The mine closure specialists

Broken Hill Operations Pty Ltd

RASP MINE

DUST MANAGEMENT OPTIONS ASSESSMENT

JULY 2021

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S. Perry S. Gregory	S. Mackenzie	D. Roberts G. Wilson	12 March 2019	Revision A
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EXECUTIVE SUMMARY

Mine Earth were commissioned to undertake an assessment of dust management options for closure at the Rasp Mine (the Mine). As described in the BHOP Mining Operations Plan (MOP), the options assessment for dust management approaches is required to (BHOP, 2020a):

1. Examine previous revegetation programs undertaken at the Mine to gain an understanding of their success or failure.
2. Identify the likely areas at the Mine where dust generation is most probable.
3. Review existing information detailing the predicted contributions to lead levels to the surrounding areas adjacent to the Mine.
4. Identify any opportunities for the use of vegetation to achieve acceptable dust management outcomes (especially in areas where significant dust generation is less likely) over time and under drought conditions.
5. Analysis of the visual amenity aspects of the various approaches, consistent with possible end land use scenarios.
6. Provide a discussion into potential barriers to success of revegetation (e.g. costs, maintenance, characteristics of available materials etc).

Multi-criteria analysis (MCA) was used to evaluate the dust management options available for the Mine.

1. Previous revegetation programs

Previous revegetation programs at the Mine have been largely unsuccessful. This is mostly due to ongoing drought conditions in the region. The use of irrigation has had limited success at the Mine however revegetation has not been sustainable once irrigation ceases.

2. Dust generation

Dust has the potential to be generated from the following areas once the Mine has closed:

- Exposed ‘free areas’ that do not have any land disturbance from the mine activities.
- Unsealed roads.
- laydown areas used for equipment storage and parking
- ROM pad.
- TSF2 and proposed TSF3.

Most of the lead bearing dust emissions from the Mine are currently generated from the ‘free areas’, which consist of small pockets of the Mine which have been left as uncapped hardstand areas. Free areas are not disturbed by current mining activities but have the potential to generate dust from wind take-up. Active mining areas account for small proportion of lead bearing dust emissions and are attributed to the unpaved roads, ROM stockpile and TSF.

3. Review of predicted contributions to lead levels

Ambient air quality is monitored by BHOP personnel via a combination of seven dust deposition gauges, four high volume air samplers (HVAS) and two tapered element oscillating microbalances (TEOMs) sampling units. Dust deposition gauges measure the quantity of dust particles that settle out from the air in grams per square metre per month ($g/m^2/month$).

During the 2020 assessment period, there were nine occasions where the dust deposition limit of 4 g/m^2/month was exceeded at the Mine attributed to external sources such dust storms, historic mining impacts and nearby bare areas outside of the active mining area. It should be noted, at Thompsons Shaft and Junction Mine monitoring locations, baseline dust deposition levels (collected in 2010, prior to mining commencing) exceeded the dust deposition limit (4 g/m^2/month) at 4.3 g/m^2/month and 5.7 g/m^2/month respectively. Dust deposition is typically higher in the summer months due the increased wind velocity, dust storms, high evaporation rates and below average rainfall. Deposited lead dust was also consistently above baseline levels (recorded in 2010 prior to mining commencing), at the Thompsons Shaft, Junction Mine and Block 10 monitoring locations associated with historic mining activities, earthworks activities during the reporting period and the location of monitoring sites near bare areas outside of the Mine.

Monitoring at HVAS from 2008 to 2020 has illustrated that the total suspended particulates (TSP) and TSP-lead have remained well below the EPA threshold of 90 μg/m^3 for TSP and 0.5 μg/m^3 for TSP-lead within all areas. Monitoring at all HVAS indicates that the rolling annual average for PM_{10} exceeded the criteria of 25 μg/m^3 on a number of occasions related to naturally occurring dust storms..

There are two TEOM air quality monitors which record real time PM_{10} data. Monitoring data from 2013-2020 indicates that the annual average results for PM_{10} are below the EPA criteria of 25 μg/m^3.

During 2021, ERM were commissioned to model the air quality impact of the proposed Modification 6 (MOD6) activities planned for the Mine (ERM, 2021). The modelling considered three scenarios:

- Dust produced during current operations;
- Dust produced during the MOD6 construction scenario and;
- Dust produced during the MOD6 operational scenario

For the MOD6 construction scenario, there is anticipated to be a net increase in lead concentrations / deposition rates. However, all air quality metrics are predicted to be below their respective NSW EPA criteria.

For the MOD6 operational scenario, there is a predicted net reduction in lead concentrations / deposition rates when compared to the current operations. All air quality metrics are predicted to be below their respective NSW EPA criteria for the MOD6 operational scenario.

4. Revegetation for dust management

It is unlikely that revegetation at the Mine would provide sufficient coverage (i.e. greater than 50% cover) to adequately manage dust. The barriers to the success of revegetation are described in point 6 below. Other potential dust management options (i.e. covering with waste rock) will be more effective (see dust management options assessment).

5. Visual amenity

There are numerous areas of the Mine that can be seen from the road or town areas, however a number of the free areas (where dust generation is the greatest) are not visible from the town as they are situated in elevated positions in the landscape (i.e. Mt Hebbard). While the use of revegetation could potentially increase the visual amenity of the Mine the following should be considered:

- Revegetation will be impacted by the drought conditions and declines in vegetation health will be visible.
- The use of larger tree species may block the view of the mining areas which are considered important in a heritage context.

- Revegetation is unlikely to be effective in controlling dust.

6. Barriers to revegetation success

There are a number of factors that are likely to impact the success of revegetation activities at the Mine including:

- Climate – in particular, drought conditions and high evaporation rates.
- Lack of growth medium.
- Dominance of weeds.
- Excessive grazing by goats.
- Excessive dust generation which impacts plant growth and wind erosion which can remove seed from the soil surface.

Due to the barriers described above including drought conditions, lack of growth medium, the occurrence of weeds and grazing impacts, revegetation is unlikely to be successful without considerable intervention. Intervention strategies including irrigation and import of growth medium are expensive and are unlikely to achieve viable long term revegetation outcomes.

Multi Criteria Analysis

An options assessment was undertaken to identify and rank dust management options for closure. The results of the MCA indicated that covering areas with waste rock is likely to be the most effective closure option for controlling dust. Other options which could also be considered include:

- Stabilising mining areas with an impervious cover (e.g. concrete).
- Installing bunds or other wind breaks.
- Re-profiling areas to reduce dust potential.

A number of knowledge gaps are limiting the effectiveness of the current risk assessment and evaluation of closure options for dust management. These gaps are listed here as scopes of work to be resolved:

1. Undertake stakeholder engagement to determine preferences for dust management and if Option 1 would be acceptable as the primary means for the long-term management of dust.
2. Determine the required and available quantity of waste rock for use in suppressing dust.
3. Develop a design concept for a waste rock cover in exposed areas to manage dust. Design concepts may include; paddock dumping waste rock to create establish piles and troughs to encourage moisture/resource accumulation; or dozing out rock in a nominal 0.5 m thick cover and contouring/shaping (using a dozer or grader) to create depressions to encourage moisture/resource accumulation.
4. Define options to establish depressions in the landscape to encourage moisture/resource accumulation (overlap with knowledge gap 3).

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1 INTRODUCTION

The Rasp Mine (the Mine) is located in the town of Broken Hill in far west New South Wales (Figure 1 and Figure 2). Broken Hill has a long history of mining activity dating from the late 1800's. The Mine is owned and operated by Broken Hill Operations Pty Ltd (BHOP), a wholly owned subsidiary of CBH Resources Ltd (CBH).

As described in the BHOP Mining Operations Plan (MOP), the options assessment for dust management approaches is required to:

1. Examine previous revegetation programs undertaken at the Mine to gain an understanding of their success or failure.
2. Identify the likely areas at the Mine where dust generation is most probable.
3. Review existing information detailing the predicted contributions to lead levels to the surrounding areas adjacent to the Mine.
4. Identify any opportunities for the use of vegetation to achieve acceptable dust management outcomes (especially in areas where significant dust generation is less likely) over time and under drought conditions.
5. Analysis of the visual amenity aspects of the various approaches, consistent with possible end land use scenarios.
6. Provide a discussion into potential barriers to success of revegetation (e.g. costs, maintenance, characteristics of available materials etc).

Multi-criteria analysis (MCA) was used to evaluate the dust management options available for the Mine.

