Mine Closure 2026 – AB Fourie, G Boggs, J Heyes & M Tibbett (eds)

doi:10.36487/ACG_repo/2615_15

Integrating catchment, waterway and environmental risk to support a pit lake closure strategy

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Abstract

The rehabilitation of large open cut coal mines presents complex, interdependent challenges where void filling strategy, water resource management, environmental protection and long-term landform stability must be assessed together and reconciled with adjacent mine closure proposals. The Hazelwood Rehabilitation Project in Victoria provides a nationally significant case study demonstrating how complex closure elements and large volumes of technical assessment can be integrated into a coherent risk narrative that supports pit lake filling strategy, regulatory decision-making and management commitments under contemporary environmental and water governance frameworks.

The project involves the transformation of the former Hazelwood mine void into a pit lake, supported by extensive earthworks, decommissioning of legacy infrastructure, and restoration of altered waterways. As part of the EES process, the catchments, rivers and wetlands assessment was used to separate existing approval settings from project elements requiring approval, align modelling platforms, base cases and project descriptions across technical disciplines, and trace project impact pathways through risks, impacts, mitigation measures and residual commitments.

Integrated modelling and risk assessment demonstrated that the alternative scenarios can be delivered with limited and manageable impacts on downstream rivers, wetlands and the Gippsland Lakes system. Faster filling reduced the duration of altered flow conditions and therefore some ecological exposure, while connected configurations offered potential benefits for fill time and flood behaviour but introduced additional regulatory, operational and contingency requirements.

This paper highlights practical lessons for mine closure planning where the central challenge is integrating extensive technical assessments into a defensible chain of reasoning from assumptions to consequences to commitments. The key lessons are that approval questions need to be separated from optimisation choices, technical disciplines need a common assessment platform, and impact pathways need to be carried through consistently from project activity to residual risk and management commitment.

Keywords: *lessons, mine closure planning, water resource management, waterways, wetlands*

1 Introduction

The Hazelwood Rehabilitation Project (the Project) involves final rehabilitation of the former Hazelwood Mine and Power Station, in the Latrobe Valley Victoria, Australia, to achieve a safe, stable, sustainable and non-polluting landform capable of supporting productive future land uses, with the proposed mine void end-state being a pit lake (ENGIE Hazelwood 2023).

The Hazelwood open cut coal mine was commissioned in 1964 by the State Electricity Commission of Victoria, to support the accompanying Hazelwood Power Station. The power station and mine were sold by the state government in 1996. The Hazelwood Power Station and mine ceased production in 2017.

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The Project has been proposed by the owners of the site, ENGIE Hazelwood, and is being assessed through an Environmental Effects Statement (EES) process under Victoria's Environment Effects Act 1978 (Victoria Governement 1978). The Project is also being assessed by the Australian Government as a controlled action under the Environment Protection and Biodiversity Conservation (EPBC) Act 1999 (Australian Government 1999), including the 2013 amendment to the EPBC Act referred to as 'The Water Trigger'. The 2013 Water Trigger amendment to the EPBC Act 1999 was established to include water resources as a matter of national environmental significance when affected by coal mining or coal seam gas extraction. The EES process serves as the accredited assessment and approvals process under a bilateral agreement between the Victorian and Australian governments.

This paper focuses on the catchment, waterway and wetland (CRaW) assessment for the Project EES. The CRaW assessment identified and documented the risks of the Project on regional waterways and wetlands and related environmental values. The CRaW assessment identified potential project impacts, mitigation measures and residual impacts. The paper has not sought to detail the assessment methods adopted for the CRaW assessment nor detail the identified risks, impacts and mitigation measures. These can be found in relevant EES and related documentation if and as published. This paper has sought to draw on the site context and project description, the challenges presented by the Project and its context, and the broad approach adopted by the authors for the CRaW assessment, to identify and discuss three linked lessons. The first lesson is the importance of separating preference choices, that lie within existing approval frameworks, from project elements that require EES approval. The second is the need to align technical disciplines through common project descriptions, baselines, assumptions and modelling platforms. The third is the need to identify impact pathways and to track those pathways through the assessment method, including the identification of project elements, environmental values at risk, impacts, mitigation measures and residual risks.

2 The Hazelwood Rehabilitation Project

The Hazelwood site is located within the Latrobe City local government area, directly south of the Morwell township and north-west of Churchill, in the Latrobe Valley. The site has an area of approximately 4,000 ha, of which approximately 3,258 ha is covered by an existing mining licence. The project area for the purposes of the EES largely consists of land within the existing mine licence, the Hazelwood Cooling Pond, the Morwell River Diversion at Hazelwood, and immediately adjoining land owned by ENGIE Hazelwood.

