Latrobe Valley Regional REHABILITATION STRATEGY

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CONTEXT AND SCOPE

The Latrobe Valley Regional Rehabilitation Strategy (LVRRS) is part of the Victorian Government’s response to the findings of the Hazelwood Mine Fire Inquiry (HMFI), which found significant uncertainties and knowledge gaps surrounding the rehabilitation and closure of the Latrobe Valley’s three brown coal mines.

The HMFI’s Board of Inquiry found that, with the current knowledge available, some form of water body was the most viable rehabilitation option for the coal mine voids, but that many unanswered questions remain concerning the feasibility of the potential mine pit lakes\(^1\). The Strategy will address some of these knowledge gaps and be informed by several technical studies.

The Strategy will consider the mines individually and collectively in the context of potential impacts (positive and negative) on the environment, Aboriginal and non-Aboriginal cultural heritage values, infrastructure and land uses in the Latrobe Valley, with a particular focus on water and land stability. The primary objective of rehabilitation is to achieve a safe, stable and sustainable landform for the closed mines. The strategy does not negate the obligation on the mine operators to develop individual mine rehabilitation and closure plans, rather it will provide guidelines that inform the preparation of these plans by the mine operators.

As part of the LVRRS, the Victorian Government commissioned a Regional Geotechnical Study. Specialists investigated the stability and fire risks associated with the coal mine voids, whether these risks could be mitigated by supplying water to fill the voids to a level that achieves stability (to reduce the need for ongoing active controls), and whether filling the mines with water could result in adverse ground movement impacts within and around them.

KEY FINDINGS

1. ACTIVE AND PASSIVE CONTROL OF RISKS

Active controls such as groundwater pumping and drainage, surface water management and extensive monitoring are required to maintain safe operating conditions at the Latrobe Valley coal mines. Nonetheless, unexpected and undesirable land movements have occurred ranging from small, continuous movement of mine walls (known as batters) to major batter failures extending beyond the mine crest. Exposed coal has caught fire a number of times, causing impacts to communities and the mines, most recently during the 2014 Hazelwood Mine Fire.

It is clear that active controls and regulation practices can’t guarantee there won’t be major ground movements or coal fires, as evidenced by these past failures and movements over the life of the Latrobe Valley mines.

Passive controls avoid the need for ongoing action in managing risk. In the context of mine rehabilitation, this is achieved through landform design. Passive design elements include the use of sediments and water to stabilise mine floors and batters, and covering coal (e.g. with soil) to prevent coal ignition by external sources.

As the mines close it will be necessary to transition to passive controls to manage stability and fire risk, to ensure that post-closure risks to the community and environment are minimised and that maintenance of the rehabilitated landform is environmentally and economically sustainable.

2. STABLE FLOORS AND BATTERS

The study found that:

- The pit lake rehabilitation option can achieve a safe, stable and sustainable landform through a largely passive control by:
  - Providing a counterweight to upward pressures from aquifers below each mine, thereby preventing instability caused by ‘floor heave’ and eliminating the current need to pump large quantities of groundwater (around 30 GL/year in total, across all three mines) from the aquifers to maintain stability.
  - Increasing lateral pressure to stabilise batters, thereby reducing the current need to actively control batter movement through groundwater drainage and surface water management.
- Extended fill times arising from limited water availability, or not filling to a level that provides the required counterweight for lateral pressures, present stability challenges that would need to be actively managed.
- Minimisation of seepage inflow through the management of surface waters and coal cover materials, in addition to coal groundwater pressure control through drainage boreholes, may be required to maintain low ground movement risks. Controls will be required during the filling period, and potentially on an ongoing basis for any coal batters extending above the final water level.
- Areas outside of the pit requiring ongoing management and/or planning controls would be reduced compared to current requirements if water levels are at or above the minimum required to achieve counterweight to future vertical and horizontal groundwater pressures.

- Ground movements will occur in response to filling a mine with water, due to a ‘lake loading’ effect. These are not expected to have adverse impacts but will need to be monitored to ensure that if any impacts arise to existing and future infrastructure, they are addressed as part of the mine rehabilitation process.