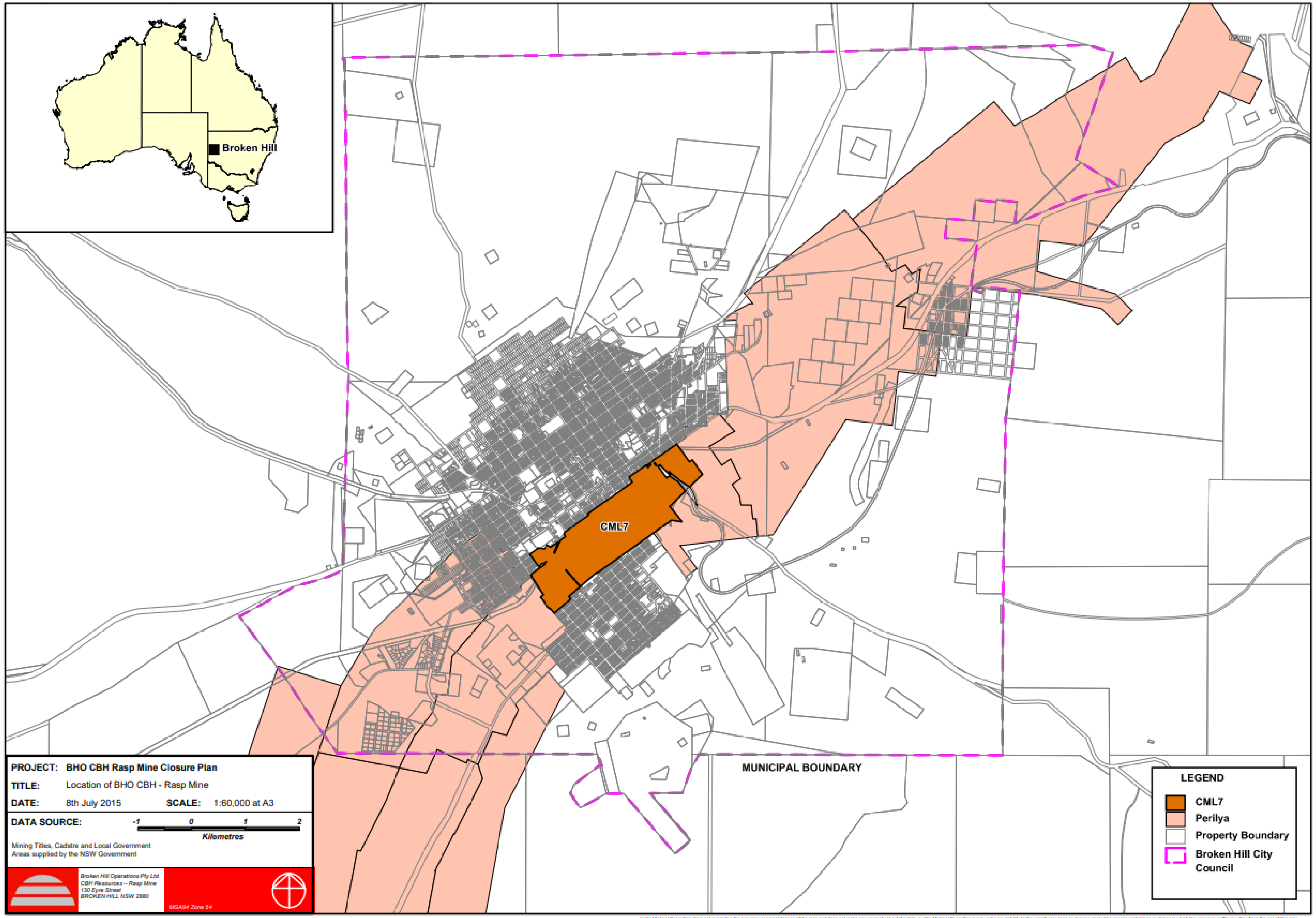

Figure 1 Location of the Rasp Mine, Broken Hill

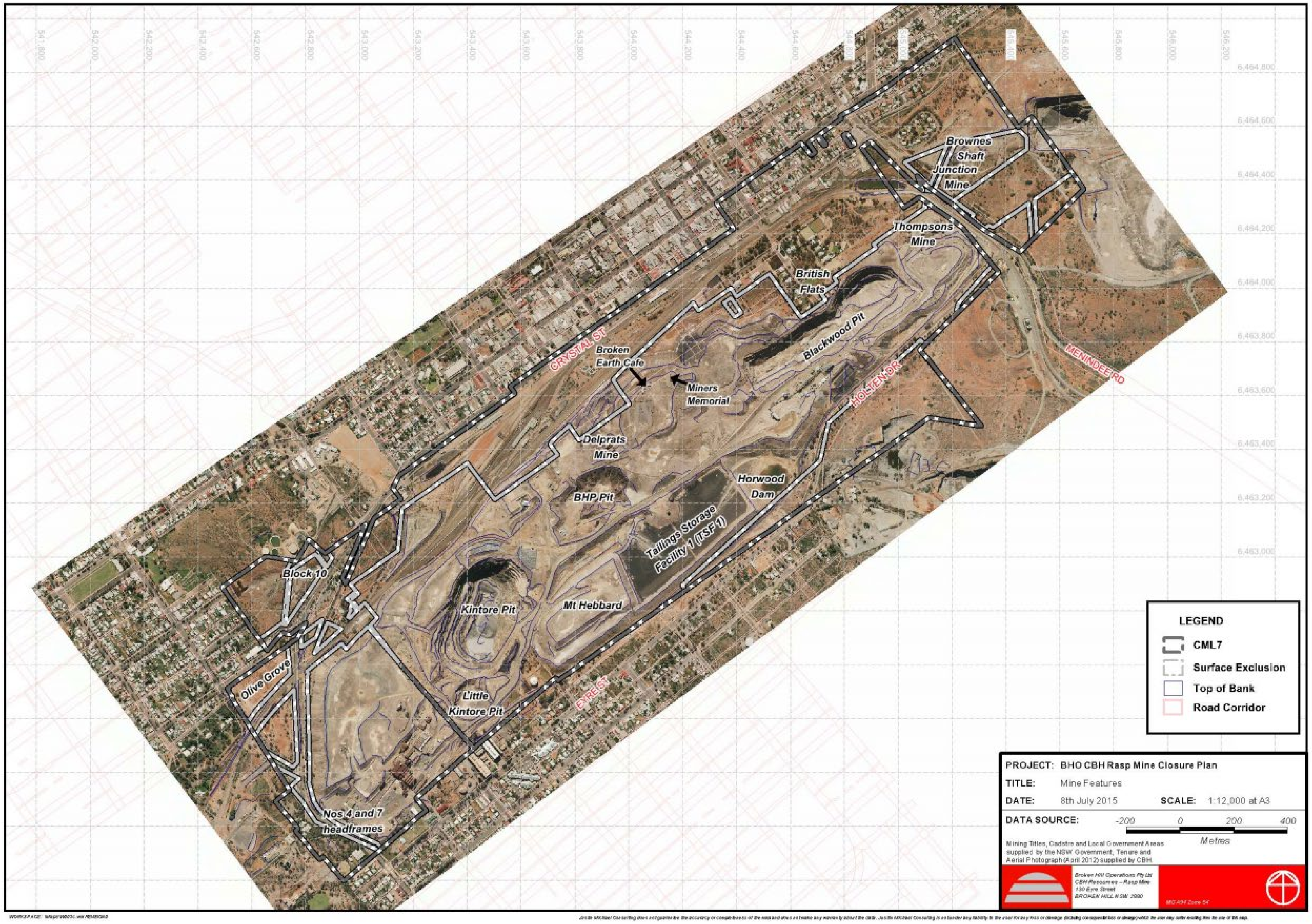

Figure 2 Layout of the Rasp Mine

2 BACKGROUND

2.1 Current operations

The Mine was approved by the Minister for Planning on the 31 January 2011 under Part 3A of the Environmental Planning and Assessment Act 1979. Project Approval 07_0018 will expire on 31 December 2026.

The Mine and most associated infrastructure are situated in Consolidated Mine Lease 7 (CML7) (Figure 1) which occupies a central position along the historic Line of Lode. CML7 allows for underground mining to the boundary of the lease and for certain activities to be conducted within the lease boundary, subject to development consent. CML7 also includes surface exclusion zones, in which no surface mining activity can be undertaken

Some BHOP activities are not located on CML7 and are located on adjacent freehold and Western Land Leases, including administration offices, rail infrastructure and stores warehouse.

Other occupants conduct activities within CML7. The Broken Earth Café and the Broken Hill Miners Memorial, the olive grove plantation (Broken Hill Gourmet Products Co-Operative) and Vodafone communications tower are also located on CML7.

2.2 Historic operations

Broken Hill has been one of the great mining centres since the discovery of one of the largest and richest silver-lead-zinc ore bodies in the world in 1883. The history of mineral development at Broken Hill and the heritage value of associated infrastructure has State and National significance (NSW Government, 2020). In January 2015, the City of Broken Hill was granted heritage status and placed on the National Heritage Listing for its contribution to mining (Australian Government, 2020).

Historic operations have left the Mine area highly modified and disturbed. The original landform has been significantly altered, most native vegetation has been removed and soils have been degraded and covered with waste rock or tailings (BHOP, 2020a).

From 1885, mining has been undertaken continuously, by multiple companies, on earlier leases that now comprise CML7. It is the original home of BHP mining operations. Minerals Mining and Metallurgy (MMM) ceased mining on CML7 in April 1991. Normandy Mining Limited held a controlling interest in MMM. Rehabilitation of CML7 commenced in 1991 and was completed in 1999 (Normandy, 2000). The Mine was purchased by CBH from Normandy Mining in 2001.

