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Evaluation of historic and contemporary rehabilitation performance to optimise rehabilitation planning, methodologies and outcomes

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Abstract

Mine rehabilitation methodologies, objectives, success measures and stakeholder expectations often evolve over the life of a mining operation, as rehabilitation activities are completed, and as a site- and area-specific knowledge base is built. This may result in different rehabilitation outcomes depending on the age of the rehabilitation, the nature of the underlying spoil material, the design of the constructed landform, adoption of differing erosion control techniques, changes in topsoil management, and differences in the species mixes that were sown.

As with anything that varies over the life of an operation, there is potential for knowledge to be lost due to turnover in personnel who manage the rehabilitation process. Given this, it is important to review rehabilitation outcomes in order to capitalise on an operation's investment in progressive rehabilitation, monitoring and trials. Conducting such a review can provide a valuable contribution towards improved rehabilitation planning and optimisation of practices over time. In particular, such a review can provide insight and assurance that the rehabilitation methodologies employed will: 1) result in positive rehabilitation outcomes; and 2) achieve the intended post-mining land use outcomes.

In this case study, such a historical review of rehabilitation practices and outcomes was completed for Anglo American's Capcoal Complex in Central Queensland. The Capcoal rehabilitation appraisal utilised personnel with extensive rehabilitation knowledge and experience to undertake a detail review of rehabilitation records, trial outcomes, monitoring results, processes, prescriptions and procedures in order to build a concise record for each rehabilitated area. The information was evaluated and formatted to enable upload into the site geographic information system platform.

The desktop evaluation was then followed by a detailed site inspection to evaluate historic and contemporary rehabilitation areas that were representative of differing rehabilitation ages, prescriptions, spoil/soil types, and rehabilitation objectives. The site visit built on knowledge obtained from direct interviews with former site personnel, as well as internal and external stakeholders to obtain insights into contemporary rehabilitation practices, perceptions on rehabilitation success to date, and desired rehabilitation outcomes. External stakeholders' views were sought on their expectations on rehabilitation outcomes and preferred post-mining land use objectives for differing site domains.

The review culminated in refinement of rehabilitation prescriptions based on rehabilitation success from the historical record, confirmed with observations at the site, and combined with a knowledge of industry best practice methodologies appropriate to the site. Remedial actions were suggested for areas that may not be on a trajectory to achieve a desired relinquishment outcome. Documented outcomes included revisions to the

recommended site rehabilitation prescriptions, amended post-mining land use mapping, and further refinement of post-mining land use outcomes. Finally, potential rehabilitation knowledge gaps that were identified were highlighted and opportunities for adoption of innovative technology were suggested.

This case study showcases a methodology that can be applied at other mining operations to extract maximum value from their historic and contemporary rehabilitation performance and can optimise progressive rehabilitation methodologies for the site.

Keywords: *historic and contemporary rehabilitation performance, rehabilitation methodologies and prescriptions, rehabilitation outcomes, post-mining land-uses, success criteria, evidence-based assessment, knowledge retention, stakeholder engagement*

1 Introduction

It is important to have a detailed understanding of rehabilitation methodologies and prescriptions to drive sustainable rehabilitation outcomes (Loch 2010). Rehabilitation must be site-specific, taking into account materials, climate, footprint constraints, post-mining land-uses, adjacent vegetation, and stakeholder views.

Rehabilitation practitioners develop an extensive knowledge of what prescriptions have worked, and where, with theories as to why. There is a wide range of ways in which this detailed knowledge base can be developed at a particular location, including some of the following typical approaches:

- Application of different methodologies over time (try-and-see approach and/or evolution of technologies and innovations).
- Formal trials (with experimental plots established and scrutinised).
- Monitoring programs with feedback of methodologies based on performance.
- Development of objectives and success measures that drives outcomes.
- Involvement of different stakeholders with varied backgrounds, experience, expectations and outlooks.
- Input of new operational/contract/consulting personnel with particular expertise in an aspect of environmental management or rehabilitation execution – usually in response to a 'problem'.

Often these approaches are implemented in an ad-hoc, unstructured manner and the ideas evolve as the data is collected and the practitioner strives for 'success'. However, both the investigation of 'failures' as well as the application of new methodologies and prescriptions are subject to the inherent bias of the rehabilitation observer/practitioner (Dale et al. 2018). Time can also be a strong influence on rehabilitation success which is often not well considered and means that a 'wait and see approach' in some situations can actually be prudent.

