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Acknowledgements

Daniel Ray of Aquatic Science provided considerable assistance in this review of water quality monitoring results and the writing of this report.
1 Introduction

The Savage River Rehabilitation Program (SRRP) has been monitoring water quality at and in the vicinity of the Savage River Mine site since 1998 when the remediation program began. Monitoring results are used to identify water quality issues, which in turn guide the remediation strategy. Water quality monitoring is also used to evaluate the effectiveness of remediation actions and to determine the impact of the lease site on the downstream environment.

Previous water quality reviews were completed in 1999 (Koehnken and Ray), 2001 (Ray and Koehnken), 2005 (Koehnken), 2007 (Koehnken), 2009 (Koehnken) and 2014 (Koehnken).

This report provides a summary of water quality results and trends for the period January 2014 to July 2015, and identifies water quality issues pertinent to ongoing adaptive management of the program. The scope of the report includes:

- Description of the water quality monitoring program
- Presentation of water quality results (as graphs) of present water quality trends on the lease site and in the lower catchment with attention focussed on known and potential acid drainage sources
- Analysis of chemical and pollutant mass balances in Savage River and in Main Rivulet
- Recommendations.

A related project is currently underway to review toxicity targets for the program, and is expected to be completed in the second half of 2016. The next biological assessment of downstream river reaches of the Savage River and its tributaries will also build on these water quality results when it is undertaken in 2017.

2 Monitoring sites

Eight sites are currently monitored on a monthly basis in the Savage River catchment, as shown in Figure 1 and summarised in Table 1. Five of the sites are located in the Savage River catchment above Main Rivulet, two in the Main Rivulet catchment, and one downstream of the lease site near the mouth of the Savage River (at Smithton Road).

River level and/or flow is continuously recorded at all sites except ‘Savage River at Smithton Road’ (SRaSR) and ‘Savage River below South West Rock Dump’ (SRbSWRD), where flow is modelled by Entura Tasmania using the Heazlewood River rain gauge as input. Telemetered water level, pH, conductivity and turbidity monitoring stations are managed and serviced by Entura Tasmania on a quarterly basis.

Monthly monitoring is also carried out at four sites which are not direct sources into the Savage River or Main Rivulet (Table 2). Monitoring at these sites provides a better understanding of contaminated water movement on the mine lease.

Whilst most 'tributary' sites have good flow records, it appears that the Savage River sites have poor control data prior to July 2015. Flow has been modelled from the Heazlewood River rain gauge, and is therefore considered to have low accuracy. This report therefore does not consider mass loads in...
the lower Savage, where data is restricted to analysis of instantaneous concentrations. This may allow the information to be biased by flow conditions on sample dates. It is therefore important to establish better flow gauging control on the Savage River sites in order for mass flux to be calculated.

Water sampling is conducted by Grange Resources on a monthly basis. Measurement of pH, electrical conductivity, water temperature and river level are continuously monitored at the telemetered sites, and water samples are also collected for subsequent analysis. All water samples are analysed by Analytical Services Tasmania, a NATA-registered laboratory, for alkalinity, acidity, total suspended solids, major cations (calcium, magnesium, potassium, sodium), total and dissolved (<0.45 µm) metals (aluminium, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel and zinc) and sulphate. Monitoring results are stored in the SRRP database and accessed with the Schooner water management package. The database also provides fluxes/mass loads by combining sample and flow data. Recent improvements to the monitoring regime include increased organic carbon monitoring and improved metal detection limits which will be available for future water quality analysis.

Table 1. Water quality monitoring sites on the Savage River and Main Rivulet catchments.