The main project components and activities to be completed in the active rehabilitation phase are filling the mine void to RL +45 m AHD, earthworks to rehabilitate, stabilise and reshape landforms, diversion of the Morwell Main Drain into the mine void (and pit lake), decommissioning, draining and rehabilitation of the Hazelwood Cooling Pond (and the associated restoration of the natural alignment of Eel Hole Creek), decommissioning of remaining redundant infrastructure, and construction and operation of infrastructure necessary to maintain lake level and water quality, including potential Morwell River interconnection in a connected lake scenario (see Figure 1).

A core project activity is filling the mine void. The mine void is approximately 6 km long, 3.5 km wide and up to 135 m deep (ENGIE Hazelwood 2023). It is proposed that the mine void be filled to achieve a lake level of +45 m AHD. This pit lake water surface elevation is approximately equal to the adjoining Morwell River floodplain elevation and is required to achieve weight balance in the pit lake, preventing floor heave, essential to the establishment of a safe, stable final landform. At this elevation the pit lake will contain approximately 637 GL of water. However, water is currently being retained in the mine void following existing works and approvals, and it is anticipated that at the commencement of the Project, post the EES process, the mine void could contain up to approximately 170 GL of water.

A target mine filling period of between 10 and 15 years is anticipated, although this could be significantly longer if drought was to occur, or accelerated if conditions permit and additional commercial volumes of water can be sourced.

The proposed pit lake represents not only a landform stabilisation measure but also the creation of a long-term aquatic ecosystem with hydrologic, hydraulic and geochemical evolution continuing over many decades, consistent with observations from pit lakes internationally (Gammons et al. 2009; Schultze et al. 2024; Moser et al. 2025). This evolution not only impacts on the pit lake and its beneficial uses, but the wider regional receiving environment for the connected pit lake arrangements (Scenarios 1 and 3).

