

Case study for avoiding treatment in perpetuity – the Brukunga pyrite mine example

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Abstract

Iron sulfide (pyrite and pyrrhotite) was mined by open pit methods at Brukunga, located 40 km east of Adelaide in the Mount Lofty Ranges of South Australia, between 1955 and 1972 to provide feedstock for sulphuric acid production in the South Australian fertiliser industry. The site has been managed by Primary Industries and Resources South Australia (PIRSA) since 1998. Eight million tonnes of waste rock (2 wt % S) were mined and stored in three waste rock dumps. 3.5 Mt of tailings (1.7 wt % S) were produced and stored in an above ground facility. The total area of disturbance at the Brukunga Mine site is 155 ha, comprising the tailings dam, waste rock storages, quarry and Brukunga township. Oxidation of the mine and processing waste, and exposed remnant sulfidic rock mass, has resulted in acid drainage (pH<3) with elevated sulfate and dissolved metals.

A hydrated lime-based water treatment plant was commissioned at Brukunga in September 1980 to treat acid drainage. The plant initially treated acidic seepage from the tailings storage facility (estimated at mine closure to be 80,000 m³/year), but has subsequently been expanded to treat acidic drainage collected from the waste rock dumps and the mine workings. The plant was upgraded to a high-density sludge operation, which has improved reagent efficiency and water quality, and also reduced overall treatment costs.

Dawesley Creek drains the mine site precinct and prior to June 2003 this acid drainage entered this Creek making the water unsuitable for livestock and irrigation use for up to 20 km downstream. A diversion drain was constructed in June 2003 to separate non-mine related flow in Dawesley Creek from acidic mine drainage, which is collected and treated in the water treatment plant, in an attempt to reduce the total volume of water requiring treatment. Water treatment timelines to reduce acid, metal loads are estimated to range from 300 to greater than 1000 years.

PIRSA has implemented a process for determining the most effective long-term solution for the remediation of the Brukunga Mine site. The goal of the Brukunga Remediation Project is to develop a walk-away solution, which is remediation allowing return of the land to a landuse suitable for release of the land from Government ownership such that the site requires no further intervention by, ongoing responsibility for or cost to Government and/or community.

1 Introduction

Iron sulfide (pyrite and pyrrhotite) was mined at Brukunga by Nairne Pyrites Pty Ltd (Nairne Pyrites) between 1955 and 1972 to supply raw feedstock for superphosphate manufacture. The mine is located in gently undulating countryside 4 km north of Nairne and 40 km east of Adelaide in the Mount Lofty Ranges of South Australia. The site lies adjacent to Dawesley Creek which drains the northern portion of the Bremer River catchment.

The legacy of mining and mineral processing is an area of 155 ha of disturbance encompassing waste rock dumps, tailings storage, quarry and a townsite, and acid and metalliferous drainage.

Acidic drainage manifested at the site in the early stage of the mining operations and has continued more or less unabated since, contained only by remedial actions of the South Australian Government, who assumed responsibility for the site in 1977. Acid drainage generation from the site has been estimated to continue for a period ranging from 350 to greater than 1000 years (ANSTO, 1994; TAG, 2007). Ongoing remediation maintenance and water treatment required to maintain the site is estimated to cost in excess of A\$1M per annum.

Responsibility for managing and implementing remediation works was vested in the South Australian Department of Primary Industry and Resources (PIRSA) in 1998. PIRSA continues actively to reduce acidity loads downstream of the mine site and lower water treatment costs.

In 2007 PIRSA implemented a process for determining the most effective long-term solution for the remediation of the Brukunga Mine site. The Brukunga Remediation Project – Technical Advisory Group (TAG) was formed to assist PIRSA in this process. The purpose of the TAG is to advise and recommend to PIRSA an appropriate technical remediation option for the Brukunga Mine site. The goal of the TAG is to develop a “walkaway” solution, which is remediation allowing return of the land to a landuse suitable for release of the land from government ownership such that the site requires no further intervention by, ongoing responsibility for or cost to Government and/or community (McLeary, 2009).