The study did not examine stability due to future water level changes in the rehabilitated mines arising from either regional water resources management or climate-controlled changes in water supply. Since ground movements could occur under dynamic water level changes, this is an area that requires further consideration as part of rehabilitation planning and implementation.

The study did consider the possibility of increased seismic activity induced by filling a mine void with water but did not establish the likelihood of either increased seismic frequency or magnitude. A qualitative assessment suggests that a possible increase in frequency could occur but that an increase in seismic magnitude is not likely. Further work is required to improve this assessment given the particular nature of the hydrogeological setting of the Latrobe Valley and the changes in deep geological stresses that have occurred due to mining to date.

The study did not specifically consider in-pit design issues related to mine rehabilitation.
3. GROUND SUBSIDENCE AND REBOUND
The study found that:
• Groundwater extraction for mine stability has led to gradual land subsidence across the region.
• If groundwater extraction for mine stability control can be stopped following mine rehabilitation, land surface rebound is expected. The magnitude of the rebound is expected to be less than the subsidence that has occurred and it is anticipated that this rebound would occur gradually over many decades and relatively evenly across the region. This is an area that requires further consideration as part of rehabilitation planning.

4. MANAGING FIRE RISK
The study found that:
• Coal fire risk is best managed by covering exposed coal.
• If water is provided for ground stability control it would cover large areas of exposed coal. As such, active controls on fire risks would be significantly reduced for the final rehabilitated landform if the water levels required to passively control ground movement are achieved.
• Coal coverage above the water line can be achieved by providing a suitable soil-vegetation cover system that is resistant to erosion\(^2\). Where vegetated soil or other materials are used to cover coal, a long-term cover maintenance plan is recommended.
• Extended fill times arising from limited water availability present greater stability challenges and fire risks (due to the extended period of exposed coal) that would need to be managed compared to a shorter fill time.

5. AREAS FOR CONSIDERATION IN REHABILITATION PLANNING
The study highlights that water, if available in sufficient quantity, can provide an effective resource to support the long-term rehabilitation of the mine voids that reduces the need for ongoing active management of ground movement and fire risk.

The study also shows that there are issues that remain unresolved at the present time that will require consideration. Areas that require further consideration as part of rehabilitation planning by the mine operators include:
• Batter specific stability analysis, design, management measures and monitoring.
• Designs for surface water drainage and groundwater pressure management during the fill period and, if required, for ongoing stability of elevated land areas adjacent to the mine.
• Ground movement risk management due to possible future water level changes in the rehabilitated mines arising from water supply shortages.

\(^2\) As no soil cover system will be completely resistant to erosion a long-term cover maintenance plan is likely to be required.
ACHIEVING A SAFE AND STABLE LANDFORM FOR THE LONG TERM

1. GROUND MOVEMENT OVERVIEW

Ground movements have been a feature of mining in the Latrobe Valley since the first mine was opened. These movements can be attributed to the nature of the rocks that make up the geological structure of the Latrobe Valley, the significant volumes of coal and sediments extracted through mining, and the nature of the surface and subsurface water bodies and the hydraulic pressures that they exert on the rocks. Ground movement occurs when stresses are redistributed within the ground as a result of mining.

Observations over many years have provided a good understanding of the type and extent of ground movement impacts related to mining. This knowledge is the basis for mine stability management practices which include analysis of movement mechanisms, mine design, water control methods and review of outcomes against expected conditions. This same knowledge also provides the basis for the assessment of potential outcomes from mine rehabilitation.

The mining induced ground movements of significance to rehabilitation are identified to be:

1. Block sliding
2. Sinkhole formation
3. Floor heave
4. Subsidence

Each of these movement types can occur separately or together depending on the conditions prevailing in the mine. While block sliding typically results in rapid movements after onset, sinkhole formation, floor heave and subsidence are all longer time processes that occur over weeks to decades.

Seismic events are also considered by the mine operators as possible initiators of ground movement.