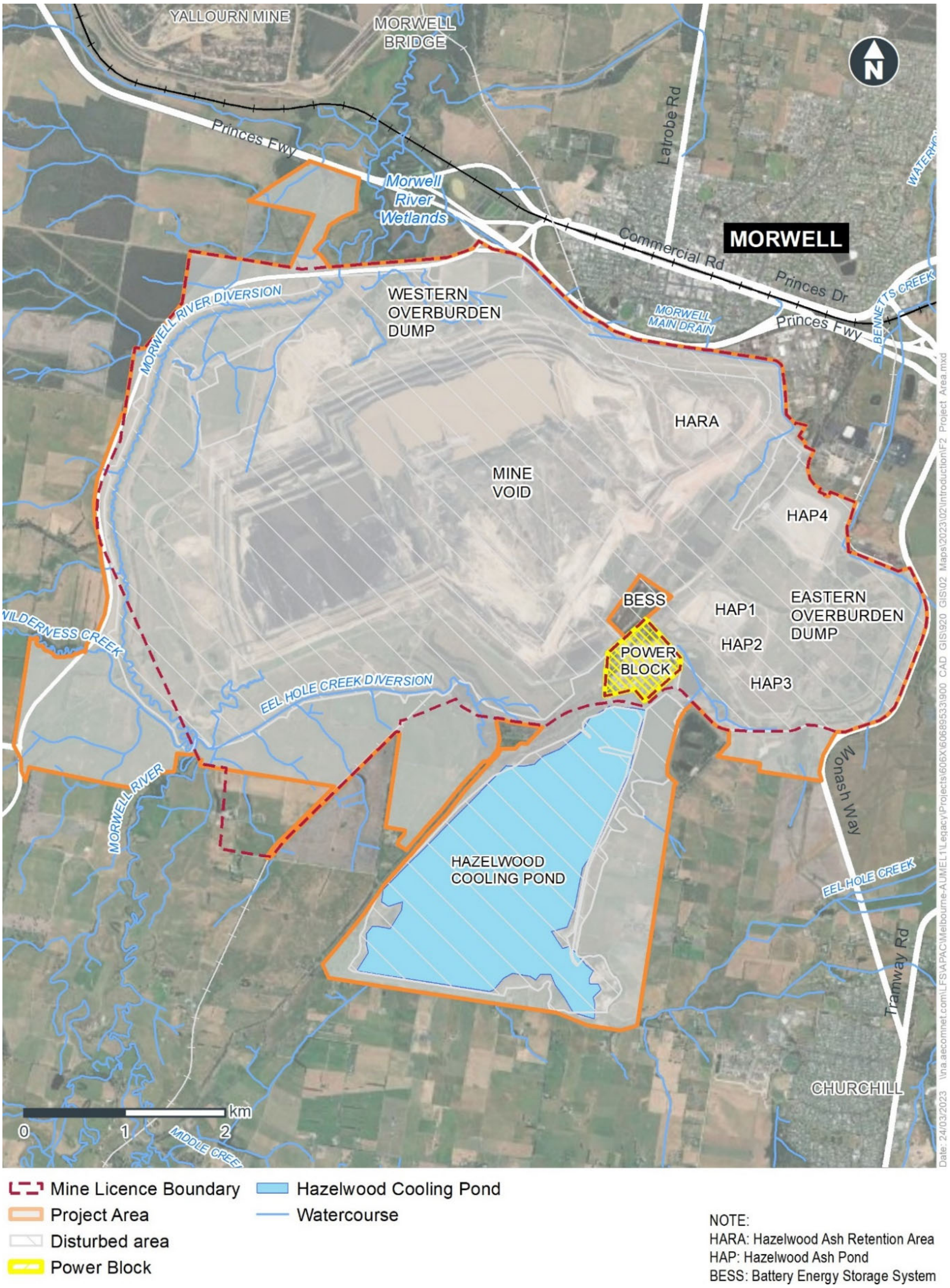

Figure 1 Locality map of the Hazelwood site and its proximity to the Morwell township

The EES and CRaW assessment contemplate a single Project Baseline and three alternate water management arrangements (scenarios) for the Project. The Project Baseline contemplates continued use of commercial water supplied to the site from Moondarra Reservoir under a commercial agreement with Gippsland Water. Water is used at the site to, among other purposes, meet regulatory requirements for dust suppression and fire management. The Project Baseline maintains the current surface water hydrologic separation between the Morwell River and the mine void (and pit lake). The three alternate water management arrangements comprise:

- Scenario 1: a slow fill connected arrangement. This scenario uses the same annual volume of commercial water as that historically supplied to the site for power production and currently supplied to the site to meet regulatory requirements (dust suppression and fire mitigation). The scenario also includes a physical, surface water hydrologic connection to the Morwell River enabling overbank flood flow from the Morwell River into the proposed pit lake and discharges from the pit lake back to the Morwell River.
- Scenario 2: a fast fill unconnected arrangement. During the fill phase this scenario uses a 50% increase in the commercial water currently supplied to the site. However, this option does not include a physical surface water hydrologic connection between the Morwell River and the proposed pit lake.
- Scenario 3: a fast fill connected arrangement. This scenario has an equivalent commercial water supply as Scenario 2 but with a physical connection to the Morwell River as per Scenario 1.

The Project Baseline and the three project scenarios are summarised in Table 1.

A post-fill pit lake water level top up arrangement will be required to offset evaporative losses. A pit lake top up protocol was adopted for each scenario, with top up triggered if lake levels drop below RL 44.5 m AHD, using commercial surface water supply where available, otherwise pumped groundwater.

Table 1 Summary of the Project Baseline and project void filling scenarios

Scenario	Fill phase surface water demand (Moondarra)	Filling phase summary	Post-filling summary
Project Baseline	20 GL/y	Current surface water use for dust/fire and operations continues; water retained in the void (no return flows)	Evaporative losses from full pit lake replaced by Moondarra supply
Scenario 1: slow fill, connected	20 GL/y	Fill from Moondarra at current rate plus partial diversion of Morwell River flood flows (above 2,400 ML/d)	Top up from Morwell flood flows plus Moondarra, subject to protocol
Scenario 2: fast fill, unconnected	30 GL/y	Fill from Moondarra at higher rate than current	Top up from Moondarra
Scenario 3: fast fill, connected	30 GL/y	Fill from Moondarra at higher rate plus partial diversion of Morwell River flood flows	Top up from Morwell flood flows plus Moondarra, subject to protocol

3 International pit lake experience

A pit lake forms a core component of the Project, but not the only project component. Pit lakes have become a common rehabilitation outcome for large open cut mines globally, with successful closure dependent on long-term hydrological stability, acceptable water quality and achievement of agreed post-mining land uses (McCullough & Lund 2006; Simmons et al. 2008; Castendyk & Eary 2009).

International experience with pit lake closure demonstrates that pit lakes are complex, evolving systems that require integrated assessment across hydrology, hydrogeology, geochemistry and ecology, and that long-term performance is often governed by processes that operate over decadal timescales (Castendyk & Eary 2009; Sakellari et al. 2021).

A consistent finding across global case studies is the central importance of water balance and hydraulic setting in determining long-term pit lake behaviour (Gammons et al. 2009; Moser et al. 2025).

