a period of increased pollutant generation suggests that the liming of the bed and banks of the river has reduced the release of this metal relative to sulphate.

Table 1. Comparison of pre-2000 and post-2000 zinc and sulphate fluxes at Site 14.

Parameter	Pre-2000 (kg/day) (n=9)	Post-2000 (kg/day) (n=12)
Zinc - Average	44.8	43.0
Zinc - Median	46.1	46.8
Sulphate - Average	684	940
Sulphate – Median	733	899
Zinc – Average Medium flows	49.3 (n=8)	31.6 (n=3)
Sulphate – Average Medium flows	756 (n=8)	721 (n=3)

If the low and high flows are removed from the record, and a comparison of zinc fluxes associated with medium flows is made, the results show that the average zinc loads have decreased from 49 to 32 kg/day, a decrease of 32%, whereas sulphate fluxes vary by only 5%. Initial mass balances completed by JMP (1998) showed that the Precipitation dam contributed ~15% of the total zinc load upstream of Site 14. If it is assumed that this zinc has been removed from the system, then an additional 10 – 15% reduction in zinc load has been achieved through the other remediation works.

3.5 Comparison of water quality with guideline values

The aim of remediation at Storys Creek is to improve water quality in Storys Creek such that there is an improvement in the aquatic ecosystem in the Creek and downstream waterways, and the water is suitable for agricultural uses. Davies (in JMP, 1998) found a declining trend in abundance and diversity of macroinvertebrate communities in Storys Creek and the South Esk River, and attributed the trend to the cumulative impacts of land use within the catchment and a major impact due to the input of Storys Creek water. It was estimated that the main zone of impact in the South Esk River extended 30 km downstream from the confluence of Storys Creek.

Table 2 contains a summary of water quality data collected from Storys Creek since 2000 compared to ANZECC/ARMCANZ (2000) guideline values for Protection of Aquatic Ecosystems, Irrigation and Livestock watering. In the initial assessment of Storys Creek in 1997, JMP identified aluminium, cadmium, copper and zinc as the pollutants of concern with respect to ecosystem health. Table 2 demonstrates that these metals continue to be present at concentrations greatly exceeding guideline values for the protection of aquatic ecosystems for all of the monitoring sites except Site 2, which is located upstream of the mining area. The liited water quality results from Site 2 demonstrate that the 'background' composition of Storys Creek is within ANZECC/ARMCANZ guideline values.

Water quality in Storys Creek near the mine workings (Sites 5 – 14) exceeds guideline values for irrigation for cadmium and zinc, although values below Aberfoyle Creek (Site 23) are within acceptable limits. Although not shown in Table 2, the water is also acceptable for irrigation from the standpoint of salinity, with conductivities, sodium and chloride values well within recommended levels. The water quality within Storys Creek at all sites is also within guidelines established for stock watering.

Table 2. summary of water quality results from Storys Creek since 2000 compared with ANZECC/ARMCANZ (2000) guideline values for Protection of Aquatic Ecosystem, Irrigation and Livestock Watering. Data from MRT.

	Aluminium mg/L	Cadmium mg/L	Copper mg/L	Iron mg/L	Manganese mg/L	Zinc mg/L	Sulphate mg/L	Fluoride mg/L
ANZECC Protection of Aquatic Ecosystems (80% - 95% protection levels)	0.055 – 0.150	0.0002 – 0.0008	0.0014 – 0.0025	Not Established	1.9 – 3.6	0.008 – 0.031	Not Established	Not Established
ANZECC Irrigation (long-term and short-term use)	5 - 20	0.01 – 0.05	0.2-10.0	1 - 4	0.2 - 10	2 – 5	Not Established	Not Established
ANZECC Livestock watering	5	5	0.5 – 5	Not Established	Not Established	20	1,000	2
Site 2 (n=1) Storys above mine	0.02*	0.001*	0.004*	0.02*	0.005*	0.001*	1*	0.02*
Site 5 (n=10) Storys bel Precip dam	0.02 – 0.08	0.002 – 0.040	0.001-0.004	0.02 – 0.04	0.011 – 0.31	0.071 – 1.26	1 – 13	0.06*
Site 8 (n=12) Storys bel Side Creek	0.02 – 3.88	0.003 – 0.35	0.005 – 0.233	0.02 – 7.17	0.11 – 2.99	0.105 – 6.87	2 – 270	0.84*
Site 11 (n=6) Storys bel Eastern Hill	0.04 – 2.32	0.004 – 0.209	0.004 – 0.221	0.03 – 3.30	0.05 – 2.6	0.14 – 6.0	8 – 220	No data
Site 13 (n=8) Storys bel Nisbet Creek	0.01 – 0.33	0.010 – 0.091	0.002 – 0.079	0.02 – 0.40	0.05 – 0.45	0.17 – 2.95	9 – 130	2.8*
Site 14 (n=13) Storys bel Pumphouse	0.01 – 0.36	0.015 – 0.124	0.021 – 0.151	0.02 – 0.30	0.08 – 0.44	0.530 – 3.40	11 – 75	0.25*
Site 15 (n=3) Storys at Rossarden	0.06 – 0.29	0.020 – 0.140	0.030 – 0.140	0.05 – 0.30	0.05 – 0.16	0.55 – 2.74	10 – 68	0.23*
Site 21 (n=3) Storys above Aberfoyle	0.06 – 0.20	0.03 – 0.08	0.010 – 0.075	0.02 – 0.08	0.03 – 0.10	0.84 – 2.10	18 – 51	0.9*
Site 23 (n=3) Storys bel Aberfoyle	0.02 – 0.08	0.01 – 0.03	0.006 – 0.021	0.02 – 0.09	0.02 – 0.11	0.31 – 0.83	18 – 88	0.58*

*One measurement only

4 Proposed monitoring program

The aim of water quality monitoring in Storys Creek is to assess the effectiveness of the remediation works by documenting water quality trends in the catchment. The water quality information will also be able to be used to assess trends in the larger South Esk catchment, although this cannot be accomplished solely through the present monitoring program.

