Mine Closure 2021 – AB Fourie, M Tibbett & A Sharkuu (eds)

https://papers.acg.uwa.edu.au/p/2152_06_Tones/

Knowledge makes the work go round: Knowledge management in mine closure planning

A Tones

L Howe *Eco Logical Australia (ELA), Australia*

J du Plooy *Eco Logical Australia (ELA), Australia*

Abstract

The importance of knowledge and data management from mine inception to cessation and beyond is thought to be well documented and understood. However, significant data gaps, inconsistent or unstructured approaches to data management and conflicting operational needs continue to present challenges in mine closure and the closure plan development processes. Gaps in site knowledge, monitoring data or an environmental database which isn't integrated or connected to site operations/ design processes, have the potential to lead to increased closure related costs and ultimately ineffective closure. Knowledge gaps may also introduce delays during the tenement surrender and relinquishment process, while the tenement holder and the Regulatory agencies establish a common understanding on the level of detail required to be provided in the Closure Plan, as well as the supporting evidence demonstrating achievement of completion criteria. While each mine site has its own specific data requirements, data collected on sites commonly relate to the achievement of approval being sought or for demonstration of compliance with environmental licence conditions rather than demonstrating long term trends against closure objectives. This is applicable to all scales of mining and mine life stages.

Establishing a vision for closure and realistic closure objectives early in the life cycle of the mine and having an evidence base derived from measured data that supports the closure vision and objectives can provide long term confidence to key stakeholders such as mine owner, regulator, technical specialists and future landowner. Mine closure planning and documentation are recognised as having a higher level of effectiveness and practicality when supported by knowledge and data collected as part of an integrated site system, rather than a standalone process.

The challenge is to recognise how the existing knowledge and data base can be optimised to support closure planning and refinement (if not already developed) of closure objectives and criteria. Tried and tested methods for improvement start with evaluating a site's current knowledge and data base against closure needs. Following this, the state of the data will influence the process taken to breach any recognised gaps and in turn determine the process or approach to closure planning. Undertaking a gap analysis with respect to state rehabilitation and closure plan legislative frameworks also provides an opportunity to identify areas of development, improvement and alignment with existing site processes. Regardless of operational status, identifying gaps in the environmental knowledge and data base can lead to improvements in the approach to knowledge and data collection throughout the life of the asset, which in turn can minimise the closure financial liability and potential reputation impacts from sub optimal closure outcomes.

Keywords: *knowledge base, data management, mine closure plan, closure planning, gap analysis*

1 Introduction

Access to and use of the most relevant, recent and required knowledge is a fundamental component relevant to all stages of mine operations, from mine inception to cessation and beyond. An accurate and comprehensive knowledge and data base enables effective stewardship. It also helps to achieve, and demonstrate the achievement of, management objectives and legislative requirements. While the

importance of knowledge and data is thought to be well documented and understood, patchy, inconsistent, or significant data gaps to support closure planning remains a challenge to the successful closure of a mine. Essential elements of a mine closure plan, including but not limited to closure objectives and completion criteria, need to be developed with reference to relevant scientific data specific to the site. Often due to the variation of environmental setting, legislative and other obligations, scale and approach to mining as well as stakeholder expectations, the knowledge and data base must suit the requirements specific to each site. To ensure optimal outcomes for closure of a mining operation the evolution in knowledge about the site, should aim to be accommodated for in any data base or knowledge management system. Identifying, building and resolving gaps in the knowledge base is an ongoing and iterative process as mining, progressive rehabilitation (inclusive of research or trials) and closure activities progress.

> *"Data collection and management needs to be strategic. Attention must be given to what information is needed to plan and manage…" Worboys (2005).*

Gaps in site knowledge and data can be due to a variety of reasons, being operational changes and phase transitions (i.e., exploration, project, operational or care and maintenance), staff turnover, unstructured approaches to capturing site information and monitoring results and evolving legislative requirements. For older mines these gaps likely stem from when operational commencement predated the environmental legislative frameworks applicable today. Differing audiences and expectations can also result in data being collected and organised around the achievement of approval being sought, or for demonstration of compliance, rather than for strategic management in the long term. Regardless of the reason,

> *"…disconnects between environmental studies, approval documentation and the application of satisfactory Life of Mine (LOM) planning and control measures in project feasibility planning and resourcing. This is a fundamental flaw, one that allows development approvals to be given prior to end-to-end planning being conducted." McCullough (2018).*

Information requirements can vary from relevant baseline conditional monitoring data e.g., flora and fauna, and scientific knowledge of site resources to financial records and remediation costings; and while are able to meet immediate operational requirements, if collected without consideration towards mine closure, implications can arise.