The evolution of pit lake water quality is widely recognised as one of the most critical and uncertain aspects of closure. Water quality is controlled by a combination of inflow chemistry, geochemical reactions in exposed pit walls and waste materials, and internal lake processes such as stratification, mixing and biogeochemical cycling (Castendyk & Eary 2009; Herrell et al. 2022). The Project pit lake water quality assessment, undertaken by other members of the Project EES multi-disciplinary team, was important to the understanding of impacts on regional waterways and wetlands for the connected pit lake scenarios (Scenarios 1 and 3) investigated as part of the CRaW assessment.

Experience from the German lignite mining regions (e.g. Lausitz) provides one of the most extensive examples of large-scale pit lake rehabilitation (Zschiedrich et al. 2016; Weber et al. 2025).

At a broader level, international good practice guidance frames pit lakes within integrated mine closure planning, where environmental, social and economic considerations are incorporated from the earliest stages of mine planning and revisited throughout the life of the asset (ICMM 2025).

Recent reviews also highlight the importance of defining what constitutes successful pit lake closure, noting that traditional criteria of safety, stability and non-pollution are necessary but not sufficient (Blanchette & Lund 2016; Lund & Bernasconi 2024).

4 The challenge for the Project regional catchments, rivers and wetlands assessment

With the complexity of the Project and the approvals context and the complexities highlighted by the international experience came significant challenges for the CRaW assessment. These challenges included but were not limited to:

- defining a Project Baseline against which the Project scenarios would be assessed
- separating the project approvals from other water use decisions
- identifying, documenting, assessing and managing multiple inter-related impact pathways
- defining and agreeing on project descriptions, baselines, assumptions and modelling platforms.

4.1 Defining the Project Baseline

The CRaW assessment required the development and adoption of an agreed Project Baseline against which the Project could be assessed.

In a mine closure planning context, baseline conditions typically reflect conditions prior to mining. As the CRaW assessment informs an EES approvals process, a defined Project specific ‘without project’ baseline was required. For the CRaW assessment the adopted Project Baseline reflects the processes and conditions that would exist in the absence of the Project. However, the Project Baseline needed to be based not only existing conditions and processes but, on existing approved water uses and regulatory requirements. For the Project EES assessment, the pre mining condition provides site context and aids in the understanding of processes at work but is otherwise not relevant to the Project approval.

The existing approvals and site conditions include the historic and recent use of approximately 20 GL per year of commercial (regulated) surface water, supplied from Moondarra Reservoir via Gippsland Water's existing bulk water entitlement. This water is supplied to site via a delivery pipeline and is currently used for dust suppression and fire management. In addition, ongoing groundwater extraction is occurring to maintain the geotechnical stability of the mine site.

Pumping equipment in the floor of the pit, previously used for dewatering the mine were decommissioned and removed as part of approved emergency works that provided for the discharge of flood water into the Hazelwood mine void (following cessation of mining) for the benefit of the adjoining downstream Yallourn open cut mine. Approvals and capacity to discharge water, that is accumulating in the Hazelwood mine void, ceased with the provision of these emergency works. In the absence of approvals and equipment for the discharge of water from the existing mine void, the surface water used at the site and groundwater extracted for stability of the site, are currently being retained, and are accumulating, in the Hazelwood mine void. In the absence of the Project, the mine void will continue to retain and accumulate water. In the absence of the Project (or an alternate approved project) a pit lake is inevitable. The ongoing accumulation of water in the mine void forms a key element of the Project Baseline.

4.2 Water use decisions and approvals

Not all the water use decisions associated with the Project require approval under the EES process. A practical challenge for the Project, the assessments, stakeholder engagement and approvals is the identification, separation and communication of those items that require approval from those that do not.

As an example, the source of regulated surface water, proposed by ENGIE Hazelwood to fill the pit lake, was the subject of a previous decision by Victoria's Minister for Water and does not require further approval. Regulated water has and continues to be made available to the site under a commercial agreement with Gippsland Water. Gippsland Water’s access to water is made possible through a bulk water entitlement issued by Victoria’s Minister for Water Resources. This source of water can meet the demand for the slow fill (20 GL/year) and the fast fill (30 GL/year) scenarios. The supply of water at these rates does not require approval through the EES process. As such the CRaW has not sought to re-litigate the assessments undertaken to inform the Ministers decision. None the less, the CRaW has explored the implications of the two alternate fill rates to identify a preferred arrangement with the least potential impact. Separating the assessments that inform preferences from those that inform regulatory planning approval, introduced challenges to the CRaW.

4.3 Impact pathways and assessment methods

The Project and the alternate arrangements assessed have multiple elements (fast and slow fill, flood connection to the Morwell River, diversion of the Morwell Main Drain, decommissioning of the Hazelwood Cooling Pond) with multiple inter-related impacts on regional water resources, waterways and wetlands and their dependent environmental values. A major challenge was the documentation of the project elements, regional waterway and wetland values and the impact pathways between the project elements and waterway and wetland values. A CRaW assessment method was required for each impact pathway.