<table>
<thead>
<tr>
<th>Site</th>
<th>Rationale</th>
<th>Flow quality rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old Tailings Dam North (OTDN)</td>
<td>Direct discharges of historic contamination from the northern end of the Old Tailings Dam into Savage River.</td>
<td>Good and stable.</td>
</tr>
<tr>
<td>Savage River at Pump Station (SRaPS)</td>
<td>Good long-term flow and water quality site, includes inputs from OTDN and, prior to Oct 2006, inputs from North Dump Drain (NDD). The NDD diversion reported directly to the Savage River above this site after floods on 18 Aug 2007. They were reinstated prior to 26 Nov 2008 (when monitoring was reinstated).</td>
<td>Fair to good, since second water-level sensor was installed. Rating curve being re-established with change in control.</td>
</tr>
<tr>
<td>South Lens Pit Outlet (SLO)</td>
<td>Contaminated water from site and NDD is directed into South Lens where it mixes with naturally occurring high pH and alkalinity water.</td>
<td>Fair, with 10% inaccuracy due to high turbulence at the weir.</td>
</tr>
<tr>
<td>Broderick Creek below Waste Rock Dump (BCbWRD)</td>
<td>Monitors performance of alkalinity flow-through drain and contribution of BCbWRD to Savage River.</td>
<td>Inaccurate flow data at higher flows (20% inaccuracy) due to backwaters from Savage River.</td>
</tr>
<tr>
<td>Savage River below South West Rock Dump (SRbSWRD)</td>
<td>Indicates impact from the lease on middle Savage River.</td>
<td>Flow is now modelled at this site, as flow record was unreliable due to poor hydraulic control at gauging site.</td>
</tr>
<tr>
<td>Main Creek Tailings Dam Outflow (MCTD)</td>
<td>Monitors the discharge from the Main Creek Tailings Dam which includes seeps from the Old Tailings Dam. Tailings dam is presently discharging to Main Rivulet via Townsend Creek. During other periods, discharge has been directed downstream.</td>
<td>Good and stable.</td>
</tr>
<tr>
<td>Main Creek below South Deposit (MCbSD)</td>
<td>Indicates impact from the lease on lower Main Rivulet before it joins into Savage River. Catchment includes seeps from the B-Dump complex and from the tailing dams. Sporadic access to site.</td>
<td>Good and stable.</td>
</tr>
<tr>
<td>Savage River at Smithton Road Bridge (SRaSR)</td>
<td>Site is 15 km downstream of the mine, near river mouth. It shows overall inputs, and indicates what is being exported from catchment to the Pieman estuary.</td>
<td>Flow is modelled at this site.</td>
</tr>
</tbody>
</table>
Table 2 - Additional sites monitored monthly which are not direct sources into the Savage River.

<table>
<thead>
<tr>
<th>Site</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brett’s Drain North (BDN)</td>
<td>Historic seeps from Broderick Creek waste rock system, which enter into South Lens.</td>
</tr>
<tr>
<td>Brett’s Drain South (BDS)</td>
<td>Historic seeps from Broderick Creek Waste Rock Dump into South Lens. Flow is not currently monitored.</td>
</tr>
<tr>
<td>North Dump Drain (NDD)</td>
<td>Contaminated water from historic North Dump diverted to South Lens. Flow has been continuously monitored at this site since May 2011.</td>
</tr>
<tr>
<td>Centre Pit North (CPN)</td>
<td>Alkaline overflow from Centre Pit system into South Lens. Flow has been continuously monitored at this site since May 2011.</td>
</tr>
</tbody>
</table>
Figure 1 - Aerial photo of SRRP monitoring locations.
3 Water quality trends

3.1 Water quality data collection and analysis

Consistent with previous years, water samples are collected on site and dispatched via overnight courier to Analytical Services Tasmania’s (AST) laboratories for analysis. The full list of analytes is provided at Appendix 1: a subset of these is considered in this report.

Data regarding concentrations of the major contaminants of concern to the SRRP from January 2005 to mid-2015 are presented in plates 3.2.1 to 3.2.7. Graphs of the soluble and total concentrations of aluminium (Al), cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn) and sulphates (SO4) over time are presented. A concise analysis of trend is provided in section 3.2, which extends the detailed analysis undertaken in 2014 (Koehnken 2014). Future analysis should also be expanded to include organic carbon as recommended by the recent ecotoxicology studies (Hydrobiology 2015).

The review in this section reflects instantaneous concentrations only. It does not refer to mass flux or assess flow at collection times as this may lead to inaccurate results due to dilution.