Such implications however can pave the way for the identification of future improvements and opportunities. When considering knowledge and data management, the extent and type of data required is dependent upon what information is available and what information is necessary to demonstrate that objectives have been met (Nichol 2005). While knowledge of ecology and biology, geotechnical conditions, soil geochemistry, biochemical interactions, hydrology and technical engineering designs is all necessary information, efficient financial planning is also crucial to ensure the practicability later on (Zillig 2015). For effective closure planning, an evidence base derived from measured data can demonstrate to the regulator that the closure objectives are developed and supported by a solid knowledge base, which in turn provides confidence and increased certainty that the regulator and other key stakeholder expectations (e.g., future land owner / user) will be met and surrender of the licence and transfer to the next land holder or land user can legally take place.

Data which may be collected from an operational focus, or compliance requirement, while it may not be ultimately collected to align with closure planning requirements, can still have high value. For mines which have conducted detailed research and monitoring programs, less detailed research to close any knowledge or data gaps could be needed (Nichol 2005). In contrast, where data gaps are identified, appropriate measures such as further site-specific technical studies could be a necessity. However, prior to implementing such measures, recognising the extent of the knowledge and data base needed to bridge the gap must be determined.

2 Identifying knowledge gaps

To understand the knowledge base and data requirements needed for closure planning, an initial step is to determine the relevant commitments, legal and other obligations applicable to the site. Mining operations may not have established these requirements prior to receiving approval to commence operations. Where this is the case, these obligations and commitments may have been developed or confirmed through subsequent amendments to licence or lease documents, or through commitments made in a public manner either through media releases or stakeholder engagement forums. Locating and consolidating this information from a variety of sources is crucial to ensure a database of the requirements can be built to address the specific closure planning needs for the mine site. It is common for mining operations that commenced prior to the current legislative frameworks and guidelines for closure planning to have gaps in the knowledge base for closure. When faced with possible gaps in knowledge and data for closure planning, experience has shown that conducting a simple but targeted gap analysis against closure planning requirements (e.g., regulatory or industry guidance) is an important step. A gap analysis enables the comparison between actual performance with potential or desired performance. In respect to state rehabilitation and closure plan legislative frameworks this method can provide the opportunity to recognise where existing operational or compliance data is not directly transferrable to meet desired performance. Alternatively, a gap analysis can help identify when existing data could be used more effectively in either the closure plan or demonstrating efficacy of closure strategies. Outcomes of the gap analysis process can typically include identification of a need for new or additional:

- Monitoring requirements;
- Analysis (e.g., modelling) of existing/ new data; and/or,
- Research/ trials relating to rehabilitation or other closure activities.

Complications from such outcomes can arise in justifying the need, expenditure and regulatory requirement on why additional works may be required when at the end of operations and budgets are tight. This highlights that the sooner the gap analysis is completed and the recommendations actioned, the better.

For new mines there is an opportunity to establish and incorporate a register of closure requirements and stakeholder engagement processes to be conducted into the approval process. This enables data required for closure planning to be collected as evidence of trends towards achievement of closure objectives and linked back to the closure requirements established at project inception.

3 Building the knowledge

Once a gap analysis is undertaken, the closure requirements collated and understood, appropriate measures to build the knowledge and address data gaps can be determined and initiated. The extent and type of data to focus on will be defined by the areas where the gaps have been identified. Operational data can transition to data for the purpose of mine closure planning, especially if continuous operational data has been captured to align with completion criteria or closure objectives. For example, the parameters on which the operational data was collected, may be used to demonstrate trends over a period or even a snapshot of a specific condition at a point in time. If the latter, additional monitoring can be completed to demonstrate the continuation of this condition or improvement since the initial data had been collected. If additional monitoring is recognised as being needed, the design of this monitoring program is critical (Nichol 2005).

Monitoring programs require flexibility and should retain components of existing monitoring programs to ensure that previous monitoring data does not become obsolete (Nichol 2005). It should be noted that there is no ideal or one size fits all monitoring program. Monitoring programs need to be targeted and will vary between mines in order to provide the site-specific information required to develop and assess completion criteria (Nichol 2005). This highlights the need to consider mine closure planning on a case-by-case basis as well as for closure strategies to be founded on good empirical evidence (McCullough 2013).