4.4 Integration of the CRaW with other EES disciplines

For the Project EES, the CRaW project team needed to adopt project descriptions, baselines, assumptions and risk processes that were consistent with that for other EES assessment disciplines. This is neither new nor exceptional. However, EES introduced challenges in the integration of some assessments and in particular the integration of the CRaW regional water resource modelling and assessments, with regional groundwater modelling, and the local scale pit lake water balance and water quality modelling. Specific workflows were required to integrate the inputs and outputs from the various hydrologic, hydraulic and hydrogeologic modelling platforms adopted for the EES assessments across a diverse EES project team.

5 Assessment approach

The purpose of the CRaW assessment was to assess potential regional waterway and wetland impacts associated with the project and recommend mitigation measures to avoid, minimise or manage such impacts, consistent with EES scoping requirements (DTP 2023). The study integrated hydrology, hydraulics, geomorphology, ecology and water quality through impact pathways and a risk assessment framework.

The assessment was undertaken by:

1. identifying and documenting current and expected conditions consistent with the Project Baseline
2. identifying change in risk to environmental values arising from the project
3. assessing the impacts associated with increases in risk to environmental values
4. identifying mitigation measures to address risks and impacts
5. documenting residual risks and impacts

The approach to the assessment was based on the identification of project impact pathways and the development of assessment approaches applicable to each pathway. The project impact pathways and assessment methods are set out in Figure 2.

The CRaW assessment identified 98 impact pathways i.e. links between the Project components and environmental values with increased risk and potential for adverse impacts arising from those Project components. Seven separate methods were developed and adopted to model and assess those 98 impact pathways. Those assessment methods covered:

- a regional hydrologic (water balance) assessment used to identify the change in regional stream flows and impact on environmental water requirements
- a Lake Wellington Assessment to identify the impact of changed flow regimes and water quality on Lake Wellington, part of the Gippsland Lakes Ramsar site
- a pit lake discharge water quality assessment that integrated regional streamflow analysis results from Method 1 with pit lake water balance and water quality modelling outputs, and state and national water quality targets
- a Morwell River interconnection assessment that explored the hydraulic, flood, fluvial geomorphic and fish passage impacts arising from the proposed flood level connection of the Morwell River with the pit lake (Project Scenarios 1 and 3)
- a Morwell Main Drain assessment that sought to identify the benefits and impacts of diversion of the Morwell Main Drain from its current outlet into the Morwell Wetlands to the proposed pit lake
- an assessment of the impacts of the proposed decommissioning of the Hazelwood Cooling Pond
- an assessment of the potential for pit lake foreshore erosion and the proposed Project foreshore erosion control arrangements.