This paper reviews the cause and effect of acid drainage from the mining of iron sulfides at Brukunga, quantifies the acid loads and identifies remediation options including the walkaway solution that provides an alternative to treating acid drainage in perpetuity.

2 History

The history of the site is reasonably well documented including papers by PIRSA (2002; 2003), Cox et al. (2006), Taylor and Cox (2003). The key milestones are:

- The Brukunga Mine was established in June 1955 as a source of sulphur for conversion to sulphuric acid for manufacturing superphosphate fertiliser that was in demand to improve the poor quality of Australian soils for expansion of post-war agriculture.
- Government withdrawal of the pyrite subsidy on 31 May 1972 and mining operations ceased at Brukunga on the same day.
- The mine operators, Nairne Pyrite, appointed two caretakers when the mine closed in 1972 to collect and pump acidic seepage from the quarry to an evaporation pond up to 10 ha in area located in the tailings storage area.
- In February 1974, a summer storm caused the evaporation pond to overflow and it was soon realised that water levels could not be controlled solely by evaporation.
- In August 1977, the State Government accepted responsibility for rehabilitation of the site.
- In September 1980, the Government commissioned a lime treatment plant to treat the acid water from the site. By 1985 successful treatment of the 10 ha lake of acid water was completed with its removal from the tailings facility.
- Tailings area was covered with topsoil and trees planted in 1989 and the embankment of tailings dam landscaped and re-vegetated.
- In May 1995 the Environment Protection Agency of South Australia issued a licence to SA Water covering the operation and monitoring of activities at Brukunga. The current licence is issued to the Minister responsible for PIRSA.
- PIRSA took over the management of the site in 1998 from SA Water.
- March 1999 the Brukunga Mine Site Remediation Board (BMSR Board) was established to advance community consultation and co-ordinate activities at the site.

- In 2001 the BMSR Board made recommendations to Government for a \$26 million 10 year programme of new initiatives. The South Australian Government appropriated funds for a remediation programme in 2001 (hereinafter referred to as the “original option”) involving:
 - Diverting Dawesley Creek in an attempt to contain acid drainage on the mine site.
 - Increasing the peak water treatment plant capacity by 100%.
 - Decreasing generation of acidic seepage by relocating and capping the waste rock dumps.
- Stage I was successfully completed in June 2003 at a cost of \$2 million.
- In April 2005 Stage II was undertaken. The capacity of the treatment plant was doubled enabling the extra drainage created during winter to be treated.
- A review of the current mine management strategy was undertaken in 2007, resulting in the development of the Brukunga Mine Forward Programme, comprising six phases. Phase 1 included the establishment of a Technical Advisory Group (TAG), tasked with recommending (to Government) the most effective technical walk-away remediation solution for Brukunga Mine.
- Final Report by TAG on remediation option investigation completed and presented to SA Government in November 2008.

3 Site features

Iron sulfide (pyrite and pyrrhotite) was mined at the site between 1955 and 1972. During mining operations, two main waste rock dumps were generated from approximately 8 Mt of sulfidic overburden material (2 wt.% S), and a valley-fill tailings dam located adjacent to the mine was filled with 3.5 Mt of sulfidic sand-sized tailings (1.7 wt.% S) (Parsons Brinckerhoff, 2005). During its 17 year operation, the Brukunga Mine produced 5.5 Mt of iron sulfide (pyrite and pyrrhotite) ore at an annual production rate of about 380,000 tpa. The ore had an average grade of 11% sulphur and was crushed and processed on site to produce a 40% sulphur concentrate.

The area immediately affected by mining and mineral processing covers about 155 ha and includes:

- Two waste rock dumps – North and South waste rock dumps, and a smaller rehabilitated East waste rock dump. The estimated waste volumes of waste rock involved is 4.74 Mm³.
- Tailings storage area, including tailings, embankment, sludge storage ponds, evaporation pond, collection ponds and seepage area. The estimated volume of tailings is 2.6 Mm³.
- Quarry, including benches, cut, Southern, Central and Northern highwalls.
- Brukunga townsite.