Monitoring that is linked to completion criteria is a valuable way in which practitioners can overcome such influences, and reliable, continuous records greatly assist in understanding long-term rehabilitation performance (Emmerton 2019). However, monitoring must be approached with care, as consistency of the collection of observations and records is important, as are the metrics being recorded and methodology. Monitoring can also be costly and resource demanding, with potential to collect information of no value, or results can sit idle unless meaningful interrogation and review are conducted on the findings. Further, monitoring can sometimes be targeted towards collecting data in a way that supports a planned or desirable outcome, potentially missing problems as they arise and perpetuating sub-optimal rehabilitation practices.

Recognising these concerns, Anglo American has initiated a research-based approach to assessing rehabilitation performance and linking this to development of rehabilitation prescriptions. "Rehabilitation appraisals" are being undertaken across the company's metallurgical coal assets in Australia to better inform rehabilitation practices. Conducting such review was proposed as a mechanism for harnessing the history of the site, and ensure such historical information actually provides a valuable contribution towards improved

rehabilitation planning and optimisation of rehabilitation practices over time. A further aim of these appraisals is to ensure that proposed post mine land-uses (PMLUs) can indeed be realised through certain rehabilitation activities, which have been demonstrated to be successful in the particular geography and site conditions, and ideally, through the site history. The body of work is also supporting the development of progressive rehabilitation and closure plans for the assets.

This paper details the methodology used for the rehabilitation appraisals and presents a case study from one of the sites investigated in Central Queensland with a long history of rehabilitation.

2 The case for conducting rehabilitation appraisals

All too often, very different rehabilitation outcomes can be observed in differing rehabilitation areas with the same treatments applied. There is usually a wide range of variable exogenous factors which also play a role, such as the age of the rehabilitation, the nature of the underlying spoil material, the design of the constructed landform, adoption of differing erosion control techniques, changes in topsoil management and differences in the species mixes that were sown and the time of year (Loch 2010).

It can be difficult to understand why rehabilitation areas actually succeed or fail, without a clear understanding of the key drivers. In response, many rehabilitation practitioners become 'tinkerers', continually adjusting their rehabilitation prescriptions almost intuitively (although frequently supported by specialists) to achieve rehabilitation that achieves the desired outcomes. In doing so, many practitioners build a detailed local knowledge particular to the rehabilitation at that site, albeit this knowledge can be fragmented, based on many sources of input or even just based on the individual's own observations.

Given this, it is important to review and thoroughly capture rehabilitation outcomes in as analytical a manner as possible, to both understand these drivers, but also to continue to document the knowledge base for posterity. Natural attrition and turnover in the mining industry, and in particular for those involved in rehabilitation, also means there is high potential for such informal knowledge to be lost over time to a site.

However, mining sites rarely have time to suspend operational demands to compile, review and distill information that resides in historical documents such as rehabilitation management plans, rehabilitation procedures, rehabilitation monitoring records, rehabilitation prescriptions or seed procurement records (Henderson 2007). Having an independent rehabilitation expert conduct such a review and consolidate the rehabilitation knowledge not only compiles this knowledge base to preserve the underlying information, but also introduces an independent view on the rehabilitation performance itself which can provide some perspective of rehabilitation 'success'. It is akin to accessing a whole other independent network of knowledge on rehabilitation practices and methodologies – that are held by the independent expert.

Organisation of this information into a format that can be searched and retrieved for each rehabilitation area provides a key resource to support future planning and execution of rehabilitation. The information can then be transferred to a geographic information system platform to assist with spatial interrogation.

3 Rehabilitation appraisal methodology

An appraisal methodology was established comprising a two-phase process, whereby a range of primary and secondary data is sourced in a foundational assessment of information and practices, followed by synthesis and interpretation of this data to produce the rehabilitation appraisal outputs. The methodology applied to conduct rehabilitation appraisals is as shown in Figure 1 and detailed in the following subsections.