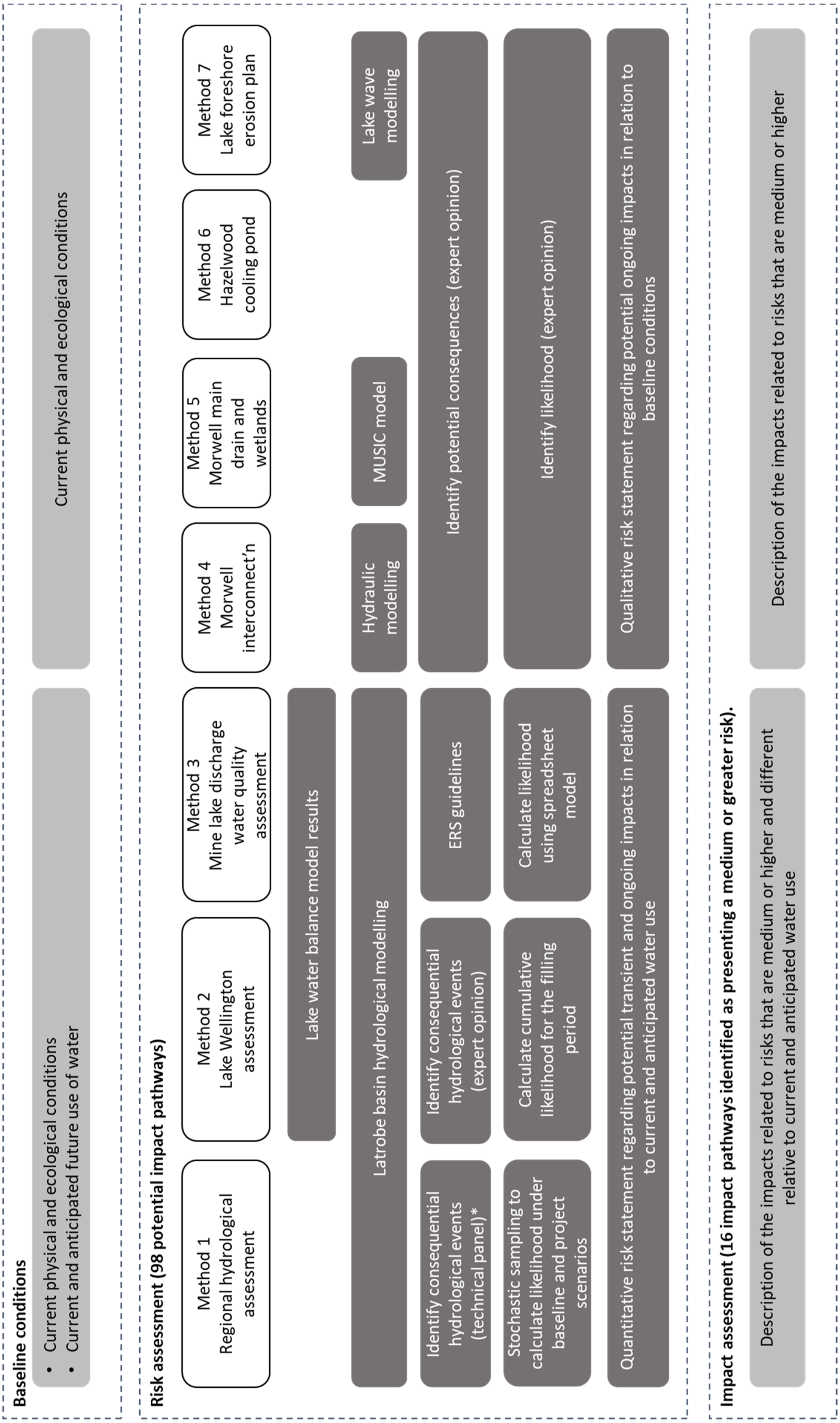

Figure 2 CRaW assessment framework linking project elements, impact pathways, risks and management measures. Source: Alluvium Consulting Pty Ltd (2026)

6 Lesson 1: separate approval questions from preference choices

The CRaW assessment sets out three surface water sources considered for assessment: Moondarra Reservoir via a commercial agreement with Gippsland Water, with water made available under Gippsland Water's Bulk Water Entitlement (all Project scenarios), Morwell River flood flows via an offtake operating above 2,400 ML/d (Project scenarios 1 and 3), and Morwell Main Drain stormwater proposed to be diverted to the pit lake (all Project scenarios).

Gippsland Water's Bulk Water Entitlement in Moondarra Reservoir was granted via a conversion order under sections 43 and 47 of the Water Act 1989 (Victorian Government 1989). The environmental impact of taking this water has been more recently assessed through the Central and Gippsland Region Sustainable Water Strategy (Victorian Government 2022) and the Latrobe Valley Regional Rehabilitation Strategy Amendment (Victorian Government 2023). No further approvals are required or sought for use of this Moondarra-sourced water.

In contrast, the diversion of Morwell River flood water lies outside the current bulk water entitlement process and does require approval. The diversion of Morwell Main Drain stormwater has not been assessed by Victoria's Minister for Water, although the diversion of stormwater may not require approval. These distinctions provide a basis for discussing the difference between exercising existing approvals and seeking approval for additional works and sources.

A separation of issues was therefore required for the assessment of impacts to values reliant on the provision of environmental water. As the regulated water source proposed for pit lake filling has already been approved, the assessment sought to identify the advantages or disadvantages of a fast fill, being a higher annual use of water over a shorter period of time, compared with a slow fill, being a lower annual water use over a longer period of time.

The comparative assessment was undertaken in the reaches impacted by such water use. It comprised a review of the accumulated probabilities of meeting environmental water requirements in reaches downstream of the pit lake over comparable periods of time. The investigation found higher likelihood of meeting environmental water requirements in downstream reaches with the fast fill arrangements when compared with the slow fill arrangements over comparable analysis periods under low and medium climate change conditions. The reverse was found under an extreme climate change scenario assessed.

Connected versus disconnected from Morwell River flood events raised a different approval question. No significant environmental issues were identified to be associated with the spill of floodwater into the pit lake in terms of downstream environmental water requirements. However, such flood water is considered to be above cap and reserved for the environment. The use of this water requires approval, and the use of this water for pit lake fill and top up has potential to reduce the demand for regulated surface water from Moondarra Reservoir.

The first transferable lesson is that the approvals boundary must be made explicit before the assessment is framed. The project should not re-prosecute impacts associated with existing approvals, but it must still compare alternate choices within existing approvals frameworks and assess project elements that require approval. For the Hazelwood Rehabilitation Project, this meant separating Moondarra supply and fill-rate optimisation from Morwell River flood water diversion, interconnection works and associated management commitments.