2.3 Post mining land use

The intended post mining land use for the Mine is suitable commercial (tourism) and/or educational uses to preserve the heritage value of the Mine and associated infrastructure where possible. No formal endorsement of the intended post mining land use has been received however and the NSW Resources Regulator is currently negotiating with multiple government agencies to identify a process for determining the post mining land use across the length of the Line of Lode (BHOP, 2020a) and is yet to provide any guidance.

2.4 Rehabilitation objectives

The current rehabilitation objective for the Mine pertaining to dust is (BHOP, 2020a):

- Minimise the generation of dust and adequately contain potentially hazardous materials within the landform.

2.5 Climate

The Mine is situated in the NSW arid zone which has a hot dry climate (NSW Government, 2019). A median rainfall of 254 mm has been recorded at the Broken Hill Airport Station with most rain failing in the summer months (Figure 3). The mean maximum temperatures range from 15.6˚C in July to 33.6˚C in January, while the mean minimum temperatures range from 4.8˚C in July to 19.3˚C in January. The annual evaporation rate is high, in the order of 2,614 mm (BOM, 2019).

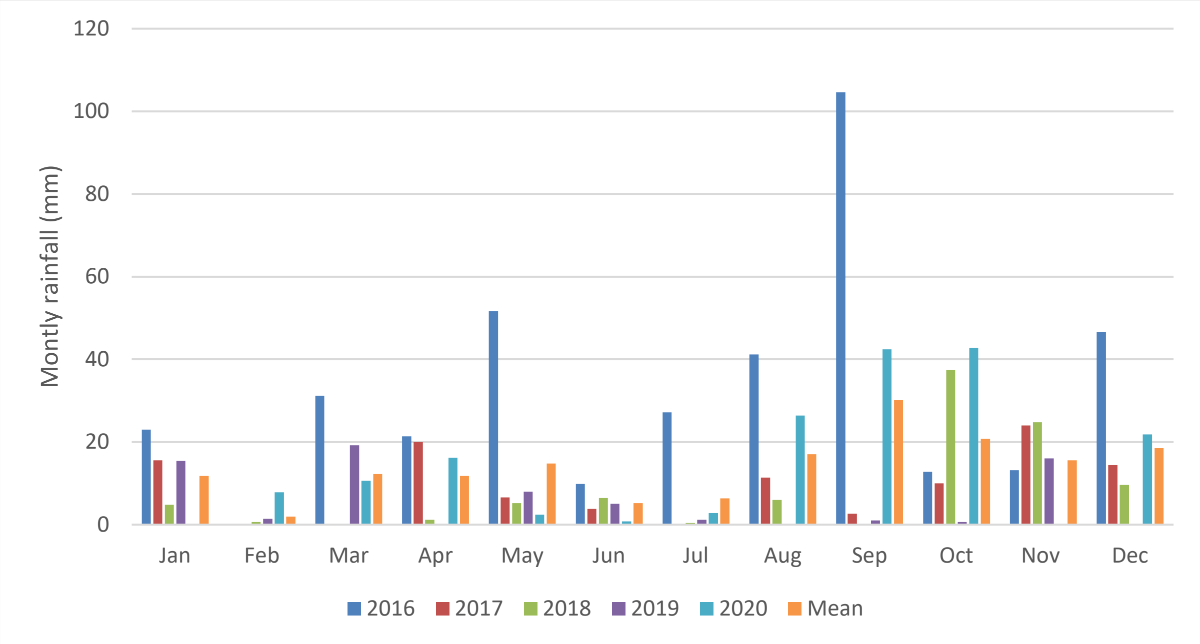

Figure 3 Monthly rainfall (in mm) compared to the long-term monthly averages recorded at the Broken Hill Airport

Wind speed and direction averages indicated the following (BOM, 2019):

- Average wind speed at 9 am is strongest in October and occurs predominantly from the south, then the north and north-east. It is weakest in June.
- Average wind speed at 3 pm is strongest in October and occurs predominantly from the south with similar contributions from the south-west and west. It is weakest in May.
- On an annual basis winds are predominantly from the south at 9 am and are still predominantly from the south at 3 pm, but with greater contributions from the west.
- At 9 am the wind is predominantly from the south in summer, autumn, winter and spring
- At 3 pm the wind is predominantly from the south in summer, autumn and spring, and predominantly from the west in winter.

2.6 Flora and vegetation

As defined by the NSW Government office of Environment and Heritage, the Mine lies within the Broken Hill Complex bioregion. This bioregion occupies approximately 5% of NSW and is bounded by the Murray-Darling Depression and Darling Riverine Plains bioregions to the south, the Simpson-Strzelecki Dunefields to the north and the Mulga Lands bioregions to the east (NSW Government, 2019).

The vegetation of the Broken Hill Complex bioregion is described as an *Acacia aneura* (Mulga) woodland with a lower storey consisting of *Atriplex* and *Maireana* species. Other communities that occur across the bioregion included Belah (*Casuarina cristata*), rosewood (*Alectryon oleifolius*), white cypress pine (*Callitris glaucophylla*) and mallee communities. Due to the arid climate, vegetation distribution throughout the bioregion is controlled by soil moisture and drainage patterns. Vegetation is more abundant and diverse on the deeper loamy soils, where there is more moisture (NSW Government, 2019).

Rocky outcrops in the bioregion are sparsely vegetated and usually treeless. Some varieties of *Eremophilia, Atriplex* and *Maireana* and annual grasses occur across the rocky slopes (NSW Government, 2019).

Due to historical ground disturbance at the Mine, the flora and vegetation communities of the area have been highly disturbed and largely removed. Small patches of isolated woodland, salt bush and rocky grassland occur on the edges of the Mine area and along roadsides. The flora of these areas consists of *Eucalyptus* species, *Acacia aneura, Atriplex nummularia, Maireana* spp., *Bassia* spp. and *Astria* spp (Corkery, 2010).

3 METHODS

The methods that were adopted for dust options assessment are described below.

3.1 Knowledge base assessment

The knowledge base assessment was undertaken via a review of available literature, a site visit and discussions with BHOP representatives.

Available literature was reviewed and summarised. The following reports were available for review:

- Closure Report CML 7, authored by Normandy Mining Limited and dated 2000
- Rasp Rehabilitation and Environmental Management Plan / Mine Closure Plan, prepared by Corkery & Co. Pty Ltd. and dated 2010
- Annual Environmental Management Report / Annual Review, authored by BHOP and dated 2017
- Mining Operations Plan for the term 1 October 2019 to 30 September 2021, authored by BHOP and dated 2020
- Rasp Air Quality Management Plan, authored by BHOP and dated 2019
- Rasp Air Quality Monitoring Programme Management Plan, authored by BHOP and dated 2016
- Community Lead Management Plan V2, authored by BHOP and dated 2016
- Health Risk Assessment for Rasp Mine Proposal, Broken Hill, authored by Toxikos and dated 2010
- Rasp Mine Waste Rock Classification, authored by PEL and dated 2017
- Rasp Mine, Broken Hill – Modification 6, Air Quality Assessment, authored by ERM, dated May 2021
- Human Health Risk Assessment for Rasp Mine, Modification 6, authored by SLR, dated 2020

A site visit was undertaken to the Mine on Tuesday 4 December 2018. S.Mackenzie and S.Gregory from Mine Earth attended the site visit and were supervised by D.Roberts from BHOP. The Mine area was inspected in a light-vehicle and on foot during the site visit. D.Roberts provided a description of the Mine area including its history, current status, associated issues and environmental and social setting.

3.2 Dust management risk assessment

An internal risk assessment workshop was undertaken to identify dust closure related risks, associated causes and potential dust management controls for the Mine area in its current state. The outcomes of the risk assessment are presented in Section 4.7.1.

The potential controls identified from the risk assessment were collated as *closure options* to be assessed during 'options identification and evaluation' (Section 4.7.2).

The risk assessment method that was adopted aligns with the Australian and New Zealand Risk Management Standard (ISO 31000:2018) and the risk matrices were sourced from the International Council on Mining and Metals (ICMM) planning for integrated mine closure toolkit (ICMM, 2019) and are presented in Appendix A.

3.3 Dust management options identification and evaluation

Closure options for the management of dust were collated from the risk controls identified from the risk assessment. The closure options were subsequently evaluated during an internal workshop.

Multi-criteria analysis (MCA) was used to evaluate the options (Section 4.7.3). The MCA criteria were developed internally from experience with similar projects. Eight criteria were applied to the MCA and score weightings were allocated to each (Table 1). Score weightings ranged from one to five; where one was lowest and five was highest.

Table 1 MCA criteria, descriptions and weightings

Criteria		Description	Weighting
1	Effectiveness	Effectiveness of the option in reducing the potential for off-site impacts	5
2	Ease to construct	Ease with which the option could be implemented	3
3	Proven method	The effectiveness of the option has been proven in other cases	5
4	Cost	Cost to implement the option (capex)	3
		Cost for ongoing maintenance and management of the option (opex)	3
5	Acceptance	Option likely to be acceptable to external stakeholders	5
6	Visual amenity	The option improves the visual amenity of the mine	3
7	Reputation	The option will have a positive impact on company reputation	3
8	Enduring	Long-term, post-closure effectiveness of the option; walk away solution	5

The performance of each option was evaluated by allocating a score to each criterion. The scoring values ranged from one to five as described in Table 2. The weighted average score for each option was then calculated and used to assess the relative performance of each option.