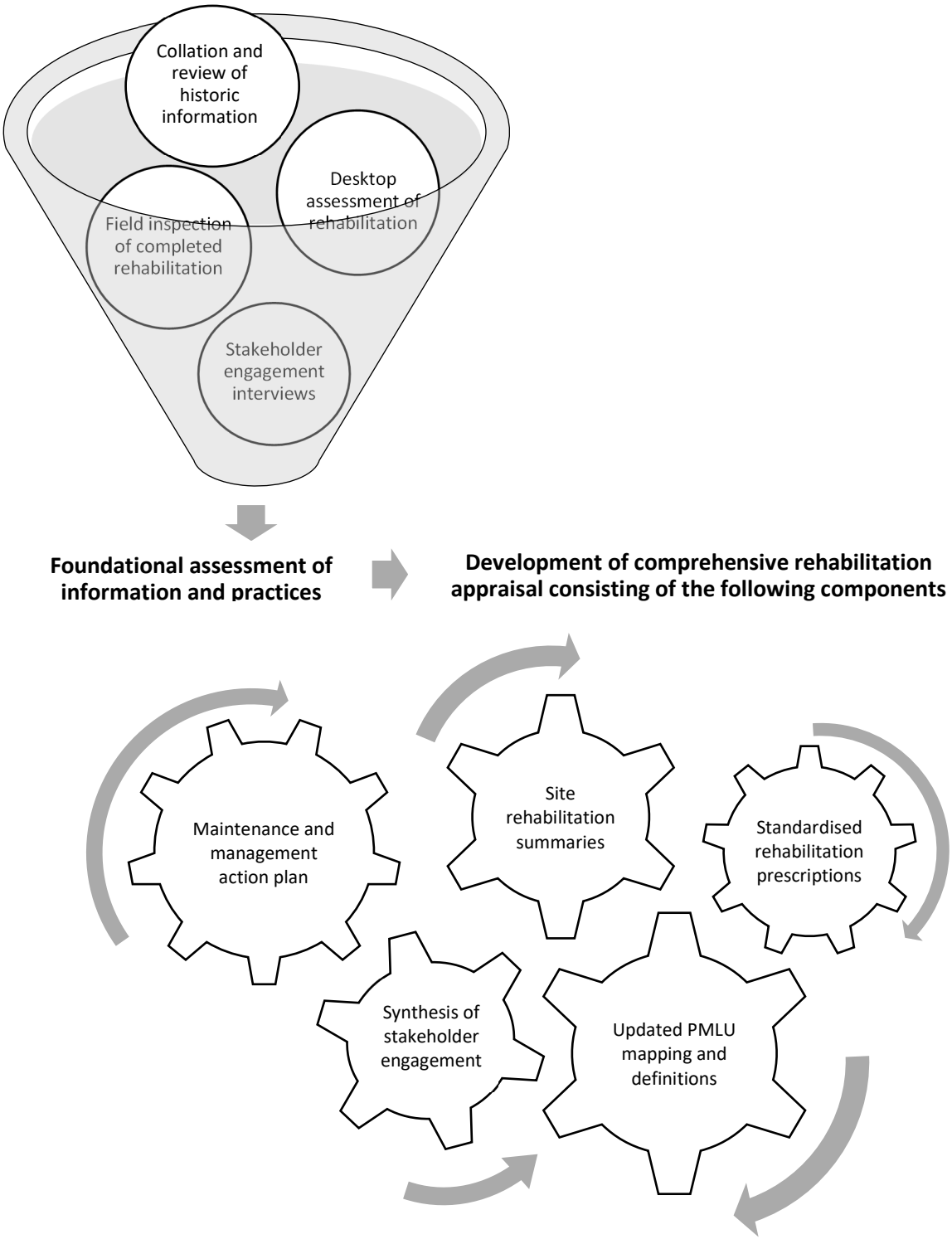


Figure 1 Rehabilitation appraisal methodology

3.1 Foundational assessment of information and practices

3.1.1 Collation and review of historic information

Initial collation and review are undertaken to explore the relevant information relating to rehabilitation history, methodologies, and practices, as well as considering past trials, research completed and monitoring data. This consists of examination of provided rehabilitation data and information, including:

- Rehabilitation trials.
- Research findings.
- Monitoring data and results.
- Technical studies.
- Management plans and prescriptions.
- Other relevant information provided.

A high-level assessment is then completed to understand the value of the data and information, to assess how data interacts with each other, and its relevance to the operation. The relevant information is collated and organised as a centralised repository of all rehabilitation information for the site, to be suitable for upload into the Anglo American spatial-based platform used to retain current environmental and rehabilitation performance (eMapper). Data and knowledge gaps were also identified for further assessment as part of this process.

3.1.2 Desktop assessment of rehabilitation

A further detailed review is then undertaken of all rehabilitation information, now collated into an organised form (as per Section 3.1.1). This consists of reviewing to analyse and further interpret all past rehabilitation trials, research and monitoring data as well as provide an independent assessment of all rehabilitation management procedures and practices.