3.2 Water quality monitoring – trend summary

The following discussion identifies trends in observations of most relevance to the SRRP’s objectives.

Water quality monitoring data are presented as plates of graphs at the end of this section, numbered to correspond with the relevant section of discussion in the text. The graphs present instantaneous concentrations of a number of water quality parameters and further detail can be made available through the Splashback application of the Schooner water quality analysis package if required.

The ‘Savage River at Smithton Road’ (SRaSR) site is discussed first to provide a general perspective of overall trends for the lease. Then the Main Rivulet catchment is discussed, and finally the upper Savage River catchment.

Mass load information relating to the sites is discussed in Section 4 Evaluation of changes in mass load.

3.2.1 Savage River at Smithton Road

The SRaSR sample site is situated below all inputs from the Savage River Mine lease into the Savage River. It is affected by both Main Rivulet and the Savage River after it has run through the active mine lease. The sample point is 2 km above the Savage River junction with the Pieman River estuary.

The graphs presented in Plate 3.2.1 show a general decline in concentration of most metals over the monitoring period. Total and soluble copper show a constant and substantial decline. Total copper concentrations in the Savage River have declined from an average of 38.5 µg/L (standard error 3.3 µg/L) in 2005 and 2006 to 16.7 µg/L (standard error 1.9 µg/L) between mid-2013 and mid-2015. This is a substantial decline, especially considering the total copper levels at the ‘Savage River Doodies Creek (SRaDC)’ sample site, only 3 km upstream and the relatively minor tributaries of Guthrie Creek and Doodies Creek averaged 75.5 µg/L (standard error 3.1 µg/L) between 1998 and 1999.
Cobalt, nickel and zinc also show declines over the period represented in Plate 3.2.1, however proportional declines are not as large as for copper. These metals are removed via neutralisation and precipitation reactions to a lesser extent than copper.

Manganese is removed when pH increases above 9 (not known to occur in the catchment), and shows little reduction in concentration. Likewise, sulphate levels have also stayed constant over the period presented. Both of these observations would suggest that the total mass of sulphides in the catchment being oxidised is remaining stable.

Aluminium levels have remained static over the time. Improvements in aluminium mitigation on the lease would be hard to detect, however, given the background levels of aluminium in the catchment. For example, aluminium at the ‘Savage River above Old Tailings Dam’ sample site averages 360 µg/L total aluminium. This site is above all known inputs from the mine. The SRaSR sample site averages 510 µg/L, suggesting that the majority of the aluminium comes from sources external to the Savage River Mine.

The alkalinity over time (Fig 2) suggests that alkalinity levels are generally increasing, with larger variation. The high alkalinity within the catchment is driven by neutralisation reactions - when an acid is neutralised by a carbonate such as calcite and dolomite, carbon dioxide is released. This in turn can be either liberated as a gas or neutralised, often forming bicarbonate ions (HCO$_3^-$) or, to a lesser extent, carbonate ions (CO$_3^{2-}$), increasing the alkalinity of the water (Stumm and Morgan 1995). Increasing neutralisation reactions (potentially from the Broderick Ck throughflow and the new SDTSF), and potentially a significant natural (karstic) input of alkalinity between the mine and the sample site are the most likely causes of increases. Karstic dolomite and magnesite in catchments contributing to reaches below the mine site provides an ongoing source of alkalinity which, whilst most likely constant over time, are likely to have a measurable effect on downstream alkalinity.

Due to improvements in water quality from the mine site, the tailings on the floodplain and bed of the Savage River and Main Rivulet below the mine may contribute an increasing proportion of the total pollutant load at this site. This depends on the rate at which these materials ‘burn out’ in the absence of mitigation measures, however these rates are unknown.
3.2.2 Main Creek Tailings Dam Outflow

The Main Creek Tailings Dam (MCTD) has shown a general decline in all pollutants, including sulphate and manganese (which are not generally removed by neutralisation reaction at near-neutral pH conditions that are encountered in the tailings dam). This would suggest that either sulphide oxidation within the tailings dam system is reducing, or that the transport of ARD generated from the Old Tailings Dam is being reduced.