4.1 Flow data

To establish long-term trends, it is essential that both water quality and flow volumes be measured, and that the newly collected information be consistent with previously collected data. For theses reasons, it is important that flow records be collected at Site 14 (Pumphouse), as this is the only site where reliable historic flow and water quality data are available. There are three possible approaches for collecting flow information at Site 14:

- Measure flow volumes during each sampling run using the DPIWE flow meter or other appropriate instrument. This is a low cost approach that would provide reasonable flow estimates during low flow, but may present difficulties and hazards during very high flows. This approach would also limit the opportunities to collect useful data to those times when flow gauging equipment was available.
- Re-establish the gauge boards at Site 14, and re-establish the height – flow calibration curve. This approach would require additional funds for Hydro Tasmania to re-establish the gauge boards and complete several river gaugings. In the long term, it would provide more accurate flow measurements, and allow more opportunistic sampling, as no special equipment would be required to establish flow other than recording the river level height.
- Re-establish the gauge boards at Site 14, re-establish of the water level – flow calibration curve and implement a continuous recording water level recorder and Electrical Conductivity probe. This approach would provide a continuous record of flow and conductivity, allowing the calculation of pollutant fluxes in the river due to the good correlation between EC, sulphate, zinc and cadmium. The continuous record would provide insights into what flow conditions result in the highest/lowest concentrations of pollutants, and largest/smallest pollutant fluxes. This would be the highest cost to implement, and would require on going maintenance.

Of the three options, the second one is probably most appropriate for the on going monitoring program. If additional works were to be completed in the catchment, then the level of detail provided in by the third option might warrant the additional expense.

4.2 Proposed monitoring sites and parameters

Table 3 lists the proposed monitoring sites for the next three years in the Storys Creek area. The sites will be finalised following discussions with MRT and a site visit to complete the first monitoring run in late September 2003.

The proposed sites will allow the quantification of changes due to the remediation works, and provide long-term water quality trends. Two sites are proposed for the South Esk River, one above the confluence with Storys Creek, and one approximately 10 km downstream in Avoca. The upstream site will provide 'background' water quality information for the South Esk, and the downstream site will provide an indication of the impact of Storys Creek on the South Esk beyond the immediate mixing zone. As noted in the table, these sites only merit monitoring *if* reliable flow estimates can be obtained in some manner. It is not feasible to measure flow in the South Esk each monitoring campaign, so hydrological modelling based on the relationship of flows in Storys with the South Esk is the preferred option, and is discussed in the next section.

Table 3. Proposed monitoring sites in Storys Creek area.

Site Number	Site Location	Justification
2	Storys Cr above mine workings	Provides background water quality and indication of upstream changes
5	Storys Cr below Precipitation Dam	Provide record of changes since dam removal – should continue to change as groundwater 'flushes' through system
8	Storys Cr below Side Creek	Significant pollutant load enters via Side Creek-should reduce due to remediation works
13	Storys below Nisbet	Indicates inputs from diffuse sources downstream of Side Creek
14	Storys below Pumphouse	Continue best long-term data collection point; indicates diffuse load entering between Nisbet and Pumphouse
15	Storys at Rossarden	Establish additional pollutant load and dilution from tributaries – only monitor if tailings evident in river
21	Storys Above Aberfolye	Final measurement of pollutant load in Storys Creek
23	Storys below Aberfoyle	Indicative of water entering South Esk
22	Aberfoyle Creek	Water is important for diluting Storys, and has elevated zinc values
24	South Esk above Storys	Establish if reliable flow data available. 'Background' water quality in South Esk River
30	South Esk at Avoca	Establish if reliable flow data available. Estimate of Storys Creek impact 10km downstream
4	Precip. dam outflow	pH & conductivity only
6	Side Creek	pH & conductivity only
?	Side Creek adit?	pH & conductivity only
?	ALD outflow	pH & conductivity only

Point sources, such as the Precipitation Dam, or Side Creek Adit should be monitored if there is a substantial flow present, and it is able to be quantified using a flow meter.

Otherwise, a measurement of pH and conductivity should be completed on a routine basis.

At each site *in situ* measurements of pH, conductivity and temperature should be made, and flow measured using a flow meter or current meter. Water samples should be collected and analysed for the following parameters:

- Metals, total and dissolved, the 'suite' completed by the DPIWE labs: – Aluminium, arsenic, cadmium, cobalt, chromium, copper, iron, manganese, nickel, lead and zinc
- Alkalinity
- Sulphate, Fluoride

Initially, it is proposed to monitor the Storys Creek four times per year, targeting one low flow, one high flow and two medium flow regimes.

4.3 Interpretation of results on a catchment scale

In order to interpret the water quality results in a broader catchment context, the Northern Midland Council and any local RiverCare or WaterWatch groups will be contacted to establish what other monitoring is occurring in the South Esk River, and discuss how the proposed monitoring program can best be integrated. Another relatively inexpensive approach would be to have Hydro Tasmania complete some catchment modelling that would provide information about downstream dilution of Storys Creek water under different flow regimes. This information could be used to estimate how far downstream water quality impacts from Storys Creek are likely to be occurring.

4.4 Data management

Water quality data will be stored in an excel worksheet in the same format as the existing Storys Creek data, with an updated copy forwarded to MRT following each monitoring run.

References

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