Research and/or conducting trials relating to closure planning aspects provide a source of additional data and learnings to inform the process. These elements can provide a critical link between current practice and successful implementation of novel or existing techniques that have not been applied widely. In 2016, a trial was introduced across the state of Queensland by the Department of Environment and Science (DES) (then Department of Environment and Heritage Protection). DES recognised that the uptake of progressive rehabilitation certification by industry needed to be improved since the introduction of the legislation into the Environmental Protection Act 1994. As a result of discussions with key industry stakeholders, a trial originated. The aim of this trial was to ultimately improve post mine land use outcomes at mine closure and final surrender, by enabling companies to go through a simulated progressive rehabilitation certification application (referred to as a 'mock application'). This trial process provided the opportunity to identify where additional clarification and areas of improvements could be made to the (then) current DES guidance material on the progressive certification process.

The assessment process for each mock application was a collaboration between the DES and the applicants and included pre-lodgement meetings, onsite inspections, initial and overall application feedback. All mock applications received by DES were assessed against the legislative guidance at that time being the progressive rehabilitation requirements s318Z – s318ZN of the EP Act, site specific Environmental Authority (EA) conditions and the rehabilitation guideline, Rehabilitation requirements for mining resource activities (ESR/2016/1875). Rehabilitation goals of safe, stable, non-polluting, and self-sustaining were also considered.

As a result of the trial, one applicant was able to certify rehabilitated land associated with part of an overburden emplacement area, becoming the first open cut mine in the state of Queensland to receive progressive rehabilitation certification. Since then, the number of mine sites across Queensland to have acquired progressive certification has increased with the Queensland Government also going through a rehabilitation reform that introduced changes to the EP Act with the aim of improving the quality, quantity and outcomes of rehabilitation and increasing the transparency on the progressive and final rehabilitation plans of mining companies (S Cooper 2019).

Outcomes from research or trials needs to be strategically considered during development and review of closure strategies. This data can also be linked to closure planning aspects such as informing completion criteria or development of indicators or closure activity scheduling.

4 Case Studies

The following provides examples of how site knowledge and data gaps have been recognised during closure planning and what actions have been undertaken to build on the existing knowledge base to meet closure requirements and leverage opportunities in the closure planning process. Examples have been selected to illustrate the variety of approaches that can be applied to develop or enhance a knowledge base for closure planning, whilst considering factors such as the stage in the mining life cycle of the operation, legislation reform and extent of existing data applicable to the closure planning process.

4.1 Existing knowledge base review

Various coal mining sites - Qld and NSW

There are numerous underground and open cut coal mines located throughout the Hunter and Gunnedah coalfields of the Sydney-Gunnedah Basin and Bowen Basin areas. Across New South Wales and Queensland there have been legislative reforms in recent years resulting in changes in rehabilitation and closure requirements, including an increase in the level of detail needing to be addressed in the closure and rehabilitation planning sections of approval and management plan documentation. During the initial stages of the legislative reform process, many sites in those jurisdictions took proactive steps to conduct a gap analysis against draft guidelines to gain a clearer understanding of the additional information required to inform the closure plans and ensure that it could be achieved and tailored to each site's circumstances. Key reference documents needed for a gap analysis against regulatory guidelines include closure risk

assessments, existing rehabilitation management or closure plan documentation and technical studies such as final void water management plans, flood modelling or geotechnical reports. Once a gap analysis has been completed, prioritisation of actions identified to address the gaps can then be undertaken to aid with allocation of the resources required.

When reviewing the outcomes from gap analyses of various open cut and underground coal mines located in NSW and Queensland, some common closure planning elements that were prioritised highest for allocation of resources to address gaps are summarised below (**Error! Reference source not found.**).