Sulphide oxidation could be being reduced as a result of the oxidation front on the Old Tailings Dam becoming deeper with time. As the sulphides near the tailings surface oxidise, the oxygen from the atmosphere would have to travel deeper within the tailings mass before being oxidised. The greater the distance that the oxygen molecules have to travel, the slower the exchange rate with the atmosphere. This would result in a lower rate of oxidation and, subsequently, of sulphate generation.

The lower rate of transport of ARD could be due to a reservoir of ARD forming within the southern portion of the Old Tailings Dam as the water levels rise within the Main Creek Tailings Dam.

In Fig 2, the alkalinity over time suggests that there has been an increase in alkalinity transfer despite the decrease in sulphate load. This may suggest that the management of the Main Creek Tailings Dam is being optimised and/or the carbon dioxide losses after neutralisation are not occurring to the same extent and more bicarbonate and carbonate are being formed. This is likely to occur if the neutralisation reactions are occurring at higher pH.

Fig 2 – The total alkalinity (CaCO₃ eq) over time at the Savage River at Smithton Road sample site.
3.2.3 Main Creek below South Deposit

The Main Creek below South Deposit (MCbSD) sample site has been affected by the construction of the South Deposit Tailings Storage Facility (SDTSF). The tailings facility is an innovative design that increases alkalinity levels in Main Rivulet. The design uses a flow-through construction and waste rock buttress that provides the structural support to a filter face and dam section. The filter face is different to normal dam filters in that it allows water into the flow through while retaining tails in the dam. The flow-through portion of the dam is complete and the filter face is approximately half complete, with tailings storage within the facility expected to start by 2017, dependent on operational decisions.

There have been substantial decreases in concentrations of most parameters at the MCbSD sample site, with reductions in most parameters appearing to be contemporaneous with the construction of the SDTSF. The mechanism of these decreases is currently unclear, however decreases could result from the neutralisation of B-dump seepages by the MCTD outflow in the rising water body of the SDTSF, or neutralisation within the flow-through portion of the SDTSF. The environmental gains made are discussed in detail in Section 4.2 in the analysis of mass loads.

There has also been a substantial recent increase in alkalinity concentration (see Fig 4). This corresponds directly with the construction of the flow-through and is the result of:
- neutralisations reaction within the flow-through,
- neutral drainage associated with waste deposited in the catchment, or
- a combination of these two factors.

The neutralisation and settlement capacity created by the South Deposit Tailings Storage Facility appears to be of great benefit towards meeting the objectives of the SRRP, and should therefore be
optimised to its full extent. In the absence of deliberate strategies to protect this capacity, it is likely that the flow-through neutralisation capacity could be reduced if it is allowed to armour when ARD is permitted to flow through without prior neutralisation by added tailings. The void spaces within the flow-through could also be filled if neutralised ARD without pre-settlement passes into the flow-through.

![Graph showing total alkalinity (CaCO₃ eq) and pH over time at the Main Creek at South Deposit sample site.](image)

**Fig 4** – The total alkalinity (CaCO₃ eq) and pH over time at the Main Creek at South Deposit sample site.

### 3.2.4 Savage River at Pump Station

The Savage River at Pump Station (SRaPS) sample site is the uppermost site currently monitored on the Savage River. Piping of the North Dump Drain ARD to the South Lens Pit water body was the main contributor to the improvement in water quality seen at this site. The diversion was first connected in October 2006 but was disconnected in August 2007 after floods destroyed the bridge where the pipeline crossed the Savage River. The pipeline was reconnected prior to 26 November 2008 when flow monitoring recommenced. The majority of the copper and aluminium, which are the pollutants of high ecotoxicology concern, are removed within the South Lens Pit prior to entering the Savage River. The reduction in pollutants from this strategy is evident in the graphs presented in Plate 3.2.4 in late 2007.

From 2008 onward, the trend in pollutant concentrations at this site has remained relatively constant. The diversion and continued mitigation of this pollutant source remains a priority.