A technical review then considers the knowledge base within the context of determining and justifying preferred rehabilitation practices and prescriptions. Specifically, reflecting on actual rehabilitation performance to guide the key desired outputs, including the development of a maintenance and management action plan and development of preferred rehabilitation prescriptions. Guidance is also provided as to rehabilitation methodologies, by aspect, considering the full ‘life cycle’ of rehabilitation from landform design through to monitoring, as well as providing targeted recommendations for rehabilitation practices and methodologies for the specific site in focus.

3.1.3 Field inspection

The desktop evaluation is then followed by a detailed site inspection to evaluate the current performance of both historic and contemporary rehabilitation areas, selected to be representative of differing rehabilitation ages, prescriptions, spoil/soil types, and rehabilitation objectives. A secondary focus is also to identify rehabilitation failures or maintenance issues that may require remediation to prevent any hindrance to rehabilitation success or result in increased expense if left unmanaged. A supplementary benefit of the field component, which is conducted by an independent experienced practitioner, is that this allowed for mentoring and training of site-based environmental staff.

Site inspections are completed using a rapid assessment, conducted via vehicle mediated walkovers. Desktop interrogation of aerial photography also occurs prior to the field inspection to assist in targeted areas for on-ground inspection.

Rapid assessments include identification of the following:

- Presence and severity of active erosion areas (e.g. rill, gully and tunnel erosion).
- Effectiveness of capping treatments (if applicable).
- Stability of slopes.
- Function and condition of existing erosion and sediment control structures and landform features, including water management structures, water ponding areas as applicable.
- Visual assessment of ground protection and vegetation cover, health, biodiversity, growth rates and succession. This enabled critical review of the historic species lists to identify species that were thriving or struggling.
- Evidence of recruitment of seedlings to demonstrate succession.
- Observations on resilience of vegetation cover (e.g. if areas have been grazed, burnt or subject to other disturbance events).
- Evidence of pasture dieback (subject to pasture actively growing versus cured due to dry conditions).
- Areas of significant weed incursion evidence or presence/impact of vertebrate pests.
- Any other disturbance factors or features, such as mine rubbish (e.g. signage, tyres, pipes, drums) and vehicle tracks through rehabilitated areas, causing unplanned disturbance.

3.1.4 Stakeholder engagement interviews

In order to add further context and depth to the appraisal, input from a range of stakeholders is sourced. Time during the site visit is dedicated to completing direct stakeholder engagement through interviews with former site personnel, as well as a range of other internal and external stakeholders to obtain insights into contemporary rehabilitation practices, perceptions on rehabilitation success to date, and desired rehabilitation outcomes. External stakeholders' views are also sought on their expectations for rehabilitation outcomes and preferred PMLU objectives for differing site domains.

Stakeholders to be consulted typically include the following participant groups:

- Neighbouring landholders.
- Traditional Owner representatives.
- Former (and current, if relevant) personnel and consultants with relevance to and involvement in rehabilitation.
- Former site environmental personnel.

3.2 Development of comprehensive rehabilitation appraisal

The information compiled during the previous steps is interpreted and synthesised into a 'comprehensive rehabilitation appraisal' that considers the following.

- An overview of the data gathering and knowledge compilation exercise.
- Reflecting on actual rehabilitation performance, as a way to guide rehabilitation planning processes and methodologies, with specific consideration as per the following points:
    - Development of a maintenance and management action plan.
    - Development of preferred rehabilitation prescriptions, both as overarching recommendations and area-specific as appropriate.

- Development of further guidance as to rehabilitation methodologies, by aspect, considering the full 'life cycle' of rehabilitation from landform design through to monitoring.
- Further targeted recommendations for future rehabilitation at a high level of detail (such as recommending future revegetation species mixes).

- Using the historical record of rehabilitation performance monitoring to demonstrate the success or otherwise of rehabilitation and PMLU outcomes, which further shaped the following key aspects:
  - Resulted in the refinement of PMLU mapping.
  - Highlighted potential innovations and further opportunities with potential relevance to the site.
  - Developed a concise summary of consultation related to rehabilitation activities.
  - Summarised potential residual knowledge gaps, with recommendations to address these gaps.

The following subsections explore the key technical components that are produced.

3.2.1 Detailed rehabilitation maintenance and management action plan

The field inspection/on-ground assessment of historic rehabilitation informs the development of a detailed action plan with recommendations for maintenance and management; that considers the practicality and cost effectiveness of its recommendations. The focus of this task is to identify rehabilitation failures or maintenance issues that may require remediation, and to develop an appropriate action plan to prevent any hindrance to rehabilitation success or result in increased expense if left unmanaged.