These movements and their controls and significance for rehabilitation are examined in the remainder of this section.
2. BLOCK SLIDING

Operating mines

The principal risk to batter stability within Latrobe Valley’s coal mine voids is elevated groundwater pressures behind the coal face, which can act as a destabilising force – ‘pushing’ large coal blocks toward the void. This is known as ‘block sliding’, as the coal blocks tend to slide along geological layers of lower shear strength (Figure 1).

In order to reduce groundwater pressures within the coal and thus minimise the risk of block sliding, the Latrobe Valley coal mine operators maintain a network of horizontal drains (installed by boring horizontally into the coal from within the mine) and surface water diversions. The horizontal drains and surface water diversions are supported by extensive monitoring networks at each mine to ensure that groundwater pressures and coal movements are within expected bounds. The monitoring networks are maintained by the mine operators, who also undertake the collection and analysis of the monitoring data. These various controls on batter stability, within the mine voids, involves significant labour, specialist knowledge and financial costs on an ongoing basis.

Despite significant operational controls on batter stability, there have been a number of large-scale batter movements over the history of mining in the Latrobe Valley, including:

- 2007 – block sliding resulting in batter failure which allowed the Latrobe River to divert into Yallourn mine (Figure 2)
- 2011 – closure of the Princes Freeway south of Morwell for seven months, due to pavement cracking as a result of block sliding of northern batters at Hazelwood mine

It is evident that the best engineering and regulation practices cannot account for all environmental conditions (e.g. extreme weather and localised ground conditions) and are highly dependent on available finances, labour, and specialist technical knowledge. It will be necessary to transition to more passive and sustainable controls on ground movement as mines close and resulting voids are transitioned to a different landform.

Mine rehabilitation

The Regional Geotechnical Study found that filling the mines with water can stabilise batters by increasing lateral pressure on the face of the batters. Put another way, groundwater pressure behind the coal faces is less critical if there is sufficient counter pressure from water within the mine voids (i.e. the hydraulic gradient across the coal face is minimised). This approach would significantly reduce the current need to actively control batter movement through groundwater drainage and surface water management.

Extended fill periods or not filling to a level that provides the required counterweight for lateral pressures presents stability challenges, both during the fill period and for the final landform design. This may necessitate significant changes to the mine batters (e.g. major earth moving to create buttresses) and long-term active management of ground and water movements.

Ongoing maintenance and drainage would be needed in elevated areas of coal batters above water level, if water is used as the rehabilitation solution, as build-up of groundwater pressure in such batters may increase the probability of adverse ground movement. If mine voids were partly filled with water, a greater batter height would remain above lake level, requiring more extensive ongoing batter drainage and maintenance.

Management of surface waters and coal cover materials to minimise the risk of seepage inflows, in addition to control of coal groundwater pressures through drainage boreholes, may be required to maintain low ground movement risks.

Controls will be required during the filling period, and potentially on an ongoing basis, for any batters above the final designed water level.

Areas outside of the pit requiring ongoing management of surface water and/or planning zone controls would be reduced compared to current requirements if water levels are at or above the minimum required to achieve counterweight to future vertical and horizontal groundwater pressures.

The study did not examine future water level changes in the rehabilitated mines arising from either planned or climate-induced changes in water supply. Since ground movements could occur under dynamic water level changes, this is an area that requires further consideration as part of rehabilitation planning and implementation, including:

- Areas for further consideration in rehabilitation planning
- Areas that require further consideration as part of rehabilitation planning by the mine operators including:
  - Batter-specific stability analysis, design and monitoring.
  - Designs for surface water drainage and groundwater pressure management during the fill period and, if required, for ongoing stability of elevated land areas relative to the final designed water level adjacent to the mine.
  - Management of ground movement risks due to possible future water level changes in the rehabilitated mines arising from water supply shortages.
  - Justification for the use of water in mine rehabilitation basins.
Figure 1: Simplified cross-section showing ‘block sliding’ mechanism.