### 3.2.5 South Lens Outlet

The water quality within South Lens Pit Outlet (SLO) trends inversely to the water quality at SRaPS, with an increase in pollutant concentrations from 2006 until 2010. However, the discussion of mass load in section 4.5 shows that there is a substantial net removal of pollutants as a result of the diversion of North Dump Drain.
Data presented in Plate 3.2.5 show that the water quality within the South Lens Pit has generally stabilised since 2010.

Further research on enhancing the mechanisms achieving metal removal within South Lens Pit should be considered, as South Lens is crucial to the ongoing remediation outcomes of the SRRP. Investigations into enhancing its performance with improved precipitation would be beneficial, as this may provide options for further addition of ARD from other locations in the mine at some point in the future. Gains in water quality more generally may also be achievable and provide additional environmental benefits.

3.2.6 Broderick Creek below PMI Waste Rock Dump

The Broderick Creek Waste Rock Dump has been built over a flow-through of alkaline waste rock, permitting the water within Broderick Creek to flow under the waste rock dumps. The dump has reduced the haul distance and provides alkalinity to the downstream environment which assists in reducing metal toxicity.

Figure 5 shows that alkalinity production at this site is approaching either a plateau or a turning point. It will be important to closely monitor and review the data to ensure that it is not being caused by increased ARD generation within the waste rock, as a large proportion of the waste rock on the Savage River Mine lease is stored in the Broderick Creek valley. The data also show that there has been a small increase in manganese, which is of concern. Sulphate data remain relatively constant, which supports the possibility that alkalinity production has reached a plateau. The mechanism for earlier increases in manganese concentration, prior to 2008, may have a different genesis from the current increase.

Quantitative water tracing to differentiate the proportion of flows to Broderick Ck outflow and Brett’s Drain North and South, and assess breakthrough characteristics may assist in the understanding of this system.
3.2.7 Savage River below South West Rock Dump

The sample site monitors the pollutant load from the South West Rock Dump. This dump is situated on the very edge of the river and is difficult to mitigate via collection and treatment. Given the placement of the dump (prior to ABM & Grange operations) there may be some potential for high, erosive flows to transport material from this site directly into the channel of Savage River.

The water quality at the SRbSWRD sample site shows a reduction in pollutant concentrations after the diversion of the North Dump Drain in 2007 (Plate 3.2.7.). The relative proportion of pollution coming from this source from a whole-of-site perspective is likely to have increased, as it has not been mitigated, other than by ageing and minimising disturbance.
Plate 3.2.1 Savage River at Smithton Road (SRaSR)
Plate 3.2.2 Main Creek Tailings Dam Outflow (MCTD)
Plate 3.2.3 Main Creek below South Deposit (MCbSD)

- Al (Dissolved) vs. Al (Total)
- Co (Dissolved) vs. Co (Total)
- Cu (Dissolved) vs. Cu (Total)
- Fe (Dissolved) vs. Fe (Total)
- Mn (Dissolved) vs. Mn (Total)
- Ni (Dissolved) vs. Ni (Total)
- Zn (Dissolved) vs. Zn (Total)
- SO4
Plate 3.2.5 South Lens Pit Outlet (SLO)
Plate 3.2.6 Broderick Creek below PMI Wast Rock Dump (BCbWRD)
Plate 3.2.7 Savage River below South West Rock Dump (SRbSWRD)
4 Evaluation of changes in mass load

The mass load evaluation in this report is relatively brief as flow monitoring along the trunk of the Savage River is being upgraded. Flow data along the lower Savage River, including the Broderick Creek site, are currently considered poor quality and are not used in the following analysis. This section discusses mass load data contributing to the Main Rivulet catchment followed by the upper and middle Savage River sources.

Late in 2015 flow modelling was investigated at the SRaPS, SRbSWRD and SRaSR to establish flow estimates, but was found to have poor correlation with measured flow. A more thorough assessment of water quality and mass loads will be undertaken by the SRRP when an improved flow dataset becomes available. The current work to upgrade the flow data follows the recommendations of the last water quality audit, conducted by Technical Advice on Water in 2014 (Koehnken 2014).