Table 1 Summary of closure planning areas with opportunities for improvement

Closure Plan Element	Common gap
Post Mining Land Use (PMLU)	An increased level of detail explaining the process for identifying the PMLUs and what data had been used to support the justification for the proposed PMLU should be included to aid stakeholder's understanding of the options considered and the reasons for selecting the PMLUs. Ensure the PMLUs nominated between various approvals documents such as site licences, management plans and operational planning documents are consistent.
Stakeholder Engagement	Whilst stakeholder engagement was recognized by many operations as critical, a description of how results from consultation has been used to inform, develop and refine the closure plan would improve transparency around the ongoing stakeholder engagement process being applied to closure planning. This is of particular importance in relation to PMLU planning, and engagement with stakeholders who are interested in and/or affected by the PMLUs beyond tenement relinquishment.
Risk Register	A closure risk register should be maintained to align with current operational and closure planning processes for the site. Mining operations are highly dynamic businesses and often closure risk register information (e.g., risk profile, mitigation strategies) needs to be updated to incorporate changes in site plans, new information from technical reports that underpin closure or rehabilitation strategies and results from implementation of trials. This will aid proactive identification of opportunities to potentially reduce the closure risk profile.
Quality assurance/ Data validation processes	Having data as evidence to demonstrate and validate the implementation of closure designs or processes is essential for enabling tenement / licence relinquishment. To do this, outlining quality assurance and data validation methods should be included in the closure planning process. Capturing those aspects, particularly in relation to 'as-constructed' plans relating to designs and how the QA processes for closure get integrated into the operational processes is fundamental for tenement/ license holders to have assurance the closure strategies are in place and effective.
Scheduling and Milestones (relevant to QLD only)	Preparing and maintaining a schedule of future disturbance activities, as well as aligning that with planned rehabilitation and closure activities is a means to assess the effectiveness of progressive rehabilitation planning over the short, medium and long term, and will identify opportunities for efficiencies in the allocation of resources for closure activities.

4.2 Compiling a knowledge base

Coal mine site (Client Confidential)

The client operated an open cut coal under a Mining Licence (ML) where mining activities were undertaken at the site for over 65 years until activities ceased in recent times. The ML details the conditions by which the mine must operate. The environmental approvals documentation, developed in accordance with the regulatory requirements, sets out how these conditions will be met and describes the activities that are proposed to be undertaken within the ML area, including progressive and final rehabilitation works. The requirement to develop a Closure Plan was a commitment in the environmental approval documentation developed for the mine.

One of the first actions taken as part of the initial development of the Closure Plan and overall closure planning process comprised a gap analysis. This was completed following initial discussions with the client relating to the requirements for the development of the Closure Plan. General principles of mine closure planning and relevant regulatory guidance information, including from other jurisdictions, was consulted to evaluate where knowledge and data gaps needed to be addressed. Undertaking the gap analysis also helped to clarify the Closure Plan scope and overarching requirements needed for the plan to be robust. The gap analysis considered the regulatory framework elements associated with other government agencies with interests in key aspects of the Closure Plan. The gap analysis highlighted aspects where technical aspects had an advanced knowledge base and other aspects that required further detailed studies to support development of key Closure Plan elements including, but not limited to, completion criteria. The undertaking of this task presented many challenges. Such challenges stemmed from:

- Changing regulatory requirements (i.e., legal obligations) and uncertainty whether this would, or would not, be retrospectively applied to the Closure Plan for the site.
- Evolution in the expectations from both government departments and company management on the closure scenarios and planning processes of the site and on the content of the plan, as more information was progressively collected to inform the plan.
- Ensuring rehabilitation and closure commitments made publicly available by the company were all captured and carried through into the Closure Plan and overall mine closure vision.
- A need for a single report depository and knowledge on the extent of technical reports having been completed for the site and how they interacted with each other.
- A need for consistency in the version control systems for key input technical documents and management plans informing the closure plan.
- Reliance on corporate knowledge from company employees to provide technical content forming inputs on the closure plan.
- Inconsistent details between historical reports, leading to uncertainty around the correct information to rely upon for the Closure Plan.
- Incomplete environmental or baseline monitoring data (including rehabilitation, hydrology, biodiversity etc.) presenting a challenge to demonstrate trends or show how areas had progressed over multiple years through monitoring.

Considering these matters, there was no one size fits all or standardised solution in the development of the Closure Plan. However, two common themes emerged. Firstly, resources needed to be allocated to review and collate the site-specific knowledge and data to ensure it could be used effectively. Secondly, consistent processes needed to be applied to prioritise the essential data required to inform the mine closure planning, as well as keep all relevant internal and external stakeholders informed during the plan's development.

By undertaking a gap analysis and assessment into the data requirements, the client was able to recognise the key challenges present and understand how they interacted with each other. A tailored approach was

then developed to address the different types of information available and breach the knowledge and data gaps to allow for closure planning effectiveness. As a result of following this process, the client was able to achieve a successful submission of the Closure Plan and take an integral step forward in the overall closure of the mine.