Figure 2: A major batter failure led to the Latrobe River diverting into the Yallourn mine for six days in 2007. (Source: Hazelwood Mine Fire Inquiry 2015/16 Report Volume IV - Mine Rehabilitation.)
3. SINKHOLE FORMATION

Operating mines
Sinkholes (Figure 3) have the potential to form as a result of ‘piping erosion’ mechanisms when either:

- Surface water flows are concentrated into open tension cracks or joints in the coal, initiating a sub-surface erosion process. Such an erosion process may develop into a void large enough to create a collapse in the overlying ground surface; or
- Surface water flows are concentrated into the ground close to the crest of a mine batter, and flow down through the coal to exit through the face of the batter. Internal erosion can then occur within coal tension cracks and joints, which can lead to piping tunnels and the collapse of the overlying ground surface, forming sinkholes.

The potential for sink holes to form is highly dependent on local geological and hydrological conditions, in both mining and non-mining environments. Areas where significant movement has already occurred and/or block sliding, which may have opened tension cracks or joints in the coal, will present a greater potential for sink hole formation.

Sinkhole formation is likely to be an ongoing feature of the areas adjacent to the mines and monitoring and maintenance of sinkholes, as they occur, will be an ongoing feature of mine land management going forward.

Mine rehabilitation
Filling the mines with water, if water is available in the volumes required, can significantly reduce the potential for sink holes and piping erosion by:

- stabilising batters and therefore minimising the potential for ongoing opening of tension cracks or joints in coal; and
- minimising groundwater gradients around the voids and therefore the potential for concentrated flows of water through the ground.

Sinkholes have also been identified and repaired along forest drains adjacent to Latrobe Road, beyond the Yallourn mine lease boundary, with minor ongoing sinkholes evident in November 2018.

Figure 3. Schematic representation of sinkhole formation
4. FLOOR HEAVE

Operating mines
Floor stability in the Latrobe Valley coal mines is maintained by pumping significant quantities (around 30 GL/year across all three mines) of groundwater from the confined aquifers below each mine (this process is also termed ‘aquifer depressurisation’). This reduces the groundwater pressure in the confined aquifers, to less than the downward weight of the remaining coal and sediments overlying the aquifer below the mine floor, a process referred to as maintaining weight balance (Figure 4). ‘Floor heave’ can occur if the upward pressure from confined aquifers exceeds the weight of coal and sediments above the aquifer at any point across the mine floor.

Heave is a problem for mining as it affects the stability of the mine machinery. It also can effectively reduce the lateral resisting forces acting at the toe of mine batters and promote batter movements and possible block sliding.

Mine rehabilitation
The Regional Geotechnical Study found that filling the mines with water could be used to counterweight upward pressures from aquifers below each mine, thereby preventing instability caused by ‘floor heave’ and eliminating the current need to pump groundwater from the aquifers to maintain stability once mines are rehabilitated.

When all groundwater pumping for aquifer depressurisation stops at all three mines the groundwater pressures will return over time to much higher pressures beneath the mines. It is not expected that the groundwater pressures will return to the levels that they were prior to mining commencing as other groundwater users will continue to operate.

Maintaining weight balance for mine rehabilitation is based on the idea that the in-pit water body level should be established to provide a positive counter weight to the maximum future groundwater pressures that can arise below the mine in the different aquifers.

While the water level in the pit is being raised during the rehabilitation phase, groundwater pressures will need to be maintained below the effective weight of water and rock above the aquifer top. For this reason, it is expected that groundwater pumping will occur throughout the whole period of rehabilitation at each mine.