Additional impacts (Taylor and Cox, 2003) included:

- Diversion of Dawesley Creek to accommodate the waste rock dumps.
- Dumping of low-grade sulfidic ore in waste rock dumps at the angle of repose immediately adjacent to Dawesley Creek.
- Exposed fresh sulfide mineralisation in the quarry floor.
- Tailings storage facility dam wall constructed by upstream up-lift using sulfidic tailings and waste rock.
- An acid water pond sited on the tailings.
- Pollution of natural drainage.

Acid mine drainage (AMD) has been a significant issue at the Brukunga Mine site since commencement of mining as a result of the oxidation of pyrite and pyrrhotite minerals within the waste rock dumps, the tailings dam, and the exposed highwall and line of lode within the quarry. This process continues to generate acidic water at the site, with pH values of 2.5 to 2.9 and highly elevated sulfate and metal concentrations. Despite

all the work done from 1980 to 2003 to intercept and treat acid drainage, only approximately half the pollution from the site was treated. The remnant 50% or ~600 tonnes/year of sulfate escaped to pollute the flow in Dawesley Creek.

3.1 Climate

The area around the Brukunga Mine experiences cool moderately wet winters and warm to hot mostly dry summers. Average annual rainfall at the site is 575 mm, most of which falls between April and October inclusive. The annual pan evaporation averages 1,100 to 1,400 mm and the estimated potential evaporation is 900 to 1,100 mm/year (based on a pan factor of 0.8).

4 Geological setting

The Brukunga orebody is a conformable pyritic meta-sedimentary layer enclosed within regionally metamorphosed Cambrian sediments of the Lower Kanmantoo Group. Host rocks are the Talisker Calc-siltstone, consisting of a metamorphosed phyllite with calc-phyllite interbeds (Gravestock and Gatehouse, 1995). Sulfide-rich bands are common in the lower part of the formation particularly in the Nairne Pyrite Member.

Iron-sulfide mineralisation occurred as three steeply-E-dipping conformable lenses separated by waste beds. Each of the 15–30 m thick ore zones consisted of iron sulfide-bearing muscovite schists and gneisses with minor lenses of calcsilicate and quartz plagioclase metasediments. The waste rock zones consisted of quartz plagioclase granofels and minor calcsilicate granofels, muscovite schists and gneisses. The lenses outcropped as ferruginous gossans with weathering to a depth of 18 m (LaGanza, 1959). Mineralisation was predominantly pyrite and pyrrhotite in roughly equal amounts (~10% each), with minor sphalerite, chalcopyrite, galena and arsenopyrite: sources of arsenic, cadmium, copper, zinc, antimony, lead, nickel, tin, barium, cobalt, manganese and sulfate (Burt and Gum, 2000a, 2000b). A thin bed of quartzite on the eastern side of the orebody coincides with a sharp hanging-wall boundary to the mineralisation (Ridgeway, 1950). The average sulphur content of the combined sulfide lenses 1, 2 and 3 is about 8% S. The estimated sulphur content of the waste is ~ 2% S.

The sulfide content and reactivity of the waste rock is quite variable, ranging from the micaceous graphitic pyrrhotitic material that rapidly breaks down when exposed to atmospheric conditions (EGi, 1995), to the very siliceous pyritic-pyrrhotitic calcsilicate granofels that manifests as blocky “tombstone” waste material within the dump. The sulfides within the siliceous blocky waste are present as fracture coatings and disseminations. The estimations of sulfides in the tailings and waste rock by Blesing et al. (1975) and EGi (1995) suggest:

- The waste rock contains an average of 2% sulfide sulphur.
- The tailings average 1.7% sulfide sulphur, ranging from < 0.5 to > 3.5% sulfide sulphur, predominantly as pyrrhotite.
- The remaining wall rocks within the mined area range from < 2% sulfide sulphur on the benches and highwall, to up to 13% sulfide sulphur in the north and south cut areas.