The action plan applies a risk-based approach, prioritising actions according to risk and cost, with an aim to increase knowledge, and detailed actions for each of the areas/factors requiring remedial action.

3.2.2 Synthesis of stakeholder engagement

A standardised engagement questionnaire is used to ensure relevant and consistent responses. All stakeholder engagement is synthesised into a formal summary record within the appraisal report that details who was consulted and the outcomes.

Stakeholder input and views are primarily sought on subjects that Anglo American can influence the rehabilitation outcomes of. Environmental commitments and approvals are also discussed to provide context. Aspects of the mining operation that are impractical to adjust for a mature mine (such as void size, void location, dump heights or slope angles for completed dumps) were not included in the consultation process.

3.2.3 Standardised rehabilitation prescriptions

The review culminates in refinement of the rehabilitation prescriptions for the site, based on rehabilitation success from the historical record, confirmed with observations at the site, and combined with a knowledge of industry best practice methodologies appropriate to the site. This standardised rehabilitation prescription considers underlying materials, agreed post-mining land-uses, suitability of practices from this historical review, as well as other environmental constraints present. The specification outlines acceptable landform parameters, surface water and erosion control structures design criteria, acceptable outcomes and high-level treatment plans for growth media as well as proposed suitable seed mixes for each PMLU.

3.2.4 Updated PMLU definitions and mapping

The definition and mapping of PMLUs can be reviewed in concert with development of the rehabilitation prescriptions. Linkages are made between the PMLU revision, and the requirements to be satisfied as part of the Queensland Progressive Rehabilitation and Closure Plan (PRCP) process itself. In this way, the revised PMLU mapping can be developed with attention to anticipated future uses of this information.

3.3 Other potential outputs

There is potential for additional outputs to be developed as part of conducting such a project such as:

- Rehabilitation cost analysis.
- Consideration of other locations or relevant public domain industry wide information.
- Development of a cost capture, breakdown and review tool for rehabilitation spend.
- Extension of stakeholder input to include more industry experts.
- Development of decision support tool to show determination and justification of PMLUs based on suitability factors, with updating of mapping.
- Extensions to field assessment and monitoring – and in particular the use of remote sensing.
- Benchmarking to bring in best practice to address residual risks.