7 Lesson 2: build a common assessment platform across disciplines

Integration was required within disciplines and between disciplines. The project required extensive investigation of project risks across hydrogeology, geotechnics, hydrology, hydraulics, geomorphology, ecology and water quality. This necessitated consistency of project descriptions, scenarios, baseline conditions, climate change assumptions and modelling approaches. Where consistency was not appropriate or possible, a clear rationale for deviation was required.

The assessment relied on several modelling platforms, each suited to a different part of the problem. The eWater Source model was used to assess the effect of changed water use arising from pit lake filling on regional environmental flow compliance. This model is fundamentally a deterministic water balance model and is well suited to accounting for complex arrangements of water supply, water demand and operating rules within a unified modelling framework. The model was configured consistent with that set out by the Dept of Energy, Environment and Climate Action (DEECA 2020).

Pit fill time was estimated using a separate pit lake water balance model. That model used a fundamentally different approach, relying on Monte Carlo stochastic analysis to account for a wide range of possible climate sequences. It also incorporated lake evaporation, inflows predicted by the eWater Source model, assumptions regarding groundwater pumping, and local inflows from the surrounding catchment. This created one of the first important modelling interfaces: the deterministic Source modelling informed the stochastic pit lake water balance modelling, which then informed associated pit lake water quality modelling, including constituent concentrations and potential discharges under connected lake scenarios.

Other parts of the assessment required different modelling approaches again. For example, peak flow rates in Eel Hole Creek under the Project Baseline and following removal of the Hazelwood Cooling Pond were predicted using the RORB catchment runoff model. This model is suited to predicting peak discharges and flood routing, rather than daily time-step water balance outputs such as those produced by the eWater Source model. These modelling outputs then needed to be interpreted alongside higher-level assessments of changes to flow regimes and environmental values. Those assessments often relied on conceptual models, previous environmental flow studies and expert knowledge to identify impact pathways and define consequential impact criteria. This helped focus the analysis on those changes most likely to have material impacts on environmental values in the Latrobe system.

Each type of analysis had its own domain-specific conventions, modelling platform and data requirements. In many cases, the output from one model or technical assessment became an input to another. This created a two-way exchange of assumptions, intermediate calculations, model outputs and interpretation between experts. That exchange required careful tracking of input data, assumptions, climate scaling methods, intermediate processing steps and output formats, particularly where data had to move between deterministic and stochastic modelling approaches.

For example, the eWater Source model applied climate change scaling to historical reconstructions of flow series, while the pit lake water balance model projected pit lake behaviour forward in time using stochastic model runs and assumptions regarding climate and many possible flow sequences. These approaches are both valid for their specific purposes, but they create a coordination issue where results are transferred between models and interpreted by different technical teams.

International pit lake guidance consistently emphasises that integrated closure outcomes depend on the successful linkage of hydrological, hydrogeological, geochemical and ecological assessments through a common conceptual understanding of system behaviour (Castendyk & Eary 2009; ICMM 2025). While a conceptual understanding of system behaviour was developed and understood, the practical integration of model inputs and outputs while challenging, was fundamental to the assessment, requiring early resolution and agreed workflows.

The lesson is that common assessment platforms need to be developed early and maintained deliberately. This does not mean every discipline must use the same model. It means that data sources, model inputs, model outputs, assumptions, climate scaling methods and interpretation steps need to be linked clearly and transparently. This is especially important when analysis is revisited in response to regulatory feedback at a later date. This has both technical and practical implications. Technically, it reduces the risk that errors enter the assessment, or that the wrong dataset is used for the wrong interpretation. Practically, it streamlines assessment, review and data access when many experts are working on a single problem, often across different consultancies and time zones.

8 Lesson 3: trace impact pathways from project activity to residual risk

The assessment was undertaken by identifying and documenting current and expected conditions consistent with the Project Baseline, identifying change in risk to environmental values arising from the Project, assessing the impacts associated with increases in risk to environmental values, identifying mitigation measures to address risks and impacts, and documenting residual risks and impacts.

The approach to the assessment was based on the identification of project impact pathways and the development of assessment approaches applicable to each pathway. This was important because the CRaW assessed a large number of project elements, including regional-scale water use impacts, Lake Wellington hydrology and water quality, interconnection impacts, diversion of Morwell Main Drain flows, decommissioning of the Hazelwood Cooling Pond and pit lake foreshore erosion.