5 Hydrology

A total of eight sub-catchments have been delineated that are either impacted or influence the hydrology of the mine site and tailings precincts. In order to understand the geochemical processes that might/are influencing water quality downstream from the Brukunga Mine site, the area has been divided into workable units using catchments based on the EGi (1995), and summarised in Table 1.

The total catchment area for the site is estimated by TAG (2008) to be 2,744 ha of which 2,480 ha is diverted or is located downstream of the contaminated water collection system. Of the 264 ha reporting to the collection system (Catchments 4, 5, 6 and 7), 152 ha constitute supposedly “clean” water from Days, Shepherds North and South Creeks and Watts Road.

The average annual flow in Dawesley Creek is 0.8 Mm³ upstream to 0.94 Mm³ downstream of the mine.

6 Assessment of site acidity and flow data

The assessment involved estimation of annual and monthly acidity loads entering the water treatment plant and determination of the proportions contributed by seepage from:

- Tailings dam.
- Runoff / seepage from the remainder of the Brukunga Mine site, i.e. waste rock dumps, highwall, benches and line of lode cuts.

Table 1 Brukunga area sub-catchments

Catchment	Description	Discussion	Area (ha)
1	Dawesley Creek upstream of Peggy Buxton Road	“Clean” water, captured in diversion	2,400
2	Brukunga township, north of tailings dam	“Clean” water, captured in diversion	28
3	South East, south of tailings dam, east of creek (includes east dump)	“Clean” water, captured in diversion	37
4	Days Creek, upstream of mine	“Clean” water to treatment plant	110
5	Lindsay and Jane Creeks, west of mine	“Clean” water to treatment plant	30 (north) 12 (south)
6	Mine workings benches and highwalls, and waste dumps, west of diversion drain	“Dirty” water to treatment plant	75
7	Tailings dam, including tailings surface, embankment and seepage zone, and tailings dam surround	“Dirty” water to treatment plant	37
8	Southern mine workings	“Dirty” water bypassing treatment plant	15

The key risk posed by the Brukunga site in its current configuration is the potential for the release of acid and metalliferous drainage associated with the oxidation of sulfidic materials from various site domains (waste rock dumps, tailings dam, highwall, line of load and benches).

The main chemical parameter that captures both the acid and metal contributions from the site pollution is “acidity”. Acidity values are a measure of pH, plus all of the latent H⁺ ions that are generated as key metals (such as Fe, Mn, Al, Cu, Pb, Zn, Cd, Ni, etc.) precipitate during the neutralisation process. Acidity values can provide a good indication of treatment requirements for contaminated water samples. Knowing the volume of polluted water with an acidity value expressed as mg/L of CaCO₃, then we can calculate the total mass of CaCO₃ (or any other reagent) that is required to neutralise this water. This value is referred to as the acidity load, and is calculated as follows:

$$\text{Acidity load (t CaCO}_3 \text{ eq.)} \rightarrow \text{Acidity (mg/L CaCO}_3 \text{ eq.)} \times \text{Flow volume (kL)} \times 10^{-6}$$

Acidity load is broadly equivalent to the pollutant load at Brukunga, and indeed all sites where AMD is an issue. It is therefore important to determine the scale and distribution of acidity loads at Brukunga in order to focus remediation efforts. Acidity values at Brukunga were provided as laboratory data, but were also calculated from pH and metal concentrations as a cross-check on the laboratory estimates.

6.1 Acidity load calculations

Site acidity loads for the years 1999 to 2007 were either provided in or calculated utilising data compiled by PIRSA for this period. Two methods were used to estimate the acidity load of water entering the water treatment plant, as follows:

1. Quarterly estimates of the acidity of water arriving at the plant were calculated using water quality data (pH and metal concentrations). Monthly acidity estimates were then derived by linear interpolation. The monthly plant acidity values were multiplied by flow volumes to obtain estimates of monthly acidity loads entering the water treatment plant.
2. Monthly estimates of hydrated lime use by the water treatment plant were converted to equivalent tonnes of CaCO₃ required to neutralise water pumped to the plant.