Throughout this section the mass loads are referred to for different parameters at the time of sampling. The mass load is calculated by taking the concentration at the time of sampling and multiplying by the average flow for the period 30 minutes before to 30 minutes after sampling. The units used for the mass load is usually kg/day. This unit system is useful for visualising the quantity of given parameter, but the reader must be mindful that the unit of time (day) is extrapolated.

It is likely that both mine discharges and tailings deposited on the bed and floodplain of Main Rivulet and Savage River between the mine and SRaSR may affect concentrations of dissolved pollutants (e.g. Houshold et. al 1999). Unfortunately it is presently impossible to separate these sources, so whilst the concentration data measured at the SRaSR site suggest that there may have been a decline in pollutant mass load from the mine, decreases may also be attributed to 'burn-out' of PAF sediments along streambeds and floodplains. This will not be confirmed until accurate flows are obtained and an estimate of contributions from stream and floodplain sediments has been undertaken.

In the following sections, data from tributaries where adequate flow data are available are used to deduce where potential reductions in load may be occurring.

4.1 Main Creek Tailings Dam Outflow

The Main Creek Tailings Dam is currently used to store the majority of the tailings from current operations of the Savage River Mine. Variation in metal and sulphate mass loads at the Main Creek Tailings Dam outflow (MCTD) site (Figs 6, 7) continues to be driven predominantly by flow.

The MCTD also contributes to the mass loads measured at the Main Creek below South Deposit (MCbSD) sample site, discussed in the next section.

There has been no recent reduction of mass loads at MCTD that would explain the recent reductions in metal concentrations observed at the SRaSR sample site.
Figure 6 – The total aluminium, total manganese and sulphate mass loads at the ‘Main Creek Tailings Dam Outflow’ from July 2009 to June 2015.

Figure 7 – The total copper and total nickel mass loads with flow at the ‘Main Creek Tailings Dam Outflow’ from July 2009 to June 2015.
4.2 Main Creek below South Deposit

There has been a substantial decrease in the total copper mass load at the MCbSD sample site from October 2014 to June 2015 (see Figure 8). Prior to this time (from July 2009), the average measured copper mass load was 7.8 kg/day (standard error 0.8 kg/day) and it has declined to 1.0 kg/day (standard error 0.15 kg/day). The improvement is likely to be due to the retention of metal precipitates within the dam structures. Other metals that are neutralised and precipitated at near-neutral pH, such as aluminium and iron, show similar mass load trends to copper.

The data suggest that the oxidation of sulphides within the catchment remains at similar levels throughout the observed period in Figure 9, with sulphate trending with flow. Sulphide oxidation and associated pollutant production have not reduced, and this supports the conclusion that reductions in copper, aluminium and iron are primarily the result of removal via neutralisation. Metals such as manganese and nickel that are not readily removed at near-neutral pH also continue to trend with flow, further supporting the conclusion that metal removal via neutralisation is occurring.

In 1998 and 1999 copper mass loads at the ‘Main Creek above Savage River’ (MCaSR) site were measured to average 25 kg/day (Ray and Koehnken 2001). The standard error for this average is calculated to be 0.8. The only likely input between the MCbSD and MCaSR sample sites is floodplain and bed sediments from tailings dam spills. Past records show that a large spill occurred prior to the Grange and PMI operations. If the output from these sediments is demonstrated to be negligible, the reduction in copper load from 25 kg/day to 1 kg/day represents a significant achievement by the SRRP, with the recent improvements most likely to be linked to the construction of the Southern Deposit Tailings Storage Facility.

Given the recent reduction in mass loads at the MCbSD site, the pollutant output from bed and floodplain sediment can be reassessed by resampling the MCbSD and MCaSR sample sites and measure the difference in mass loads. It will be important not to gauge the MCbSD site by wading, as disturbed sediment may corrupt the downstream MCaSR sample. The challenges in the future are to maintain high standards of pollutant mitigation during mining within the catchment to prevent new sources of ARD occurring, and to ensure that the South Deposit TSF works as designed. It is also important that long-term strategies are developed to maintain the levels of pollutant reduction in the event that the mine closes, noting that the new TSF has finite neutralisation capacity which is dependent on the continual addition of alkaline material.