The options that scored highest from the MCA were considered in combination as the preferred options for dust management, contingent upon resolving material gaps in the current knowledge base. Gaps in the current knowledge base that were limiting the effectiveness of the risk assessment and options evaluation process were identified (Section 4.7.4).

Table 2 MCA scores

Score	Description
1	Unacceptable
2	Below average
3	Average
4	Above average
5	Good

3.4 Plan to select preferred option for dust management

From the MCA and knowledge gap assessment, a plan was developed to resolve the current knowledge gaps and select the preferred dust management closure options for the Mine (Section 4.7.5).

4 DUST MANAGEMENT OPTIONS ASSESSMENT

The components of the dust management options assessment as prescribed by the MOP are presented in this section.

4.1 Previous revegetation programs

The purpose of this section is to:

> *Examine previous revegetation programs undertaken at the Mine to gain an understanding of their success or failure.*

Between 1993 and 1994, revegetation works were undertaken within the Block 10 area.Tailings and contaminated soil and rocky material were removed from the area and revegetation activities were undertaken. Sewage waste and imported clay soil were used and local seed species were broadcast. Revegetated areas were irrigated. These revegetation activities were reported to have only partial long-term success while irrigation was ongoing. These revegetated areas were later covered with rock (Corkery, 2010).

A historic revegetation program was undertaken at Broken Hill during the early 1990s by Pasminco Mining. Pot trials and field trials on Site C tailings dam were conducted and it was concluded that as long as irrigation and soil moisture levels were maintained then grass growth was possible. However, due to drought conditions and the cessation of irrigation activities, the revegetation failed and has since been covered to reduce dust entrainment (BHOP, 2017).

Sparse vegetation (i.e. less than 30% cover) has grown on exposed areas around the Mine including *Dodonea viscosa*, *Stipa* spp., *Eucalyptus intertexta* and weeds such as *Nicotiana glauca* and *Nerium oleander*. During the site visit, species such as *Solanum* and *Ptilotus* were noted on areas of imported fill at the Ryan Street dam. If revegetation of selected areas was to be considered at the Mine, species such as *Acacia aneura, Atriplex, Maireana, Solanum* and *Ptilotus* could be used in the seed mix. These species all occur locally and have also been used with demonstrated success in rehabilitation activities in other parts of Australia (Erickson, et al., 2016).

Regeneration reserves have been established around the Broken Hill townsite that currently cover an area of around 2,400 ha. These regeneration reserves were originally fenced off using predator-proof fencing to exclude dogs, cats, rabbits and foxes and restrict public access. In the 1930's sections of these reserves were planted with approximately 1,100 Eucalypt plants, a hedge of saltbush and another 1,400 trees of various species and these areas were irrigated with waste water. This was one of the first regeneration projects to be undertaken in Australia (Museum of applied arts and sciences, 2019).

An olive grove has been established in an area that was previously used as a water storage dam. The Broken Hill Gourmet Products Co-Operative Limited has undertaken the establishment, harvesting and maintenance of the irrigated olive grove (BHOP, 2017).

While vegetation growth has occurred in areas around the Mine, these areas are unlikely to provide protection against wind erosion. Published data indicates a high risk of wind erosion in areas with less than 30% vegetation cover (Barson & Leys, 2009) (Figure 4).

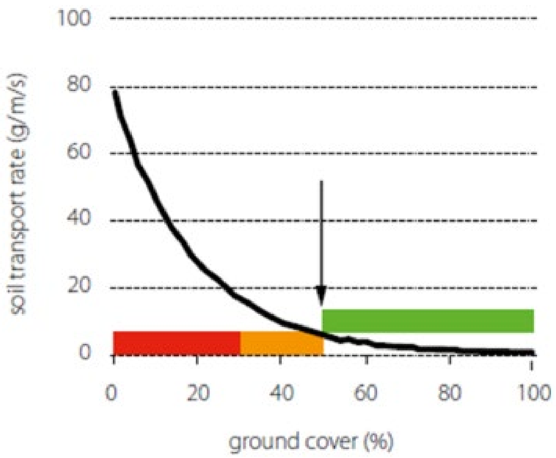

Figure 4 Relationship between wind erosion (measured as the soil transport rate) and ground cover showing low (green), medium (orange) and high (red) risk areas (Barson & Leys, 2009)

4.2 Main sources of dust generation

The purpose of this section is to:

Identify the likely areas at the Mine where dust generation is most probable.

Wind erosion occurs when three environmental conditions coincide; (i) the wind is strong enough to mobilise soil particles from the land surface, (ii) the characteristics of the soil make it susceptible to wind erosion (soil texture, organic matter and moisture content) and (iii) the surface is mostly devoid of vegetation cover or stones (Pudmenzky, 2016).

Dust has the potential to be generated from the following areas once the Mine has closed:

- Exposed ‘free areas’ that do not have any land disturbance from the mine activities.
- Unsealed roads.
- laydown areas used for equipment storage and parking
- ROM pad.
- TSF2 and proposed TSF3.

The highest ranked emission source, both in terms of uncontrolled and controlled emissions, is anticipated to be the existing ‘free areas’ (Figure 5). These areas are currently not disturbed by BHOP activities however they have the potential to generate dust from wind take-up. (BHOP, 2019)

Figure 5 Locations of 'free areas' at the Mine

The historic tailings facility All Nations TSF1 has had one metre of cover placed over the facility and the sides have been capped with waste rock, early 1990's. A final capping of slag has been placed as a top layer over the facility to minimise dust generation and this has been effective to date (Plate 1) (BHOP, 2017). BHOP proposes to cover the Blackwood Pit TSF2 progressively with waste rock (containing <0.5% Pb). The conceptual design of the cover layer includes a nominal 0.5 m thick cover of rock.

Plate 1 Slag as an effective cover on the All Nations TSF1

4.3 Existing information

The purpose of this section is to:

Review existing information detailing the predicted contributions to lead levels to the surrounding areas adjacent to the Mine.

This section describes the results from ongoing air quality monitoring and the Human Health Risk Assessment (HHRA) and the Broken Hill Lead Study.

4.3.1 Air quality monitoring

Air quality impacts from the Mine are monitored in accordance with approvals requirements, the Air Quality Management Plan (BHOP, 2019) and Community Lead Management Plan (BHOP, 2016).

Ambient air quality is monitored by BHOP personnel via a combination of seven dust deposition gauges, three high volume air samplers (HVAS) and two tapered element oscillating microbalances (TEOMs) sampling units (BHOP, 2020a). In-stack air quality is also monitored however this is not considered relevant in the context of the closure period for the Mine.

Dust deposition gauges measure the quantity of dust particles that settle out from the air in grams per square metre per month (g/m^2/month) at a particular location as shown in Figure 6. Monthly samples have been collected since 2007 and analysed by ALS laboratory in Newcastle for total deposited dust and deposited lead-dust. Criteria have been set as follows (note, dust storms are excluded from the criteria (BHOP, 2020b)):

- A maximum project contribution acceptable increase in deposited dust level over existing background levels of 2 g/m^2/month (annual average) at residence or privately owned land.
- A maximum total deposited dust level of 4 g/m^2/month (annual average).

There are no criteria set for the volume of deposited lead dust (BHOP, 2020b).

The BHOP AEMR describes the results of all air quality monitoring undertaken at the Mine. During the 2020 assessment period, there were 15 occasions where the deposition dust limit of 4 g/m^2/month was exceeded. Six of these exceedances occurred at the control locations offsite which indicates higher dust deposition was associated with increased wind velocity, high evaporation rates, frequent dust storms and below average rainfall in the summer months. Deposited lead dust was also consistently above baseline levels (i.e. 3.1 – 5.7 g/m^2/month), particularly at the Thompsons Shaft (ranging between 0.2 to 7.6 g/m^2/month in 2020), Junction Mine (ranging between 1.9 to 20.2 g/m^2/month in 2020) and Block 10 (ranging between 0.4 to 28.1 g/m^2/month in 2020) monitoring locations (BHOP, 2020b). It should be noted that high results recorded at Block 10 were linked to both dust storms, and earthworks activities being undertaken nearby. Higher results at the Junction Mine and Thompsons Shaft were also associated with increased wind velocity, high evaporation rates, frequent dust storms and below average rainfall in the summer months.

There are four high volume air samplers used to measure ambient air quality at the Rasp Mine – HVAS, HVAS1, HVAS2 and HVAS3 (note HVAS2 and HVS3 are at the same location at Blackwood pit) (Figure 4). HVAS and HVAS3 sample total suspended particulates (TSP) and lead dust, and HVAS1 and HVAS2 sample for particulate matter less than 10 microns (PM10) and lead dust. Samples are collected every six days and are sent to ALS Laboratory (NATA accredited) in Newcastle (BHOP, 2020b).