4.3 Updating a knowledge base

Metalliferous mine site (Client confidential)

The client operated this metalliferous mine since it commenced in the 1980's until recently. The site is surrounded by areas of high biodiversity value, including National Park areas. Operations at the mine are governed by both Federal and State level legislation and regulations. An update to the existing Mine Closure Plan was undertaken to integrate new data arising from a closure feasibility study, comprising several technical reports, and to ensure alignment with changed tailings and water management strategies that had been approved since previous versions of the closure plan. The new information was reviewed to ensure:

- Feedback received from key stakeholders that included the state and federal government agencies, Traditional Owners and local Aboriginal Groups was addressed.
- Closure criteria were reviewed and refined to incorporate the new technical information.
- The increased knowledge of risks and mitigation strategies gained from the feasibility study and ongoing research results had been integrated to the relevant closure plan sections.

Part of the updated technical report information included the results of the operator collating research data collected in relation to rehabilitation at the mine. This data was used to update the existing knowledge base to ensure that the comments raised by the government agencies could be addressed and revegetation and implementation strategies for the final landform design could be refined.

When mining operations are further advanced in the closure planning process and approaching cessation of mining operations, the level of detail in the planning process is often greater, so focus shifts towards integration of monitoring data collected through practical experience of closure and rehabilitation strategies being implemented for informing the closure process. This illustrates the ongoing need to integrate rehabilitation knowledge and science of restoration ecology with the process of landform creation and closure (Lacy 2019).

Updating a closure plan that already contains detailed information presents some challenges. In particular, demonstrating how the new information has been used to further inform the risk assessment profile, closure strategies, completion criteria or other core closure plan elements so it is clearly understood by all stakeholders. This challenge is accentuated when the new information requiring integration into the closure plan comprises a large data set or new data that significantly differs from the information contained within the current version of the closure plan. The complexity is due to the interrelated nature of the core closure plan information elements, as reflected by a conceptual representation of the processes influencing the regular review of the closure plan documentation shown in Figure 1.