4 Applied example – Capcoal rehabilitation appraisal

4.1 Site history

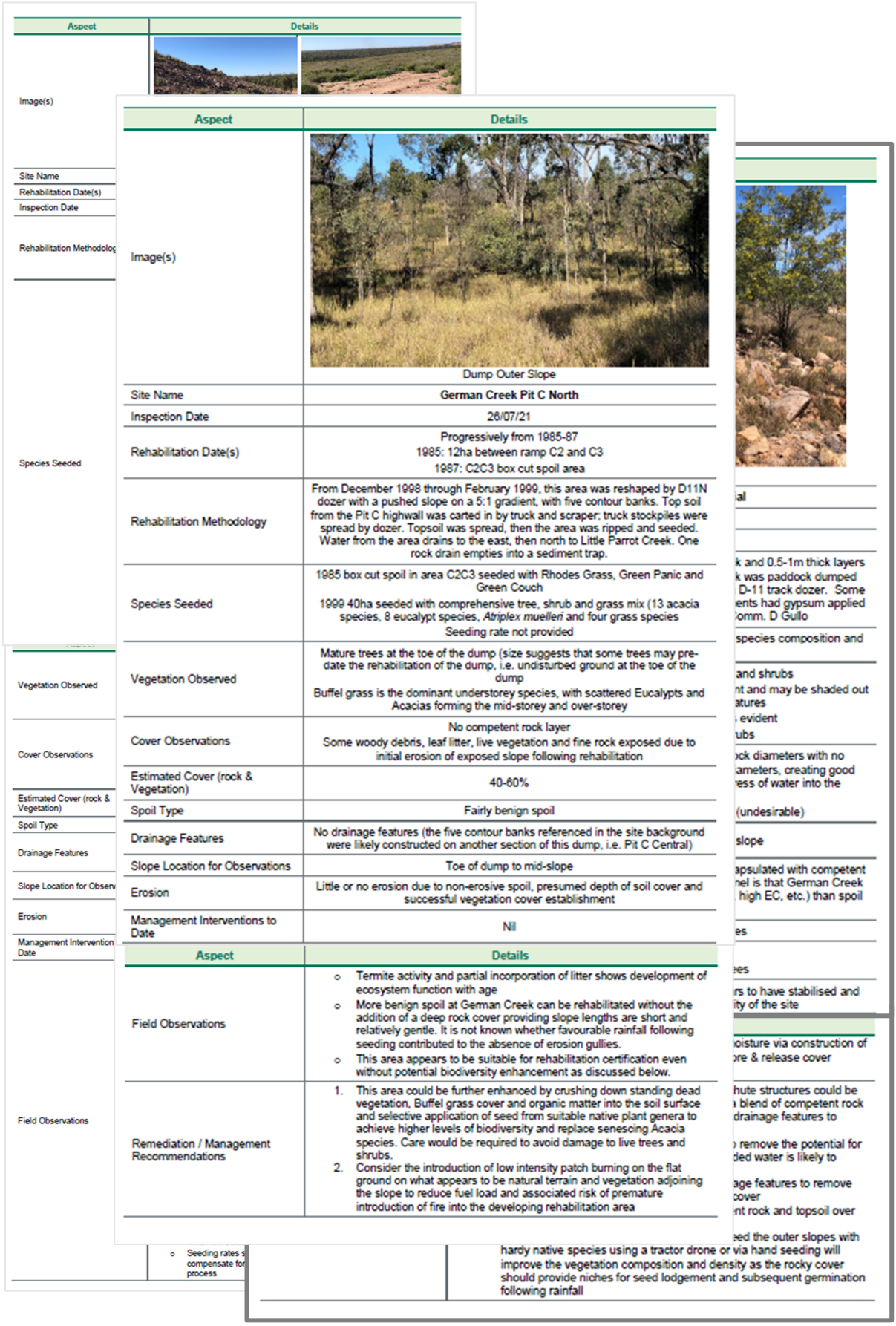
The Anglo American Capcoal Complex is located approximately 25 km southwest of the purpose-built town of Middlemount, in Central Queensland's Bowen Basin. The Capcoal Complex consists of German Creek and Lake Lindsay mining areas and includes the Capcoal open cut, Aquila underground and Grasstree underground mines, as well as associated infrastructure such as a coal handling and preparation plant (CHPP).

Open cut mining commenced at German Creek Mine in late 1981, with operations at German Creek East Mine commencing in the 1990s and Oak Park Mine in 2003. German Creek and German Creek East have ceased operations. German Creek Mine is located on mining lease (ML) 1831, German Creek East Mine on ML1998. This rehabilitation appraisal was confined to the Capcoal open cut operations. Rehabilitation of disturbed areas was undertaken progressively during mining, as areas became available, with the earliest rehabilitation on site completed at German Creek in the early 1990s.

Mining at Oak Park within ML70311 commenced in 2003, was inactive in the period 2014–2021, and has recently resumed. Lake Lindsay is an open cut mine which has been operating since 2006 and is located on ML70336. Constructed landforms at Lake Lindsay are progressively rehabilitated and are the focus of current rehabilitation programs.

4.2 Example of a site rehabilitation summary

Site-specific summaries were prepared, which detail the rehabilitation methodologies and practices applied, as well as current observations from the field inspection. Area-specific recommendations were also made, as demonstrated by the example shown as Figure 2.



Aspect	Details
Image(s)	Dump Outer Slope
Site Name	**German Creek Pit C North**
Inspection Date	26/07/21
Rehabilitation Date(s)	Progressively from 1985-87 1985: 12ha between ramp C2 and C3 1987: C2C3 box cut spoil area
Rehabilitation Methodology	From December 1998 through February 1999, this area was reshaped by D11N dozer with a pushed slope on a 5:1 gradient, with five contour banks. Top soil from the Pit C highwall was carted in by truck and scraper; truck stockpiles were spread by dozer. Topsoil was spread, then the area was ripped and seeded. Water from the area drains to the east, then north to Little Parrot Creek. One rock drain empties into a sediment trap.
Species Seeded	1985 box cut spoil in area C2C3 seeded with Rhodes Grass, Green Panic and Green Couch 1999 40ha seeded with comprehensive tree, shrub and grass mix (13 acacia species, 8 eucalypt species, *Atriplex muelleri* and four grass species Seeding rate not provided
Vegetation Observed	Mature trees at the toe of the dump (size suggests that some trees may pre-date the rehabilitation of the dump, i.e. undisturbed ground at the toe of the dump Buffel grass is the dominant understorey species, with scattered Eucalypts and Acacias forming the mid-storey and over-storey
Cover Observations	No competent rock layer Some woody debris, leaf litter, live vegetation and fine rock exposed due to initial erosion of exposed slope following rehabilitation
Estimated Cover (rock & Vegetation)	40-60%
Spoil Type	Fairly benign spoil
Drainage Features	No drainage features (the five contour banks referenced in the site background were likely constructed on another section of this dump, i.e. Pit C Central)
Slope Location for Observations	Toe of dump to mid-slope
Erosion	Little or no erosion due to non-erosive spoil, presumed depth of soil cover and successful vegetation cover establishment
Management Interventions to Date	Nil