Monitoring at HVAS from 2008 to 2020 has illustrated that the TSP and TSP-lead have remained well below the EPA threshold of 90 $\mu g/m^3$ for TSP and 0.5 $\mu g/m^3$ for TSP-lead (BHOP, 2020b).

Monitoring at HVAS1 and HVAS2 from 2011 to 2020 indicates that the rolling annual average for PM_{10} exceeded the criteria of 25 $\mu g/m^3$. Monitoring at HVAS3 (BHOP, 2020b) up until June 2019 (when HVAS was decommissioned until early 2021) indicates that the rolling annual average for TSP also exceeded the criteria of 25 $\mu g/m^3$. These elevated results were attributed to frequent dust storms and drought conditions in recent times. There are no criteria for PM_{10}-lead (BHOP, 2020b).

There are two TEOM air quality monitors which record real time PM_{10} data. Monitoring data from 2013-2020 indicates that the annual average results for PM_{10} are below the EPA criteria of 25 $\mu g/m^3$. On occasion the TEOMs have recorded above the criteria for the 24-hour average, however this has been a result of dust storms across Broken Hill (BHOP, 2020b).

Since 2017 air quality monitoring across all parameters has seen a trend of improvements in measured parameters (TSP, lead, PM_{10} and deposited dust). Like the monitoring at HVAS1-3, 2018 saw worsening air quality locally due to drought like conditions that were seen in regional NSW.

During 2021, ERM were commissioned to model the air quality impact of the proposed Modification 6 (MOD6) activities planned for the Mine (ERM, 2021). The modelling considered three scenarios:

- Dust produced during current operations;
- Dust produced during the MOD6 construction scenario and;
- Dust produced during the MOD6 operational scenario

For the MOD6 construction scenario, there is anticipated to be a net increase in lead concentrations / deposition rates when considering all sensitive receptors when compared the current operations. However, all air quality metrics are predicted to be below their respective NSW EPA criteria for the MOD6 construction scenario. The MOD6 construction scenario is expected to be approximately six months in duration and as such it is anticipated that the associated impacts will reduce upon completion of this phase.

For the MOD6 operational scenario, which incorporates the new portal location and proposed tailings harvesting activities, there is a predicted net reduction in lead concentrations / deposition rates when compared to the current operations. All air quality metrics are predicted to be below their respective NSW EPA criteria for the MOD6 operational scenario (Table 3).

Table 3 Maximum predicted concentrations at sensitive receptors (ERM, 2021)

Metric	Current operations increment	Current operations cumulative	MOD6 operation increment	MOD6 operation cumulative	NSW EPA	Units
Annual average lead concentration	0.026	0.243	0.024	0.241	0.500	µg/m^3
Annual average lead deposition	0.069	0.069	0.067	0.067	N/A	g/m^2/annum
Annual average TSP concentration	1.5	36.9	1.8	37.0	90	µg/m^3
Annual average PM_{10} concentration	1.0	13.6	1.0	13.6	25	µg/m^3
Maximum 24-hour PM_{10} concentration	6.6	46.7	6.4	46.9	50	µg/m^3
Annual average $PM_{2.5}$ concentration	0.3	5.6	0.3	5.5	8	µg/m^3
Maximum 24-hour average $PM_{2.5}$ concentration	2.2	18.9	1.9	18.9	25	µg/m^3
Annual average dust deposition	0.3	3.4	0.3	3.6	2 (increment) 4 (cumulative)	g/m^2/month

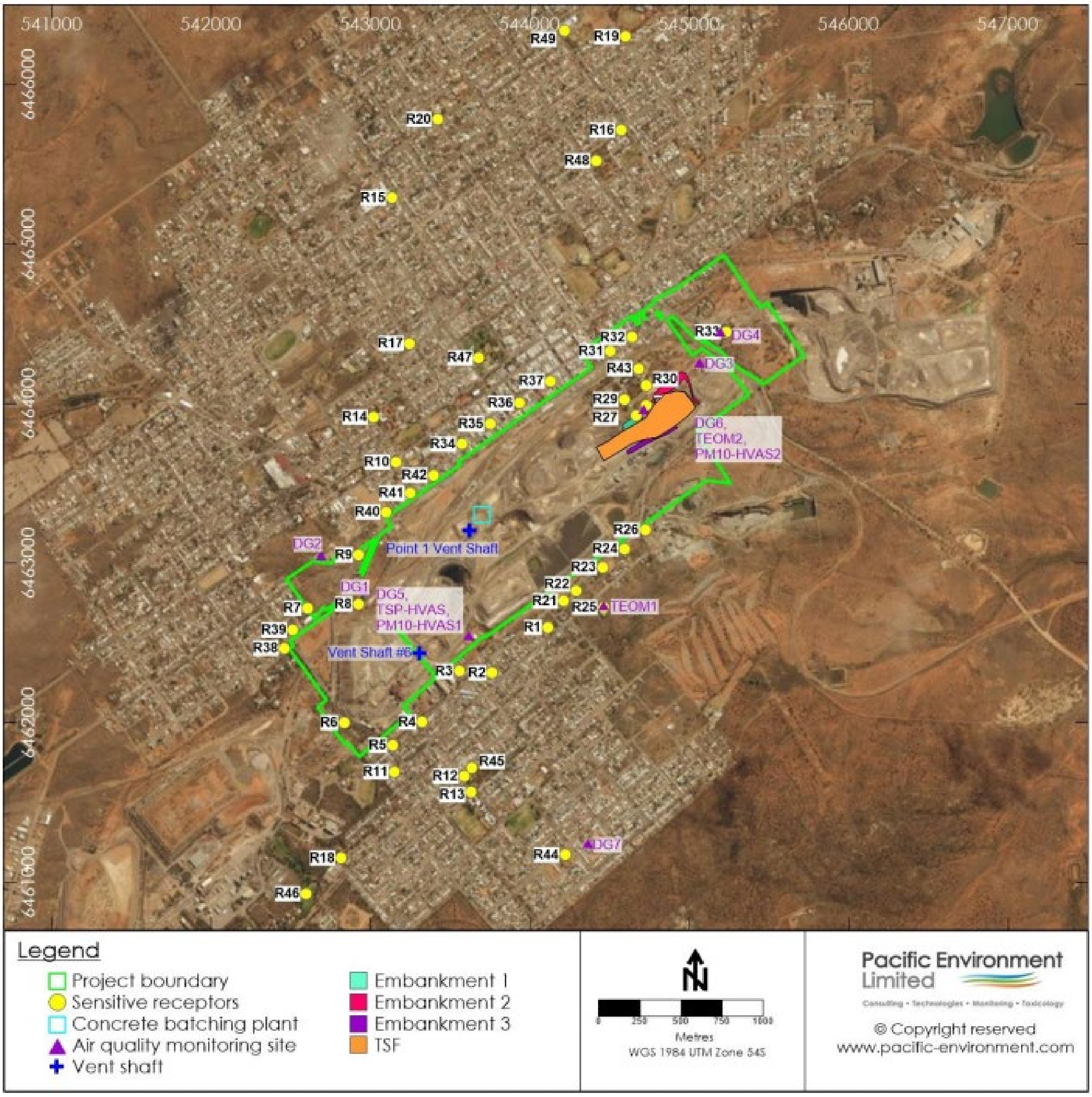

Figure 6 Dust monitoring locations and sensitive receptors

4.3.2 Human Health Risk Assessment

A HHRA was undertaken by Toxikos in 2010 that involved collecting soil samples and analysing these for their lead content and ability for this lead to be absorbed by the body (bioaccessibility) (Toxikos, 2010). The area recording the highest lead soil content (31 mgPb/g) and bioaccessibility (14.6%) was an elevated area to the west of the Mine which is now used as a water evaporation basin as part of the Site Water Management Plan. Given the expanse of the area (32,500 m^2) there is the potential for wind erosion. The closest residents to this area are approximately 200 m away. The area is a highpoint of the mining area and is not seen by residents (BHOP, 2017).

The area which recorded the second highest lead concentrations (18.7 mgPb/g) with a lower bioaccessibility is the historic tailings storage facility of Mt Hebbard which lies centrally within CML7. This area is located approximately 50 m from residential housing located on the north of Eyre Street. The dominant wind directions are to the south of the mine and South Broken Hill has been classified as the area with the highest levels of lead contamination in Broken Hill (BHOP, 2017).

The HHRA was updated during 2020 to consider the potential impacts to the community as a result of the proposed Modification 6 (MOD6) development (SLR, 2020). Approval of MOD6 will allow tailings to be co-deposited with excess waste rock from underground mining operations into Kintore Pit as a Tailings Storage Facility (TSF3).

To support the HHRA, ERM (2021) undertook air quality and dust deposition modelling. The modelling considered local land use, terrain, air quality and meteorology. The modelling predicted concentrations for airborne dust and deposition of metals at 70 locations including parks, residences and playgrounds throughout Broken Hill. The modelling indicated that all air quality metrics are predicted to be below their respective NSW EPA criteria as a result of the MOD6 development. It was also considered likely that a net reduction in air quality impacts will be realised due to the shorter ore transport distance as a result of the MOD6 development (ERM, 2021).