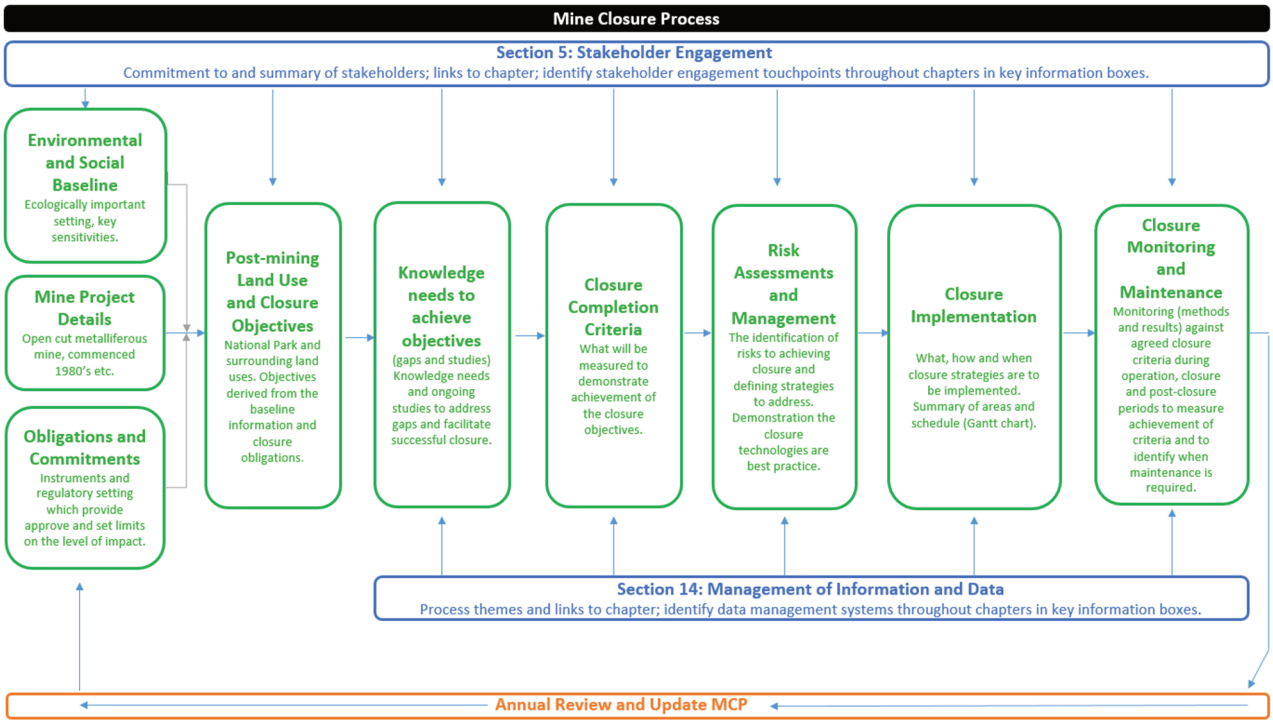

Figure 1 Example of the cyclical, inter-related nature of closure planning elements and data management

For example, if a technical study identifies through analysis of rehabilitation field monitoring data that a closure risk profile is increased, the closure strategies need to be reviewed and changed to be commensurate for the revised risk. Then, this may or may not require changes to the completion criteria to ensure all elements are consistent, depending on how interconnected those aspects are for a particular closure risk item. Articulating those types of changes and the reasons behind them to stakeholders often requires a strategic approach that integrates consultation with the closure plan update process. When it comes to integrating large data sets or data sets that span years of collection into existing closure plan documentation, different approaches should be considered. One approach to consider is developing a way to track the gaps identified, work required to address the gaps, documents containing the required additional information and how the new information has been subsequently incorporated into the updated closure plan. If this process is to apply to specialised technical reports, such as when a concept design has been further refined to a detailed design, having the Subject Matter Expert (SME) provide input on how the new information aligns with the existing closure planning elements is key to resolving knowledge gaps. A summary of the approach adopted to integrate the additional information should be included in a closure plan, so stakeholders are able to follow the evolution of the process.

5 Resolving knowledge gaps

The approach to resolving knowledge and data gaps can differ with the size of the mining operation, commodity, site-specific legislative requirements and should be tailored to meet the mine's site-specific conditions. The approach also needs to consider the point at which the operation is in its life cycle, as well as the maturity of its closure planning process. Determining actions and the priority of these actions to address identified knowledge gaps may be influenced by how critical the data is to regulatory alignment, lead times for data generation, complexity and cost. A multicriteria analysis is a widely used approach to assist decision-making when a range of options need to be assessed according to several criteria (Worboy 2005). Criteria may include requirements for external parties' involvement (i.e., regulator or stakeholders), long lead time to fill the gaps (detail studies), internal resource availability or mine planning decision making.

Actions taken to improve and/or have practical benefits for effectively managing data to inform closure planning, may not always require great cost or involve high risk, resource intensive approaches. It may

require strategic review and identification of ways to modify existing operational processes so that data collection, integration and application fully aligns with the site systems and requirements. Approaches which have been proven practical and useful to expedite gap analysis processes and create efficiencies in the closure planning process include:

- Develop a register of all legal and other obligations, inclusive of any commitments for the site, which has a means of grouping certain commitments to be applicable to closure and rehabilitation activity planning/ requirements. Where a formal database is not achievable there should be a single document that is controlled through an Environmental Management System (EMS) or similar that contains this information. It is critical that this is systematically managed to ensure resources for completing this step are utilised as efficiently as possible to consolidate and rationalise this information.
- Identify and engage with key stakeholders to proactively establish any potential regulatory changes that may apply to the closure planning requirements to clarify expectations as they evolve.
- Monitor broader regulatory requirement changes in other jurisdictions or federal requirements that may impact on closure planning requirements.
- Clarify the scope of the closure plan, closure vision, post mining land uses, and other requirements needed to inform the plan.
- Establish a library of documentation that would inform the closure plan.
- Establish a structured framework to build upon as the closure plan developed more detail as the knowledge base increased or was subsequently informed through additional monitoring data, modelling, technical studies analysing existing and new data.

In general terms, there are four key steps to establish the process of knowledge management in closure planning:

1. Determine commitments, legal and other obligations required for closure planning;
2. Compare existing data and knowledge base against closure planning requirements;
3. Develop plans to gather missing data or undertake further analysis of data; and,
4. Feed additional knowledge and data back into the closure plan.

All four elements are fundamental for development of a closure plan, to ensure that it remains relevant to the operation during the various life cycle stages and provide transparency for all stakeholders on the mine's progress towards demonstration of completion criteria and closure objective achievement.