Aspect	Details
Field Observations	○ Termite activity and partial incorporation of litter shows development of ecosystem function with age ○ More benign spoil at German Creek can be rehabilitated without the addition of a deep rock cover providing slope lengths are short and relatively gentle. It is not known whether favourable rainfall following seeding contributed to the absence of erosion gullies. ○ This area appears to be suitable for rehabilitation certification even without potential biodiversity enhancement as discussed below.
Remediation / Management Recommendations	1. This area could be further enhanced by crushing down standing dead vegetation, Buffel grass cover and organic matter into the soil surface and selective application of seed from suitable native plant genera to achieve higher levels of biodiversity and replace senescing Acacia species. Care would be required to avoid damage to live trees and shrubs. 2. Consider the introduction of low intensity patch burning on the flat ground on what appears to be natural terrain and vegetation adjoining the slope to reduce fuel load and associated risk of premature introduction of fire into the developing rehabilitation area

Figure 2 Rehabilitation summary for Capcoal

4.3 Observations regarding rehabilitation performance monitoring

Formal rehabilitation monitoring commenced in 2003. Reviewing the historical rehabilitation performance monitoring records for the case study site since that time, several patterns became clear. Firstly, monitoring techniques, resolution, and effort and reporting outputs change regularly over time. There was a lack of consistency in reporting due to different service providers and intent of monitoring. Secondly, it was also rare for any performance monitoring reports to consider changes in performance through time, or to consider or reflect against success, completion criteria or trajectory models.

For rehabilitation performance monitoring to be of value, it must be placed within the surrounding context and acknowledge the many factors acting on rehabilitation which can influence positive outcomes. Without a clear understanding of key drivers, it is hard for rehabilitation monitoring to provide meaningful, long-term and evidence-based recommendations or adjustments to the rehabilitation methodologies.

Detailed rehabilitation performance monitoring techniques, such as transect-based assessment, automatically restrict the potential for the monitoring to provide broader observations and raise concerns about representation which must be overcome. Whilst they may not support statistical analysis, the value and importance of such 'softer' monitoring techniques should not be underestimated. Undertaking a rapid field assessment and recording observations, inclusive of photographic records, for a large cross-section of rehabilitation treatments and outcomes greatly assisted in preparing an enhanced rehabilitation prescription and recommendations for maintenance or remediation works for completed rehabilitation areas. Revisiting older (>20 years) rehabilitation sites also enable observations to be made regarding resilience, succession and ecosystem development. This approach is advocated for similar rehabilitation appraisals, as well as annual monitoring campaigns, with the caveat that the field assessment must be conducted by a skilled and experienced rehabilitation practitioner.

4.4 Observations regarding stakeholder engagement on rehabilitation

The case study specifically included interviews with former site personnel who were involved in rehabilitation planning and execution. This proved invaluable to the collation of historical knowledge and understanding rehabilitation performance as observed through the field assessment. Particular care was taken to develop a standardised questionnaire for all interviews, so the same suite of questions was asked of all interviewees. In this way, consistent information was obtained from all stakeholders.

Often knowledge had been retained but not formally documented, with interviewed personnel being able to recall what approach was adopted for different rehabilitation areas on site where rehabilitation outcomes varied. This filled knowledge gaps for specific locations, which allowed a more accurate appraisal of the success of differing methodologies. In cases where the methodology was not documented, or where the actual rehabilitation methodology deviated from the planned prescription, obtaining this firsthand recollection from people who were involved in the process was able to provide a more comprehensive picture of historic rehabilitation, as well as explore informal trials and modified approaches not otherwise documented.

Some of the variables that may have influenced a rehabilitation outcome, and can be better understood through consultation with current and former rehabilitation practitioners at the site, include:

- Source, condition and application depth of topsoil.
- Rock armouring source and depths.
- Amelioration treatment.
- Species that were sown.
- Weather conditions experienced at the time of rehabilitation and during the establishment phase.
- Rework of an area.