The HHRA used modelling to estimate mean blood lead (BPb) levels in hypothetical populations of 1-2 year old children living in Broken Hill to determine if there would be any changes between current operations and as a result of the MOD6 development. The modelling incorporated incidental ingestion of Pb in soil/dust, inhalation of Pb in air (PM10), as well as inclusion of modelled intakes of Pb from the diet, reticulated drinking water, soil, and contribution from maternal BPb. It was concluded that the MOD6 development would result in little change to mean BPb in this age group (ERM, 2021).

The HHRA (SLR, 2020) also assessed the risk from MOD6 by observing changes to the cancer and hazard indices (HI). The HHRA determined that the MOD6 development posed no additional inherent carcinogenic risk.

4.3.3 Broken Hill Environmental Lead Study

The Broken Hill Environmental Lead Study (NSW Government, 2020) is currently being conducted over a four-year period to monitor airborne and deposited lead and assess contributions of current emissions from Line of Lode mining leases and emissions from areas affected by historic emissions (‘legacy lead’). Specific study objectives are to:

- Determine likely source areas contributing to airborne lead levels in Broken Hill based on a year of wind-directional measurements of ambient air lead at selected locations, and analysis to identify the location of sources contributing to airborne lead.
- Monitor airborne and deposited lead levels for a further two years to evaluate the effectiveness of remediation works in reducing lead levels.

Wind-directional high-volume air samplers are being deployed at five sites representative of local community exposures: three sites in North Broken Hill and two sites in South Broken Hill. Dust deposition gauges have been installed at the sampling sites to provide information on total dust deposition and deposited lead levels. Ambient particulate matter concentrations are being continuously measured at two sites using DustTrak Aerosol Monitors (DustTraks).

Study findings have yet to be published but will be of use to BHOP in determining sources of lead dust and effectiveness of remediation measures (NSW Government, 2020).

4.4 Use of revegetation to achieve dust management outcomes

The purpose of this section is to:

> *Identify any opportunities for the use of vegetation to achieve acceptable dust management outcomes (especially in areas where significant dust generation is less likely) over time and under drought conditions.*

As described previously it is unlikely that revegetation at the Mine would provide sufficient coverage (i.e. greater than 50% cover) to adequately manage dust. The barriers to revegetation success are described in Section 4.6. This section explores other dust management options including operational controls and the use of waste rock to manage dust over the long-term.

4.4.1 Operational dust controls

The Air Quality Management Plan (BHO-PLN-ENV-001) lists the dust management strategies that are in place for the existing operations at the Mine. In summary, the major controls include:

- The use of chemical dust suppressant on non-active mining areas and roads
- Sealing of all major roads and the use of a street sweeper and water truck
- Wing walls and roof over the ROM Bin and water sprays on the apron feeder to the crusher
- Fully enclosed primary crusher operating under negative pressure to a baghouse.
- Fully enclosed conveyors and transfer points prior to the Sag Mill with installed dust collectors
- Restricted access to non-active mining areas
- Use of water sprays on the ROM Pad
- Concentrate loading into containers occurs in an enclosed building and containers are covered prior to exiting the building
- All vehicles leaving site are washed, including trucks taking containers to the rail loadout area
- Traffic light system informing all staff and contractors of wind speeds
- Wind speed alerts from the onsite weather station notifying mine personnel of wind speeds greater than 35 km/hr

4.4.2 Waste rock for dust control

Waste rock is routinely used as an effective dust control measure in mine site rehabilitation at mines in Australia and around the world, especially on tailings storage facilities.

In 2017 BHOP engaged Pacific Environment Ltd (PEL) to undertake a study of waste rock and in particular provide recommendations for its suitability and effectiveness as a medium for dust suppression over selected surfaces of the Mine (BHOP, 2017). Waste rock from a stockpile present within the Kintore Pit was assessed with the following results:

- The rock type varies, however all rock types identified were competent and mostly hard, with good resistance to weathering.
- The rock comprises only approximately 1% fines capable of producing dust.
- Lead concentrations averaged 2,371.5 mg/kg (0.24%) and were taken from crushed samples (and therefore conservative as there is only 1% of fines capable of producing dust). This is approximately four times the NEPM health investigation level (HIL-C) criterion (600 mg/kg) but significantly below surface dust averages (15,640 mg/kg, or 1.56%).
- Bioaccessibility was very low (7.3% on average). This is much lower (6.8 times) than the 50% bioavailability assumed for the calculation of HIL's. This would suggest that results, if adjusted for bioaccessibility, would meet HIL-C criteria.
- Air quality modelling conducted by PEL (2017) has assumed lead concentrations of 0.5% (5,000 mg/kg), which is above those identified in the waste rock on site (0.24%) and therefore the waste rock is likely to meet NSW EPA impact assessment criteria for air quality parameters

assessed and is unlikely to impact further upon surface soil lead concentrations within local communities (PEL, 2017).

The results supported the use of waste rock for dust suppression for the TSF and ‘free areas’, and is considered unlikely to cause an unacceptable risk to human health based upon the final proposed land use as a tourist/recreational site (BHOP, 2017). PEL recommended that that:

- Waste rock be tested prior to placement to ensure median level of lead concentration does not exceed 0.5%.
- Dust suppression water spraying is carried out during capping material (waste rock) placement to ensure finer particles are washed between the larger rocks.

BHOP (2017) reports that waste rock was used successfully by Normandy in the 1990’s and by BHOP on site to reduce wind entrainment of dust into the air. PEL (2016) undertook an investigation to determine the efficiency of waste rock on the reduction of dust emissions in 2016. Results indicated that the waste rock trial on site provided a control efficiency of 99.7%. BHOP therefore identified priority zones within the ‘free areas’ which would be appropriate for this treatment. Selection criteria considered:

- The results of lead in soil and bioaccessibility undertaken during the HHRA.
- The potential for windblown dust to be generated.
- The proximity and potential for the wind to deposit lead bearing dust to affected areas off-site.
- The visual aesthetic value of the area.
- The current use for the area.

Based on the selection criteria above, the surface of Mt Hebbard was selected as a priority area for trialling waste rock as a dust management option. Revegetation had been attempted in this area and was not successful due to cessation of irrigation. BHOP installed three dust deposition gauges in 2017 at Mt Hebbard and samples have been collected monthly since. This information, together with rainfall and wind direction and speed, will be analysed to assess the effectiveness of the rock cover in reducing dust generation. Chemical dust suppressant are currently used to control dust at Mt Hebbard.

4.5 Revegetation and visual amenity

The purpose of this section is to:

Analyse the visual amenity aspects of the various approaches, consistent with possible end land use scenarios

Amenity is described as the pleasantness of a place as conveyed by desirable attributes including views, noise and odour (NSW Government, 2021). The city of Broken Hill was added to the National Heritage List in January 2015 which recognised Broken Hill’s mining history and outback location (Broken Hill City Council, 2021). In particular, Broken Hill was listed due to the unique mining landscape.

The Broken Hill City Council has an overarching plan to “maintain and enhance heritage as a distinguishing visual and experiential feature of Broken Hill”. As such all closure plans and dust management options will need to be cognisant of the need to maintain the cultural and heritage value of mining areas.

There are numerous areas of the Mine that can be seen from roadways or town areas, however a number of the free areas are not visible from the town as they are situated in an elevated position in the landscape (e.g. Mt Hebbard).

Revegetation is commonly used to improve the visual amenity of and area (Land for Wildlife, 2016). While the use of revegetation could potentially increase the visual amenity of Mine areas, the following should be considered:

- The establishment of vegetation will be impacted by drought conditions and declines in vegetation health are likely to be visible.
- The use of larger tree species may block the view of the historic mining areas.
- Revegetation is unlikely to be successful in effectively controlling dust.

4.6 Barriers to revegetation success

The purpose of this section is to:

> *Provide a discussion into potential barriers to success of revegetation (e.g. costs, maintenance, available materials etc.).*

There are a number of factors that are likely to impact the success of revegetation activities at the Mine including:

- Climate – in particular drought conditions and high evaporation rates
- Lack of growth medium
- Dominance of weeds
- Excessive grazing
- Excessive dust generation and wind erosion
- Financial viabilty

4.6.1 Climate

Current climatic conditions (i.e. drought and high evaporation rates) are unlikely to promote plant growth and germination of seed within Mine areas. Successful revegetation programs in the region have utilised irrigation to overcome the climatic issues. The use of town water for irrigation however, is not considered to be a viable long-term closure solution. Wastewater was used successfully for the establishment of vegetation in the 1930s in the Broken Hill area. Irrigation is unlikely to be a suitable option given the value of water resources in Broken Hill and the likely failure of the revegetation once irrigation activities cease.

Loss of seed as a result of wind erosion is also a consideration for any revegetation activities at the Mine.