The connected pit lake arrangement provides a useful example. Discharges from the proposed pit lake are only contemplated for the connected pit lake options in a post-fill environment. The connected pit lake arrangement has the potential for periodic discharges from the pit lake to affect water quality in the Morwell River and downstream waterways. Risks were assessed for 35 water quality indicators. Thus, the water quality impact pathway is one subset of the broader potential impacts that only applies to a specific scenario for a specific phase. A significant issue identified in the pit lake discharge water quality assessment was the existing high concentration and loads of insoluble copper in the Morwell River during flood events. The investigation revealed the potential for intermittent discharges from the pit lake to provide additional inputs of copper. The CRaW assessment proposes water quality monitoring and regulating gates on inlet and outlet structures to prevent release during elevated copper conditions. This pathway therefore connects a connected lake operating arrangement to water quality risk, downstream exposure, monitoring and operational control.

Morwell River interconnection provides another example. The CRaW assessment describes the connected lake scenario as diverting a portion of peak Morwell River flows to the pit lake during flood events, with inflow set at an elevation preventing diversion at flows less than 2,400 ML/d. Beyond water use and water quality pathways, the investigations identified three interconnection risk themes: flood impacts, Morwell River stability, and fish passage. The assessment described low-likelihood, high-consequence failure modes. Failure of the outflow or inflow structure could result in capture of the Morwell River and drive large-scale incision through the river with adverse consequences for water-dependent flora and fauna. The likelihood of such failure can be managed via design and ongoing monitoring. For fish passage, the CRaW assessment identifies potential for native fish to move through inflow or outflow structures and become entrapped in the pit lake, with mitigation including arrangements that prevent or limit native fish movement toward the pit lake.

Local construction and decommissioning pathways were also carried through the same logic. The CRaW assessment identifies two primary impact themes from decommissioning the Hazelwood Cooling Pond: changes in hydrology, particularly flood peaks, and erosion and stability impacts. The dedicated HCP assessment describes the concept design intent to reinstate Eel Hole Creek through the former pond area via a breach and compound channel, including grade control structures and rock ramp fishways.

The third transferable lesson is that impact pathways need to remain visible throughout the assessment. The CRaW investigation relied on the identification of project impact pathways and based on these pathways, the development of assessment methods that trace each pathway from source, through risk assessment, impact assessment, mitigation measures and residual risk and impact documentation. This approach avoided devolving into disconnected technical particulars and kept the thread from project activity to consequence and commitment.

This emphasis on explicit impact pathways is consistent with modern pit lake closure practice, which increasingly relies on adaptive management frameworks linking model predictions, monitoring outcomes, management triggers and closure criteria (Schultze et al. 2024; Weber et al. 2025).

9 Transferable applications for mine closure assessment

The CRaW assessment provides practical lessons for future investigations for proposed mine closure plans that include pit lake arrangements.

The first application is to separate approvals required for the project from choices made within existing approval frameworks. Assessments should not seek to re-prosecute and reassess impacts associated with existing approvals. They should separate alternate choices that lie within existing approvals frameworks from project elements that require approval and then apply the appropriate assessment method to each.

The second application is to establish a common assessment platform across disciplines. Integrated assessments are required within disciplines and between disciplines. This requires consistency of project descriptions, scenarios, baseline conditions, climate change assumptions and modelling approaches. Where consistency is not appropriate or possible, the assessment needs to explain the rationale for deviation.

The third application is to identify impact pathways and use them to structure the assessment. The method should trace pathways from source, through risk assessment, impact assessment, management measures and residual risk and impact documentation. This is the mechanism by which large volumes of technical assessment become defensible decisions and durable commitments under contemporary water and environmental governance frameworks. This third application lends itself toward the establishment of long-term monitoring and adaptive management programs capable of testing model predictions and informing ongoing intervention where required.

10 Conclusion

The Hazelwood Rehabilitation Project illustrates that the assessment of proposed pit lake arrangements is not only complex but requires the integration of extensive assessments into a defensible chain of reasoning from assumptions to consequences to commitments. The CRaW assessment provides a structured example of that integration by defining an agreed Project Baseline that reflects current and approved operations, and tracing scenario-specific hydrologic and water quality changes through to ecological risk pathways and mitigation measures.

The CRaW assessment headline conclusion, that proposed water use for filling and maintenance can be achieved within the current Latrobe system consumptive cap and that scenario differences are primarily about the location and duration of impacts, helps reframe the water availability debate into a distribution and exposure problem that can be tested and managed.

This paper has drawn on international experience, the local context, and examples from the CRaW assessment for the Hazelwood Rehabilitation Project into three key lessons that can be applied to similarly large and complex Environmental Effects Statements. These lessons provide a transferable framework for integrating complex technical assessments into defensible mine closure decisions and adaptive management commitments for pit lakes and other large rehabilitation projects.

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