Figure 4: Simplified cross-section showing ‘floor heave’ mechanism (Source: Hazelwood Mine Fire Inquiry Report 2015/16 Volume IV – Mine Rehabilitation).
5. SUBSIDENCE AND REBOUND

Operating mines

Floor stability in the Latrobe Valley coal mines is maintained by depressurising the aquifers below each mine, as previously noted in Section 4. As the aquifers being depressurised underly the Latrobe Valley region, the effects of depressurisation extend across the region resulting in land level subsidence, centred around the mines and reducing radially (Figure 5). Changes in land level have been observed and well documented on a regional scale in the Latrobe Valley since the 1950s. The Latrobe Valley Regional Groundwater Management Committee oversees monitoring and reporting of regional subsidence, and projection of potential future subsidence. The results from this program indicate that:

- subsidence of up to 2.6 metres (total, from the 1950s to date) has been observed near the mines and while most subsidence (an estimated 80%) is interpreted as having already occurred, it is continuing due to ongoing groundwater depressurisation. Recent observations in the Morwell township indicate ongoing subsidence rates at approximately 10 millimetres per year.

- subsidence in the Latrobe Valley from the 1950s to date has been generally gradual (both spatially and temporally), with no known significant impacts to the built or natural environment.

Mine rehabilitation

Subsidence will continue as long as the current rates of groundwater pumping are required to maintain stability of the mines. Groundwater pumping for mine stability could be eliminated following rehabilitation, if the mines are filled with water (Section 4), thereby halting regional subsidence.

When all groundwater pumping for aquifer depressurisation stops at the three mines groundwater pressures will return over time to much higher pressures beneath the mines, although it is not expected that the groundwater pressures will return to the levels that they were prior to mining commencing (Section 4).

The study found that:

- Following rehabilitation regional land level subsidence will reverse (rebound) to some extent in response to aquifer repressurisation.

- As with subsidence, rebound is expected to occur gradually and relatively evenly across the region over many decades.

- Preliminary estimates of the extent of rebound range from 25% to 50% of the observed subsidence. Rebound is not anticipated to have any significant impacts on the region’s built or natural environment, given the timescales involved and relatively even distribution of ground response. This will need to be confirmed through further studies as part of detailed rehabilitation planning, and any associated monitoring and management requirements identified.
Figure 5: Subsidence to 2015 (contour values in millimetres)
1. MANAGING FIRE RISK

Operating mines

The Hazelwood Mine Fire Inquiry Report 2015/16 Volume IV notes that “at present, each mine operator manages fire risk through a combination of mine design, training, on-hand expertise, equipment, vegetation management and monitoring. Since the introduction of mining licence condition 1A in January 2015, each mine operator has prepared a Risk Assessment and Management Plan, which includes a focus on fire risks and controls”\(^3\).

The Board of Inquiry also noted that “as the 2014 Hazelwood mine fire demonstrated, uncovered coal represents a serious fire risk”\(^4\).

The Hazelwood Mine Fire (Figure 6) is the latest in a number of major fires at Latrobe Valley coal mines over the course of their history. Observations over many years have provided a good understanding of the type and extent of fire risks related to mining. This knowledge is the basis for mine fire management practices which include design and placement of fire suppression systems and emergency response. This, together with lessons learnt from past fire events, provides the basis for assessment of potential fire outcomes from mine rehabilitation.

Mine rehabilitation

The study found that:

- Coal fire risk is best managed by covering exposed coal.
- If water is provided for ground stability control it would also assist in fire management by covering large areas of exposed coal.
- Active controls on fire risks could be significantly reduced for the final rehabilitated landform, compared to management of the existing mines, if the water levels required to passively control ground movement are achieved.
- Coal coverage above the water line could be achieved by providing a suitable soil-vegetation cover system that is resistant to erosion. As no soil cover system will be completely resistant to erosion a long-term cover maintenance plan is likely to be required.
- Extended fill times arising from limited water availability present greater stability challenges and fire risks (due to the extended period of exposed coal) that would need to be managed compared to a shorter fill time.
- If final water levels vary, a zone of exposed coal may occur between the water level and the soil-vegetation cover. Assessment will be needed of the fire risks arising from the exposed coal and a suitable fire risk management plan developed.
- Climate projections for the region include potentially longer periods of dry weather and more extreme weather events, which could present additional challenges to managing fire risks across the region in the long-term. This must be considered in the planning and design of controls for fire risk for the rehabilitated mines.
- Rehabilitation of the mines should include an objective that the final landform presents no greater fire risk to the community than the surrounding environment.