As described in Section 2.5 the climate of Broken Hill is characterised by low annual rainfall and high evaporation rates. During 2019 and 2020, Broken Hill experienced drought conditions with total annual rainfall being 96 and 109 mm respectively. Both years were below the long-term annual average rainfall (150 mm) at Broken Hill (BOM, 2019). These drought conditions are unlikely to support revegetation efforts.

4.6.2 Growth medium

There are no topsoil resources available within the mining area. Topsoil is an important factor in revegetation activities as it contains a seed resource, and fungi and bacteria that help to facilitate the establishment of vegetation (Golos & Dixon, 2014). Soil is also important to improve water holding capacity (Munoz-Rojas, et al., 2015).

Waste rock is the only growth medium present at the Mine. During the site visit, vegetation was not typically observed on areas treated with waste rock. This is most likely associated with low concentrations of nutrients and a low water holding capacity of the waste rock.

Waste rock has been used as a growth medium at other mine sites throughout Australia, however the success of revegetation has been varied with vegetation typically taking longer to establish. If waste rock is used as a growth medium, ameliorants are typically required to increase the water holding capacity, improve the nutrient status and increase the concentration of organic matter.

To increase the storage of water and other resources in a rehabilitated area, it is recommended that surface treatments such as shallow ripping are considered. Surface treatments are intended to increase plant available water, reduce surface rainfall runoff and runoff velocities, and form niches and microhabitats to assist with seed germination and plant establishment. It is recommended that the ripping be undertaken on non-windy days and in combination with active dust suppression.

In areas including the Pilbara in Western Australia and America, seed that has been coated or pelletised has been used successfully on native seed in rehabilitation trails. The coatings typically consist of germinating promoting agents, clays and water holding gels which help to promote and assist germination of the seed and growth of the plant (Erickson, 2016).

It is likely that lead and other metals will be elevated at depth (only waste rock with <0.5% Pb will be used at surface) within areas treated by waste rock. If revegetation is utilised at the Mine, the potential for plants to uptake elements of concern will require consideration before revegetation activities are undertaken. Lead is commonly absorbed by plant roots and can result in negative effects on plant growth (Pourrut, 2011). Bioaccumulation of metals in foliage should also be considered in terms of the potential for these metals to be passed through to grazing animals.

4.6.3 Weeds

Weeds are a threat to rehabilitation, as they efficiently disperse and readily establish in disturbed areas and outcompete the native vegetation for resources such as water and nutrients.

Weed taxa that are known to occur within the Broken Hill Complex bioregion include; Athel pine (*Tamarix aphylla*), Mesquite (*Prosopis* spp.), Noogoora burr (*Xanthium occidentale*) Parkinsonia (*Parkinsonia aculeata*), Patersons curse (Echium plantagineum), Silver leaf nightshade (*Solanum elaeagnifolium*) and Wild mignonette (*Reseda luteola)* (DoEE, 2019). During the site visit, Mesquite, a weed of national significance and Onion weed (*Nothoscordum inodorum*) were both observed at the Ryan Street Dam area. In addition, during inspections in 2019, individual Bush Tobacco (*Nicotiana glauca*) trees and a stand of rhizomatous bamboo (*likely Phyllostachys spp*) were identified. The Bush Tobacco, which grows along water storages and some isolated locations on dumps, will be controlled by spraying.

The control of weeds within the Mine area will be difficult due to the close proximity of the town site and the occurrence of many non-native species within that area. To minimise the potential for negative impacts it is recommended that weed management should focus only on those species identified as environmental or declared weeds. The following weed management is recommended:

- Seed and weed inspections should be undertaken prior to any machinery entering the Mine area
- Opportunistic removal of small or new weed occurrences should be undertaken by hand and any fruiting material should be destroyed
- Weed mapping should be undertaken routinely
- Targeted annual weed spraying should occur if weed growth is identified as a problem

4.6.4 Grazing

Feral animals that are known to occur within the Broken Hill Complex bioregion include Feral pig (Sus scrofa), Feral goat (*Capri hircus*), Fox (*Vulpes Vulpes*), Rabbit (*Oryctolagus cuniculus*), Wild dog (*Canis* spp.), Starling (*Sturnus vulgaris*), Donkey (*Equus asinus*) and the Feral cat (*Felis cattus*) (DoEE, 2019). Goats have been noted in areas around the Mine and the presence of goats on newly revegetated sites could result in considerable impact to revegetation success. Grazing could be controlled through mustering and removal of goats, and installation and maintenance of fencing until revegetation is established. In addition, non-palatable species could be targeted in the seed mix.

4.6.5 Dust

Excessive dusting has the potential to impact vegetation growth by restricting photosynthesis, respiration and transpiration (Farmer, 1993). Excessive wind can also remove seed from the soil surface hampering revegetation efforts.

4.6.6 Costs

To enhance revegetation success at the Mine, interventions such as the import of growth medium and use of irrigation to sustain vegetation would be required making the cost of revegetation high. There would also be ongoing maintenance and management costs associated with the irrigation infrastructure. In addition, irrigation trials implemented historically have not achieved sustainable vegetation growth.

4.6.7 Summary

Vegetation screens and revegetation are common methods for dust management in Australia (DEC, 2011). Due to the barriers described above such as drought conditions, lack of growth medium, and the occurrence of weeds and grazing impacts, revegetation is unlikely to persist over the long term without considerable intervention at Broken Hill. Intervention strategies including irrigation and importation of growth medium could be considered but are unlikely to be suitable closure options and revegetation may only persist in the short term.

4.7 Dust management options assessment

Given that revegetation is unlikely to be an effective dust management control for closure, an assessment of dust management options was undertaken. The dust management options assessment was completed in a staged manner which included risk assessment, options identification and options evaluation.

4.7.1 Risk assessment

The outcomes of the risk assessment are presented in Table 3. The risk matrices used to undertake the assessment are presented in Appendix A. The potential controls identified from the risk assessment were collated as *closure options* to be assessed during 'options identification and evaluation' (Section 4.7.2 and 4.7.3).

The following closure related risk event was assessed for the Mine area:

- Windblown metal enriched dust is generated from the mining area and impacts the surrounding environment.

Table 4 Risk assessment of dust generation

Event	Causes	Consequences	C	L	Inherent risk	Potential control options
Windblown metal enriched dust is generated from the mining area and impacts the surrounding environment.	Contaminated ground from historical and current operations. Imported rock cover may be enriched / mineralised. Natural ground and outcrop may be enriched / mineralised. Open / exposed ground. Fine grained material on ground surface. Dry, windy conditions. Exposed dry tailings. Unauthorised vehicle movement.	Human health impacts. Environmental impacts (flora, fauna). Company reputation. Litigation. Remedial costs.	H	L	HIGH	Cover mining areas with waste rock (<0.5%Pb). Stabilise mining areas with concrete to bind contaminants and fine particles. Spray chemical dust suppressants. Install water sprays in mining areas. Use street sweepers and water trucks to control dust. Install bunds or other wind breaks to reduce wind velocity. Company to purchase affected properties. Revegetate exposed areas. Re-profile areas to reduce susceptibility to dusting.

4.7.2 Options identification

Post-closure dust management options were collated from the risk controls identified from the risk assessment and are presented in Table 4.

Table 5 Post-closure dust management options identification

Options		Description
1	Cover mining areas with waste rock	Use waste rock (<0.5%Pb) available from within the mining area, as has been effectively used already around the heritage areas.
2a	Stabilise mining areas with an impervious cover (e.g. concrete) to bind contaminants and fine particles	Use concrete or equivalent, as has been effectively used already.
2b	Stabilise mining areas with an impervious cover (e.g. slag) to bind contaminants and fine particles	Use slag, as has been effectively used already.
3	Install bunds or other wind breaks to reduce wind velocity	Install bunds around TSFs to reduce wind velocity. Install other wind breaks such as fencing, targeted vegetation rows with tall vegetation that is non-palatable.
4	Revegetate exposed areas	Revegetate areas to reduce entrainment of dust.
5	Re-profile areas to reduce susceptibility to dusting	Re-profile / contour areas to create depressions in the landscape which encourage moisture and resource accumulation and promote natural revegetation overtime.
6	Spray chemical dust suppressants	Use chemical dust suppressant as is currently used during operations.
7	Install water sprays in mining areas	Maintain use of water sprays during closure.
8	Company to purchase affected properties downstream of the areas likely to dust	Identify which residential areas are likely to be impacted by dust and purchase these properties to maintain without tenants in perpetuity.
9	Use street sweeper and water truck	Do nothing at the Mine but use street sweeper and water truck on town roads to remove/reduce dust.
10	Monitor dust levels	Monitor for a finite period and if there is no impact then there is no dust control required.
11	Leave as is / do nothing.	Leave the site in its current state.

4.7.3 Options evaluation

All twelve options were advanced through the MCA. The MCA and resultant findings are presented in Table 5 and are discussed in this section. Knowledge gaps and other issues were also identified for each management option (Table 5).