Translating these principles of knowledge management into practice remains the challenge. Whilst the steps for data management and building a knowledge base to inform closure planning are relatively straightforward and not onerous, it is still common to identify opportunities to improve knowledge or data bases underpinning closure plans. This provides evidence that tangible barriers to data management and building a knowledge base is a reality. Some of these barriers can be:

- The stage or phase of the site in its life cycle.
- Unclear or evolving guidance and parameters to collect data against.
- Inconsistent metrics or missing information to explain the transition to different metrics leading to difficulties comparing monitoring trends over extended periods of time.
- Large volumes of collected data, requiring additional resources to synthesize and interrogate data into a suitable format for interpretation and application to improve closure and rehabilitation strategies.

- Often history and corporate knowledge resides with key individuals and relies upon corporate knowledge to navigate where the important and relevant data is stored within systems that have evolved.
- Availability of resources to ensure effective implementation of systems for data management in relation to closure planning.

Constraints on systematically populating and managing the knowledge base to inform the closure plan from commencement of the planning process to mining cessation, may result in missed opportunities to maximise the use of the planning process and reduce the potential project risk at closure. Examples include the inability to fully realise the power of the data collected to improve and drive efficiencies in the closure planning process, value or business loss due to waste of resources allocated to collect data that is not used and risk of further resources allocated to repeat previous work.

6 Conclusion

> *"Given the myriad of variables in mine site terrain, geology, ecology, climate, social expectation, financial conditions, regulation and other factors, a prescriptive road map for an individual operation's LOM can never be offered" McCullough (2018).*

Mine closure planning is complex. Capturing knowledge and data by applying robust processes early in the life of the asset, in alignment with the closure vision and objectives, can lead to improved post mine land use outcomes and optimise resource utilisation when closure activities are undertaken. However, a disconnect remains. Patchy, inconsistent data or significant data gaps to inform the closure planning has the potential to present many challenges in the closure planning process. Overall, a solid understanding of a site and the associated closure needs is essential, particularly for older operations where corporate knowledge has been lost or ad hoc records kept. Source data from any existing knowledge base relevant to the operation as a starting point to initiate trials or technical studies required to develop and refine the closure planning elements. Often outcomes determined from research and trials can be integrated into the review of closure risks and mitigation strategies, while modifying current operational processes can improve the integration of data collection and application to suit the site systems and closure planning aspects.

The collection of requisite data to inform the knowledge base can sound simple but, remains uncommon for many reasons including evolving regulatory requirements, operational focus on compliance requirements, staff turnover and inadequate resource allocation. While the extent of knowledge gaps can vary, undertaking a gap analysis and building of the knowledge base using a few guiding principles will provide a valuable opportunity to identify and prioritise the resources needed to both plan and implement closure activities, in full alignment with existing site processes.

Acknowledgement

The authors would like to thank the companies who have provided us the opportunity to support them in the development of their closure plan documentation.

References

Cooper, S 2019, 'Maximising post mining land use: Queensland Government reforms' in in AB Fourie & M Tibbett (eds), *Proceedings of the Thirteenth International Conference on Mine Closure*, Australian Centre for Geomechanics, Perth.

Lacy, HWB 2019, 'Mine landforms in Western Australia from dump to landform design: review, reflect and future direction' in AB Fourie & M Tibbett (eds), *Proceedings of the Thirteenth International Conference on Mine Closure*, Australian Centre for Geomechanics, Perth.

McCullough, CD, Marchand, G & Unseld J 2013, Mine Closure of pit lakes as terminal sinks: Best available practices when options are limited?, *Mine Water Environ* vol. 32 pp. 302–313

McCullough, CD, Harvey, B, Unger, CJ, Winchester, S, McCarthy, B & Coetzee, J, 2018, 'From start to finish – a perspective on improving sustainable development aspects of life-of-mine practices' in *From start to finish: a life-of-mine perspective*, AusIMM Spectrum Series 24.

Nichol, OG, 2005, ACARP Project No.C13048, Development of Rehabilitation Completion Criteria for Native Ecosystems Establishment on Coal Mines in the Hunter Valley, Australian Centre for Minerals Extension and Research, Kenmore.

Worboys, GL, Lockwood, M & De Lacy, T 2005, *Protected Area Management, Principles and Practice*, Oxford University Press, South Melbourne.

Zillig, LJK, Keenan, N & Robert, T 2015, Mining Rehabilitation in New South Wales (Australia) and Germany, *Journal of Earth Science and Engineering,* vol. 5, pp. 499-511