The study did not examine:

- The feasibility of different options for covering coal above the water line; this is an area that requires further consideration as part of rehabilitation planning.
- The risk of spontaneous combustion of the coal under future vegetated soil covers; this is also an area that requires further consideration as part of rehabilitation planning.

\(^3\) Hazelwood Mine Fire Inquiry Report 2015/16 Volume IV – Mine Rehabilitation, p. 87
2. LAKE LOADING

‘Lake loading’ refers to the weight and lateral pressure of water added to the post-mining pit floor and batters – producing vertical and horizontal movement in response.

The study utilised industry-standard analysis methods to provide a preliminary indication of the potential extent of such movements, using parameters representative of the region while not being specific to any one mine site.

The preliminary analysis indicates that:

- During lake filling, there is potential for horizontal movements due to the weight of water acting on the mine batters. The magnitude of the movement will depend on the material properties, groundwater pressures and batter geometry and may not be exhibited by all batters.
- The maximum potential horizontal and vertical movement away from the mine due to lake loading of the batters is anticipated to be close to the mine crest, reducing with distance away from the mine.
- Based on the simplified model used, the maximum vertical and horizontal movements are calculated to be less than 20 centimetres within 300 metres of the pit crest, reducing to small movements (and within tolerable thresholds for infrastructure) at 1 kilometre from the crest. Different model assumptions would have produced different results, but these figures give an indicative scale of the response.
- The response time of these effects closely follows the establishment of a particular lake level, such that lake-induced movement can be considered a short-term effect.
- Ground movements, due to ‘lake loading’ are not expected to be a problem and are expected to be limited to the areas already subject to mining-induced ground movements. Lake loading movements will need to be monitored to ensure that any adverse impacts that might arise to existing and future infrastructure are addressed as part of the mine rehabilitation process.

While the preliminary analysis provides an indication of the potential extent of ground movements due to lake loading, actual ground movement responses will vary depending on site-specific conditions such as batter geometry, geology, groundwater conditions and coal jointing.

Mine specific responses will need to be modelled as part of the detailed rehabilitation planning for each mine, the results factored into design, and the actual response monitored during rehabilitation and post-closure, to ensure that any potential for adverse impacts to existing and future infrastructure is addressed as part of the mine rehabilitation process.

3. SEISMICITY

Operating mines

The Australian Standard 1170.4-2007 Structural design actions Part 4: Earthquake actions in Australia, sets out procedures for determining earthquake actions and associated design requirements for structures. More recently, Geoscience Australia produced a National Seismic Hazard Map of Australia. These references are used by the Latrobe Valley coal mine operators to inform the design of batters.

Mine rehabilitation

The design of final batters and slopes, as part of the rehabilitation of the Latrobe Valley coal mines, will need to comply with relevant Australian Standards and guidelines on earthquake actions.

The study considered the possibility of risks arising from seismicity induced by filling a mine with water and ceasing groundwater pumping but did not establish the likelihood of either increased seismic frequency or magnitude. A qualitative assessment suggests that a possible increase in frequency could occur but that an increase in seismic magnitude is not likely. Further work is required to improve this assessment given the particular nature of the hydrogeological setting of the Latrobe Valley and the changes in deep geological stresses that have occurred due to mining to date.
NEXT STEPS

The geotechnical, water and land use planning studies, carried out by technical specialists from 2017 to 2019, considered the regional benefits and risks associated with stabilising the mine pits (or voids) by creating full or partly full pit lakes. The studies will inform the Victorian Government’s preparation of the Latrobe Valley Regional Rehabilitation Strategy.

The Strategy will provide information on the:

- regional risks that need to be considered and addressed in rehabilitation plans;
- feasibility of supplying water for rehabilitation if required; and
- possible future land uses for the rehabilitated sites in a regional context.

The Strategy will identify the risks to the natural and built environment that mine operators are required by legislation to address in their rehabilitation plans.

The final Strategy is due to be prepared by 30 June 2020.