Option 1 (cover mining areas with waste rock) was considered to be the most effective solution to managing dust post-closure. However, this is contingent upon the following:

- Stakeholder acceptance
- The quantity of waste rock available
- Waste rock containing <0.5% Pb

Option 1 may not be the most effective solution over the entire site, and could be considered in combination with other options including:

- Stabilise mining areas with an impervious cover (Option 2a and 2b), particularly around heritage sites.
- Install bunds or other wind breaks (Option 3).
- Re-profile areas to reduce dusting potential and encourage resource accumulation / natural revegetation (Option 5).

Table 6 MCA of post-closure dust management options. Options highlighted in green were considered to be the most effective solutions

	Options	Effectiveness	Ease to construct	Proven method	Cost - capex	Cost - opex	Acceptance	Visual amenity	Reputation	Enduring	Weighted average score	Gaps / issues / comments
	Weighting	5	3	5	3	3	5	3	3	5		
1	Cover mining areas with waste rock	5	5	5	3	5	4	2	4	5	4.3	Determine stakeholder acceptance/availability of waste rock/quality of waste rock/cost. Develop a design concept for the waste rock cover.
2a	Stabilise mining areas with an impervious cover (e.g. concrete) to bind contaminants and fine particles	5	4	5	1	3	3	1	3	3	3.3	Expensive but could be used in targeted areas
2b	Stabilise mining areas with an impervious cover (e.g. slag) to bind contaminants and fine particles	5	4	5	1	4	3	1	3	3	3.4	Expensive but could be used in targeted areas
3	Install bunds or other wind breaks to reduce wind velocity	3	4	3	4	3	3	2	3	3	3.1	
4	Revegetate exposed areas	2	1	3	2	2	4	4	3	2	2.6	Revegetation is likely to be unsuccessful in the long-term
5	Re-profile areas to reduce susceptibility to dusting	2	3	3	2	3	3	3	3	2	2.6	Define options to establish depressions to encourage moisture/resource accumulation
6	Spray chemical dust suppressants	4	3	4	2	2	2	2	3	1	2.6	Not sustainable long term once operator leaves the site
7	Install water sprays in mining areas	3	2	4	2	2	2	2	2	1	2.3	Ongoing water source required so not sustainable
8	Company to purchase affected properties downstream of the areas likely to dust	1	2	2	2	3	2	2	2	2	1.9	Not likely to be acceptable by stakeholders
9	Use street sweeper/water truck on town roads	2	3	3	2	2	1	2	1	1	1.9	Not likely to be acceptable by stakeholders
10	Monitor dust levels	1	4	1	4	2	1	2	1	1	1.7	Not acceptable by stakeholders
11	Leave as is/ do nothing	1	5	1	5	1	1	1	1	1	1.7	Not acceptable by stakeholders

4.7.4 Knowledge gaps

A number of knowledge gaps are limiting the effectiveness of the current risk assessment and evaluation of closure options for dust management. These gaps are listed here as scopes of work to be resolved:

1. Undertake stakeholder engagement to determine preferences for dust management and if Option 1 would be acceptable as the primary means for the long-term management of dust.
2. Determine the required and available quantity of waste rock for use in suppressing dust. Determine whether the waste rock has suitable chemical properties (i.e $<0.5\%$ Pb).
3. Develop a design concept for a waste rock cover in exposed areas to manage dust. Design concepts may include; paddock dumping waste rock to create establish piles and troughs to encourage moisture/resource accumulation; or dozing out rock in a nominal 0.5 m thick cover and contouring/shaping (using a dozer or grader) to create depressions to encourage moisture/resource accumulation.
4. Define options to establish depressions in the landscape to encourage moisture/resource accumulation (overlap with knowledge gap 3).

4.7.5 Plan to select preferred options for dust management

The plan to select the preferred closure dust management options for the Mine incorporates the steps described below.

Resolve knowledge gaps

Resolve those knowledge gaps that are currently limiting the effectiveness of the risk assessment and options identification and evaluation process.

An appropriate scope of works should be developed for each knowledge gap and this should be issued to suitable internal or external specialist/s to resolve.

Update risk assessment

Once relevant knowledge gaps have been resolved, the closure dust risk assessment for the Mine (Section 4.7.1) should be updated. Additional causes, consequences and controls may be identified, and these should be updated in the risk assessment.

Revise closure options

The dust management options (Section 4.7.2) should be revised once the risk assessment and associated risk controls, have been updated. Additional dust management options may be identified and/or existing dust management options may be able to be better defined. Individual options should be collated to present broader groupings or combinations of dust management options.

Update the MCA

Once the dust management options have been revised then these should be re-evaluated via the MCA. The MCA criteria and weightings should be revised as required.

Select and develop preferred closure dust management options

Preferred closure options will be identified from the updated MCA. Once this is done a map should be produced that details dust management options relative to the risk for all areas of the Mine.

Once selected, the preferred options should be developed to the required level of engineering design to enable effective implementation.

Engage relevant stakeholders throughout

Relevant internal and external stakeholders should be given the opportunity to effectively participate in all steps outlined above.

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APPENDIX A

Risk assessment matrices

Consequence rating					
Consequence type	**Insignificant (1)**	**Minor (2)**	**Moderate (3)**	**High (4)**	**Major (5)**
Schedule	Less than 1% impact on overall project timeline	May result in overall project timeline overrun of equal to or more than 1% and less than 3%	May result in overall project timeline overrun of equal to or more than 3% and less than 10%	May result in overall project timeline overrun of equal to or more than 10% and less than 30%	May result in overall project timeline overrun of 30% or more
Financial	Less than 1% impact on the overall budget of the project	May result in overall project budget overrun of equal to or more than 1% and less than 3%	May result in overall project budget overrun of equal to or more than 3% and less than 10%	May result in overall project budget overrun of equal to or more than 10% and less than 30%	May result in overall project budget overrun of 30% or more
Safety	First-aid case	Medical treatment case	Lost-time injury	Permanent disability or single fatality	Numerous permanent disabilities or multiple fatalities
Environment	Lasting days or less; affecting small area (metres); receiving environment altered with no sensitive habitats and no biodiversity value (eg urban/ industrial areas)	Lasting weeks; affecting limited area (hundreds of metres); receiving environment altered with little natural habitat and low biodiversity value	Lasting months; affecting extended area (kilometres); receiving environment comprising largely natural habitat and moderate biodiversity value	Lasting years; affecting area on sub-basin scale; receiving environment classified as having sensitive natural habitat with high biodiversity value	Permanent impact; affecting area on a whole basin or regional scale; receiving environment classified as highly sensitive natural habitat with very high biodiversity value
Legal and regulatory	Technical noncompliance. No warning received; no regulatory reporting required	Breach of regulatory requirements; report/ involvement of authority. Attracts administrative fine	Minor breach of the law; report/ investigation by authority. Attracts compensation/ penalties/ enforcement action	Breach of the law. May attract criminal prosecution, penalties/ enforcement action; individual licence temporarily revoked	Significant breach of the law. Individual or company lawsuits; permit to operate substantially modified or withdrawn
Social / community	Minor disturbance of culture/social structures	Some impacts on local population, mostly repairable. Single stakeholder complaint in	Ongoing social issues. Isolated complaints from community members/ stakeholders	Significant social impacts. Organised community protests threatening continuity of operations	Major widespread social impacts. Community reaction affecting business continuity. Licence to

Consequence rating					
Consequence type	**Insignificant (1)**	**Minor (2)**	**Moderate (3)**	**High (4)**	**Major (5)**
		reporting period			operate in jeopardy
Reputation	Minor impact; awareness/ concern from specific individuals	Limited impact; concern/ complaints from certain groups/ organisations (eg NGOs)	Local impact; public concern/ adverse publicity localised within neighbouring communities	Suspected reputational damage; local/ regional public concern and reactions	Noticeable reputational damage; national/ international public attention and repercussions

Scale	Likelihood
Improbable (1) **<3%**	Likelihood of occurring is less than 3%. It would require a substantial change in circumstances to create an environment for this to occur, and even then, this is a rare occurrence.
Unlikely (2) **3% - 10%**	Likelihood of occurring more than or equal to 3% and less than 10%. There are no specific circumstances to suggest this could happen.
Possible (3) **10% – 30%**	Likelihood of occurring more than or equal to 10% and less than 30%. There is a possibility of this risk occurring as it has occurred before (albeit infrequently) in the mining and metals industry / area.
Likely (4) **30% - 90%**	Likelihood of occurring more than or equal to 30% and less than 90%. This consequence is not uncommon in the mining and metals industry/area.
Almost Certain (5) **>90%**	Greater than 90% likelihood of occurring. Has happened/will probably happen during the mine life and there is no reason to suspect it won't happen.

Likelihood	Consequence				
	Insignificant (1)	**Minor (2)**	**Moderate (3)**	**High (4)**	**Major (5)**
Improbable (1)	Low (1)	Low (3)	Medium (6)	Medium (10)	Significant (15)
Unlikely (2)	Low (2)	Low (5)	Medium (9)	Significant (14)	Significant (19)
Possible (3)	Low (4)	Medium (8)	Significant (13)	Significant (18)	High (22)
Likely (4)	Medium (7)	Medium (12)	Significant (17)	High (21)	High (24)
Almost Certain (5)	Medium (11)	Significant (16)	Significant (20)	High (23)	High (25)

END