Estimates of acidity loads from the tailings dam were obtained using calculated acidity values and recorded flow data from a V-notch weir at the toe of the tailings dam.

6.2 Key geochemical conclusions

The key flow, acidity and acidity load results are summarised here:

6.2.1 Annual acidity loads (flow volume x acidity)

- Prior to the construction of the Dawesley Creek diversion in mid-2003, the annual acidity load treated at the water treatment plant ranged from 463 (in 2002) to 1,119 t of CaCO₃ equivalent (in 2000).
- Since commissioning the HDS plant, the highest annual acidity load treated at the plant of 816 t of CaCO₃ equivalent occurred in 2005, when annual rainfall peaked at 673 mm.
- Estimates of annual acidity load based on hydrated lime use at the plant are generally comparable ($\pm 10\%$) to those based on water quality (i.e. calculated acidity) and flow rate data between 2002 and 2007.
- Annual acidity loads from the tailings dam have gradually declined over time, from 289 t of CaCO₃ equivalent in 2000 to 187 t of CaCO₃ equivalent in 2006.
- Annual acidity loads from areas other than the tailings dam (i.e. waste rock dumps, highwall, benches and line of lode) generally constitute the majority of that treated, ranging from 53% in 2002 to 82% in 2005.

6.2.2 Acidity/water chemistry

- The tailings dam seepage acidity has remained within the range 6,000 to 8,000 mg/L of CaCO₃ equivalent between September 1999 and June 2007, but displayed some correlation with seasonal rainfall variations.
- The acidity of water to the plant varies considerably throughout the year, relative to the tailings dam seepage water acidity, with the largest discrepancy occurring in the dry seasons of 2002 and 2006, which were the lowest rainfall years during the period 1999 to 2007.
- The analysis identified that mine site acidity generally exceeded the tailings dam seepage acidity prior to the Dawesley Creek diversion, due to the relatively high acidity observed at the plant prior to mid 2003.
- Following commissioning of the HDS plant in mid 2004, the acidity of the tailings dam seepage appears to have been comparable with that of the mine site.

6.2.3 Annual flow volumes

- Prior to the Dawesley Creek diversion in mid 2003, the annual volume of water treated ranged from ~54,260 kL/year (in 2002) to ~126,000 kL/year (in 2000).

- The annual volume of water treated has decreased significantly following the Dawesley Creek diversion and commissioning of the HDS plant, ranging from around 80,000 kL/year (in 2006) to 158,000 kL/year (in 2005).
- Annual tailings dam seepage flow rates have gradually declined from nearly 40,000 kL in 1999 to just over 20,000 kL in 2006.
- Following commissioning of the HDS plant in mid 2004, tailings dam seepage flows decreased to between 15 and 30% of total flows to the plant.

6.3 Geochemical implications for site remediation

Implications for site remediation from the geochemical assessment of the site are summarised in the following points.

- Any measures designed to minimise infiltration into the waste rock material are likely to decrease acidity loads from the site, e.g. soil cover systems.
- Acidity loads from the waste rock dumps are likely to remain too high for a soil cover system to permit a walk-away solution.
- Any measures designed to minimise water additions or infiltration into the tailings are likely to further lower acidity loads from the tailings dam, e.g. improved soil cover system, vegetation cover, high density sludge plant, surface and groundwater water diversion.
- Acidity loads from the tailings dam are likely to remain too high for a soil cover system to permit a walk-away solution.