It may be concluded that decreased mass flux of metals from this site has improved concentrations at SRaSR post October 2014.
Figure 8 – The total copper mass load with flow over time at the ‘Main Creek below South Deposit’ site.

Figure 9 – The sulphate mass load with flow over time at the ‘Main Creek below South Deposit’ site.
4.3 Old Tailings Dam North

The ‘Old Tailings Dam North’ (OTDN) site has been relatively undisturbed since its closure in 1985. The water body with the Old Tailings Dam continues to overflow, discharging AMD into the upper reaches of the Savage River; however, the long-term levels of pollutants are decreasing (Koehnken 2014). The recent trends (Figure 10 and Figure 11) are consistent with a steady decline in pollutant output from this site. The flow rate at the time of sampling is also lower than normal (Figure 11) from mid-2013 to mid-2015. This in turn exaggerates the apparent recent declines.

The declining levels of metals from the OTDN site are making a minor contribution to the reduced metal concentrations at the SRaSR sample site.

![Graph](image)

**Figure 10** - The total aluminium, total iron and sulphate mass loads at the ‘Old Tailings Dam North’ sample site from July 2009 to June 2015.
Figure 11 - The total copper and total nickel mass loads with flow at the ‘Old Tailings Dam North’ sample site from July 2009 to June 2015.

4.4 North Dump Drain

The North Dump Drain (NDD) sample site measures the piped North Dump ARD discharge into the South Lens Pit water body. The alkalinity in South Lens neutralises the major pollutants (aluminium and copper) from this source, which in turn precipitate and settle to form sediment on the floor of the pit. The data (Figure 12, Figure 13) show that there is no substantive decline in metal loads from this pollutant source and the continued treatment of this water is a therefore a priority. The copper load from this source over the time period averages 4.7 kg/day with a standard error of 0.6 kg/day, which is a higher load than currently measured at the MCbSD sample site.

As mass flux of metals has not decreased here and the pollutants are mitigated with the South Lens Pit water body (discussed in Section 4.5), it cannot be concluded that improvements here have contributed to reduced metal concentrations at SRaSR.
Figure 12 - The total aluminium, total iron and sulphate mass loads at the ‘North Dump Drain’ sample site from May 2011 to June 2015.

Figure 13 - The total copper and total nickel mass loads with flow from the ‘North Dump Drain’ sample site, from May 2011 to June 2015.
4.5 South Lens Pit Outflow

The South Lens Pit is filled with water from several sources, including:

- North Dump Drain
- Centre Pit North Pond that drains the Central Pit system south of the Savage River
- North Pit water pumped from the active mining pit
- Brett’s Drains, which are springs that drain from within the flow-through of Broderick Creek as well as stormwater from the mine operation.

The surface water from the pit drains into the Savage River, via V-notch weir system at the ‘South Lens Pit Outlet’ (SLO) sample site. The combined alkalinity within the pit’s water sources neutralises the ARD in the water body, causing the majority of metals to settle out and form sediment.

The data from the SLO site (Figure 14, Figure 15) suggest that the mass load of metals and other contaminants primarily vary with flow. From mid-2010 to the end of record shown, the contaminant levels appear to have remained constant in relation to flow. This would suggest that the overall water-treatment performance of the pit remains stable. The average copper load from the SLO is 1.8 kg/day, with a standard error of 0.2. This load is lower than the ‘North Dump Drain’ (NDD) mass load entering the pit, which is 4.7 kg/day with a standard error of 0.6 kg/day, which illustrates the importance of South Lens to remediation strategies, especially considering the metal loads from other sources entering South Lens Pit water are also being treated.

Since diversion of the North Dump Drain into the South Lens Pit, the decline in the combined pollutant flux from NDD and SLO is likely to have been a significant driver of improved metal concentrations at SRaSR.