Conducting an informal, direct approach using an experienced rehabilitation practitioner driving the process assisted with engaging stakeholders on an individual basis in a manner that supported obtaining important observations and expectations regarding rehabilitation practices, methodologies and outcomes. It also uncovered many other thoughts and opinions held by stakeholders in relation to rehabilitation in a forum which allowed the interviewee to feel comfortable sharing their thoughts and wishes, which enriched the potential for rehabilitation to meet the needs of these future land users. Stakeholder engagement discussions tapped into each interviewee's own background and experience, and considered inclusion of bush food and medicinal plants, grazing limitation and achievable stocking rates, concerns regarding land management requirements, responsibility for wildlife corridor preservation, and similar. Using an informal offsite venue, creating an informal atmosphere and introducing an independent party with experience and extensive knowledge of rehabilitation provided supported a more open and honest dialogue with key stakeholders, whilst also establishing boundaries based on the known site environment and rehabilitation constraints.

Another important component of the appraisal involved direct engagement with Barada Kabalbara Yetimarala. The appraisal provided an open forum for this stakeholder group to contribute their unique and extensive knowledge, and to share their own cultural practices in addition to thoughts and information on rehabilitation practices. The engagement also allowed for two-way information sharing with specific reference to post-mining land-uses, as well as gathering of quite detailed information on aspects such as seed mixes (with intention to incorporate the Traditional Owners' wishes with respect to traditional medicine and food species within suitable rehabilitation areas).

4.5 Rehabilitation appraisal outcomes

The following is a summary of the key outcomes from the appraisal at Capcoal:

- An unambiguous understanding of what has been successful at the site over time was developed by following the methodology outlined in Section 2. PMLUs were reviewed, and in some cases adjusted, based on site-specific evidence provided by the direct rehabilitation history.
- Clear and evidence-based linkages have been made between rehabilitation methodologies and PMLU outcomes, in a manner which also informs suitable success criteria (both milestones and milestone criteria).
- Use of experienced and independent rehabilitation practitioners for the appraisal allowed for highlighting of remedial actions, for those rehabilitation areas that may not be on a trajectory to achieve a desired relinquishment outcome. This independence can be important for recognising problem areas as well as suggesting potential solutions.
- The coupling of a review of historical information with an in-person rapid assessment provides important clarity to the influence that time can play on rehabilitation areas. Taking a longer-term view and making observations from this lens are required to understand critical periods of time for intervention, and/or recognising when the best action is simply to allow more time.
- The project cumulated into a single document intended to act as a central place of all rehabilitation knowledge – a 'guidebook'. The outcomes able to be documented included the site rehabilitation history, recommended site rehabilitation prescriptions, amended PMLU mapping, and refinement of PMLU outcomes. Further, potential rehabilitation knowledge gaps identified were highlighted, and opportunities for use of innovative technology suggested.

5 Conclusion

This paper details a framework, adopted by Anglo American in their metallurgical coal business, to evaluate historic and contemporary rehabilitation performance, and to optimise current rehabilitation planning, methodologies and outcomes. This was conducted to capitalise on their investment in progressive

rehabilitation, monitoring and trials. Mine rehabilitation methodologies, objectives, success measures and stakeholder expectations can evolve over the life of a mining operation, as rehabilitation activities are completed, as a site- and area-specific knowledge base is built, in a manner which can result in different rehabilitation outcomes. The methodology provides insight and assurance that the rehabilitation methodologies employed will result in positive rehabilitation outcomes and achieve the intended post-mining land-use outcomes.

The methodology involves a historical review and compilation of rehabilitation practices and outcomes for each area of rehabilitation completed. This is followed by a detailed site inspection to conduct a current evaluation of rehabilitation areas. Stakeholder engagement is undertaken, with knowledge obtained from direct interviews with former site personnel, as well as internal and external stakeholders to obtain insights into contemporary rehabilitation practices, perceptions on rehabilitation success to date, and desired rehabilitation outcomes.

The review culminated in refinement of rehabilitation prescriptions based on rehabilitation success, with remedial actions suggested for areas not on a trajectory to achieve a desired relinquishment outcome.

This approach, and the case study presented, showcases a methodology that can be applied at other mining operations to extract maximum value from their historic and contemporary rehabilitation performance, and optimise progressive rehabilitation methodologies for the site.

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