7 Remediation options

Fifteen remediation options were considered by the TAG (Table 2). The remediation options considered are grouped under the following:

1. No water treatment (turning off the water treatment plant) or remediation (Option 1).
2. Continue water treatment, either using the existing water treatment plant (Option 2a) or constructing an upgraded water treatment plant at a new location (Options 2b and 2c).
3. Relocation of all wastes off-site and cleanup of the disturbed site (Option 3).
4. Reshape and stabilise waste storages by minimal earthworks (Options 4a to 4d), or co-dispose tailings with waste rock (Options 4e and 4f), and apply store and release covers comprising either selected clean wastes or imported materials.
5. Original option, involving the relocation of wastes on-site, blended with limestone (Option 5).
6. Maintain existing dump geometry and apply an alkaline cover comprising caustic magnesia (Option 6).
7. Saturate co-disposed wastes behind embankment downstream (Option 7a) or upstream locations (Option 7b).

The remediation options were optimised and discriminated on the basis of the TOR and the original objectives of the TAG. In this instance, the water quality, downstream of the mine was considered the ultimate test of the effectiveness of a remediation option. If an option provided for long-term acceptable water quality (meeting EPA requirements), then it was deemed to be effective and essentially met the quality/quantity requirement of the objectives. To this end, the TAG developed a 'water quality dilution model' to test each remediation option (Table 2). The water quality dilution model was based on a spread sheet, mathematically formulated to enable acidity and metalliferous production using actual data to be determined for each remediation option.

While Option 2 for continuing existing water treatment generated the lowest metal and acidity loads it is not a walk-away solution. Option 3 and Option 7a/b have been identified as walk-away solutions. Option 3,

while removing the presence of acid and metal generating waste from Brukunga, it transfers the issue to another site, requiring a remediation of the waste at the selected disposal site, thus adding a transportation cost to the selected remediation.

Table 2 Summary of ‘water quality dilution modelling’ of remediation options

Option No.	Description	Average Acidity mg/L CaCO ₃ eq	Fe mg/L	Al mg/L	Mn mg/L	Residual Acidity Load as % of original	Walk-Away Solution?
2a/b/c	Continue existing water treatment	124	1.3	2.9	2.0	0	No
3	Relocate waste off-site	250	3.9	3.1	0.3	7	Yes
7a	Saturate co-disposed wastes behind downstream wall	255	5.3	3.4	0.4	3.2	Yes
7b	Saturate co-disposed wastes behind upstream walls	277	8.5	5.4	0.6	4	Probably
6	Alkaline cover	315	22.1	6.7	1.2	9	Probably not
4e	Co-dispose tailings and waste rock, store and release cover using selected wastes	348	18.7	11.9	1.3	9	No
4f	Co-dispose tailings and waste rock, store and release cover using imported materials	348	~19	~12	~1.3	9	No
4c	Minimum earthworks, store and release cover using selected wastes, tailings dam cut-off	409	29.8	17.0	2.0	13	No
4d	Minimum earthworks, store and release cover using imported materials, tailings dam cut-off	409	~30	~17	~2.0	13	No
4a	Minimum earthworks, store and release cover using selected materials	450	47.6	17.5	2.7	19	No
4b	Minimum earthworks, store and release cover using imported materials	450	~48	~18	~2.7	19	No
5	Original Option (as proposed by BSMR Board (2001))	1418	172.7	110.9	11.9	94	No
1	No water treatment or remediation	1483	179.6	117.5	12.5	100	No

7.1 Preferred option

The preferred remediation plan is Option 7a and the major features describe are described below. The primary reasoning behind the TAG's selection of option 7a as a walkaway solution was based on cover system modelling that showed that dry cover systems were unable to reduce infiltration sufficiently to be likely to make ongoing treatment unnecessary.

- Waste rock will be excavated from the North and South waste rock storage areas and co-disposed with tailings by mixing and compacting the two waste streams in areas where local stream flow can be diverted to maintain saturation within the placed mining waste.