![Figure 14 - The total aluminium, total iron and sulphate mass loads at the ‘South Lens Pit Outlet’ sample site, from July 2009 to June 2015.](image-url)
Conclusions and recommendations

This consideration of mass loads is brief due to the current limitations with the data (particularly flows along main stream channels), and it is therefore recommended that a more thorough evaluation be completed when the reliability of flow data from the Savage River sites is improved. This evaluation will also be able to incorporate findings of the current Toxicology Review project and the 2017 Bioassessment of Savage River.

Of the reliably instrumented sites, the Old Tailings Dam North, Main Creek below South Deposit (since October 2014) and the South Lens Outlet sites have demonstrated improvements in mass flux of metals. It is however currently difficult to attribute all improvements in metal concentrations at Savage River at Smithton Road (SRaSR) to any specific site. So, whilst improvements in metal concentrations at SRaSR suggest that gains have been made, lack of mass flux data along Savage River makes it difficult to pinpoint all the causes of improvements at SRaSR.

However, the results clearly demonstrate that impressive gains have been made by the SRRP over the long term, particularly in terms of reduction of copper concentrations in the Savage River. The range of remediation strategies that have been implemented over the last decade are demonstrably effective in lowering the concentrations of a range of pollutants emanating from the site.
In order to maintain the effectiveness of the SRRP’s remediation efforts, the following recommendations should be given consideration for the next strategic planning period.

1. **South Deposit TSF**: The neutralisation and settlement capacity of the new South Deposit TSF structure assists to meet the objectives of the SRRP, and should therefore be optimised. Strategies to protect the flow-through neutralisation capacity, reduce armouring and maintain the presence of void spaces within the flow-through should be implemented, so that it continues to operate effectively in the long term.

2. **South Deposit TSF**: It is also important that there are costed long-term strategies to maintain the levels of pollutant reduction in the event that the mine closes, noting that the TSF’s neutralisation capacity is dependent on the continual addition of alkaline material.

3. **South Lens Pit**: Further research on enhancing the mechanisms that are achieving metal removal within South Lens Pit should be conducted, as South Lens is crucial to the ongoing remediation outcomes of the SRRP. Investigations into enhancing its performance with improved precipitation would be beneficial, as this may provide options for further addition of ARD from other locations in the mine at some point in the future.

4. **Broderick Creek Waste Rock Dump**: Alkalinity production at this site is approaching either a plateau or a turning point. Close monitoring of this site is required to ascertain the causes and trajectory of the changes that appear to be taking place at this site.

5. **North Dump Drain**: It is recommended that a scaled up trial of the Savage River Carbonate Reactor System at the North Dump Drain (NDD) outflow is given consideration. Such a trial would test the following assumptions:
   - The carbonate reactor can reduce the long-term treatment cost compared to lime, assuming the performance of the plant is maintained from previous pilot studies.
   - The plant can be used to add lime to the pit when required to meet peak alkalinity demand during high flow events.
   - Enhanced sedimentation processes that may occur with treatment within the pit could improve the overall performance of the water treatment.
   - It will be more cost-effective than running a full-scale lime-batching plant at the Savage River mill.
   - Depending on the practicality to isolate the B-Dump seepage a similar system can be deployed to treat the B-Dump seeps which have very similar water chemistry to the NDD water.
   - The system can be used to treat the Old Tailings Dam seeps, once they are oxidised, in the event that Savage River Mine tailings are no longer available.

6. **Accurate calculation of mass flux of key parameters along both Main Rivulet and Savage River will be necessary in order to confirm trends. This would be best approached by improvements in flow gauging at critical points below the mine.**

7. **Due to the improvements in water quality, especially in Main Rivulet, there is an opportunity for assessment of the ongoing contribution of acid/metals from floodplain and bed sediments along watercourses below the mine.**
6 References


DPIPWE, 2011. South Lens Pit water quality review. SRRP, EPA.


Hydrobiology 2015. Stage 1: Literature Review and Assessment of Contaminant Toxicity in Savage River Waters. Report to SRRP, Hydrobiology Pty Ltd, Brisbane QLD.


Koehnken, L., 2009. Summary of mass-balance investigation in Main Creek Valley. Report to the SRRP, DPIPWE.