- Crushed limestone (1% by dry mass) will be added to the co-disposed wastes to neutralise stored acidity, accumulated within the waste mass over time.
- An embankment of clay and rock fill will be constructed to contain the co-disposed mining waste with appropriate foundation preparation to ensure minimisation of seepage from the saturated wastes placed upstream. This includes removal of fractured rock from the foundation and cement grouting of permeable rock features.
- New drainage channels will be established across the top of the co-disposed wastes.
- The co-disposed wastes will be covered with a horizontal layer of permeable crushed rock overlain by a soil cover suitable for vegetation growth. The permeable rock layer is designed to distribute water from creek flows over the co-disposed wastes to maintain them in a saturated condition.
- Complete removal of the tailings, water treatment plant and sludge ponds, and rehabilitation of these areas.
- Complete removal of the north waste rock dump and remediation of the area.
- Complete removal of the areas of the south waste rock dump located above the final storage and remediation of the exposed area.
- Rehabilitation of the mine benches.

Option 7a would take advantage of the natural topography and water flow in the Dawesley Creek to saturate the mine wastes. By constructing a water retaining seepage cut-off and embankment, the entire co-disposed and compacted waste rock and tailings could be contained and saturated. A proportion of the waste, comprising the cleanest material available, would be retained to cover the mine benches and partially cover the highwall.

The successful implementation of Option 7a will require attention to the technical issues: sourcing sufficient suitable materials for the construction of the seepage cut-off and containment wall, the temporary creek diversion during construction of the seepage cut-off, placement, compaction and progressive neutralisation of the co-disposed wastes behind the containment wall, and saturation of the wastes.

7.2 Continue existing water treatment

Option 2 does not provide a walk-away solution, but requires treatment of acid and metal loads in perpetuity, that is estimated to be at least >300 years (ANSTO, 1994) but may well exceed 1000 years (TAG, 2007). The current cost for water treatment is A\$1M per annum.

Option 2 involves ongoing water treatment using the existing water treatment plant as the only form of environmental management at the site. For the purposes of cost comparison, capital expenditure on the plant has been limited to works that would be required to keep it running into the future. An operating period of 100 years was allowed for, although it might be required to be operated in perpetuity (perhaps for of the order of 1,000 years).

Variations to the current operation would include:

- Sludge management – upgrading of sludge management.
- Ongoing maintenance, replacement of plant and equipment and items of infrastructure to maintain the current performance. This is expected to comprise significant replacement and rebuild phases as follows:
 - Water treatment plant every 40 years.
 - Rising mains every 25 years.
 - Pumps every 10 years.

8 Concluding remarks

The TAG recommended that saturation of co-disposed acid generating wastes be placed behind a downstream wall (Option 7a) as it offers the lowest risk, most cost-effective and most achievable strategy for a walk-away remediation solution for the Brukunga Mine site, obviating the need for ongoing active water treatment.

The key technical risks to be addressed (as part of Phase 3 of the remediation process) prior to the implementation phase of Option 7a include the following:

- Failure to source suitable materials for the containment wall.
- Difficulty in neutralising and containing stored oxidation products during containment and saturation of wastes.
- Failure to limit sulfate and metals discharge from the site.
- Failure to maintain saturation of the wastes as a result of containment wall failure, excessive containment wall seepage and/or inadequate creek flow due to drought or climate change.
- Difficulty in neutralising and containing stored oxidation products within the wastes.
- Containment wall spillway failure, leading to wall failure.
- Acidic, metalliferous or otherwise contaminated water from upslope entering the site.

Drought, climate change and earthquake remain effectively uncontrollable risks. However, given the size of the Dawesley Creek catchment, appropriate design can lower the potential impact of both drought and climate change.

The water quality modelling of acidity and metal loads indicates that the lowest concentrations are achieved from remediation Option 7a/b, Option 3 removal and disposal of waste off-site and ongoing treatment of water discharged from mine affected areas and those containing mining and processing waste.

In the absence of a walk-away remediation solution to the Brukunga Mine site, ongoing water treatment in perpetuity would likely be required. Apart from the ongoing cost of water treatment, an ever-increasing volume of treatment sludge would have to be stored.

Acknowledgements

The authors thank and acknowledge PIRSA and mine remediation group that enabled this paper to be presented.

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