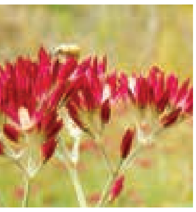
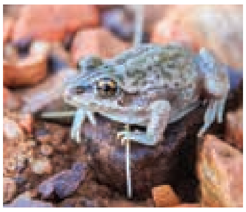
A framework for developing mine-site completion criteria in Western Australia


Government of **Western Australia**
Department of **Mines, Industry Regulation and Safety**

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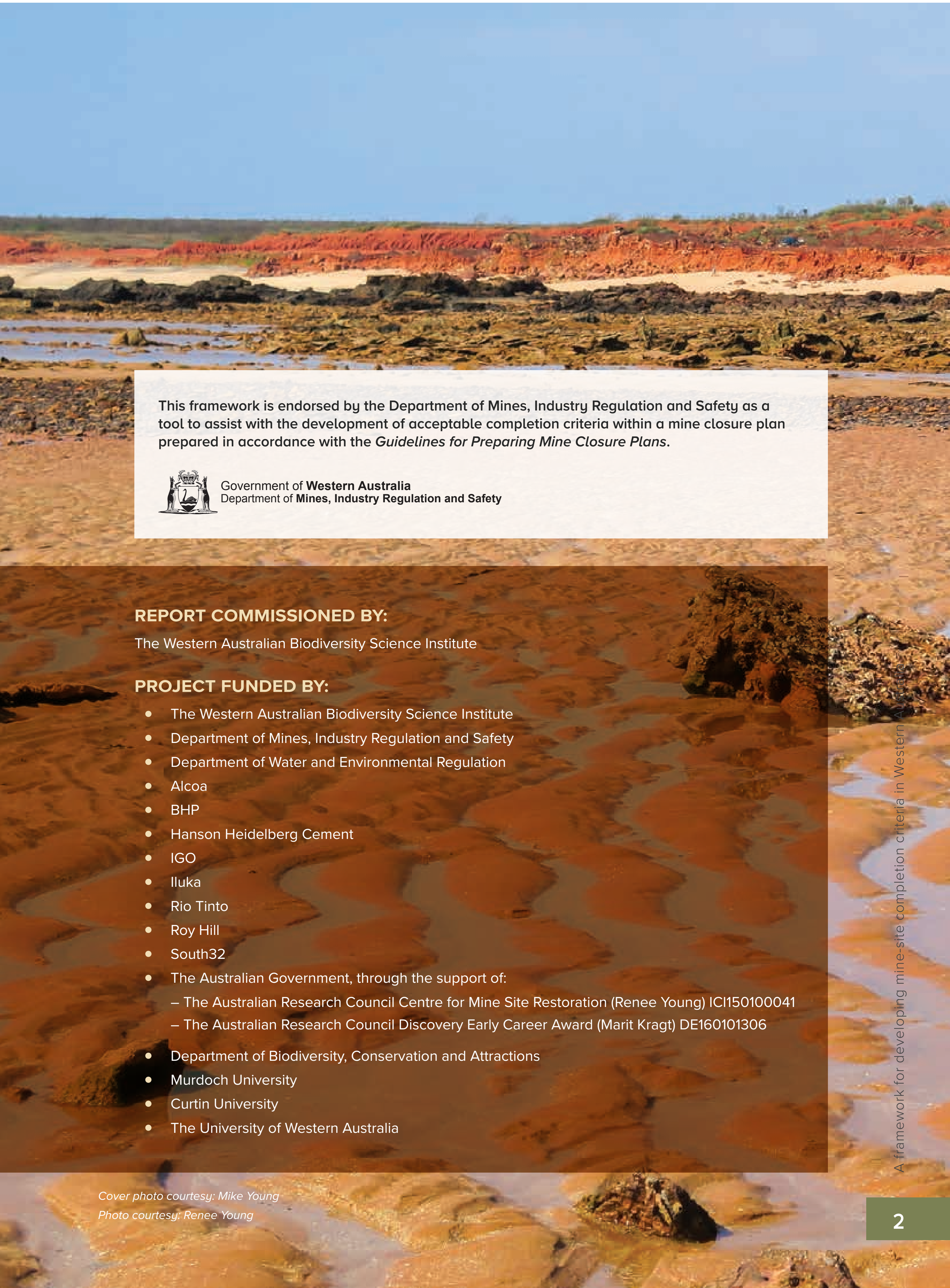

This framework is endorsed by the Department of Mines, Industry Regulation and Safety as a tool to assist with the development of acceptable completion criteria within a mine closure plan prepared in accordance with the *Guidelines for Preparing Mine Closure Plans*.

Government of **Western Australia**
Department of **Mines, Industry Regulation and Safety**

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CONTENTS

ACRONYMS

AANDC	Aboriginal Affairs and Northern Development Canada
ABARES	Australian Bureau of Agriculture and Resource Economics and Sciences
AER	Annual Environmental Report
AHP	Analytical hierarchy process
ALUM	Australian Land Use and Management
AMD	Acid Mine Drainage
ANOSIM	Analysis of Similarities
ANOVA	Analysis of Variance
ANZECC	Australia and New Zealand Environment and Conservation Council
ANZMEC	Australia and New Zealand Minerals and Energy Council
APEC	Asia Pacific Economic Cooperation
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
BCA	Benefit-Cost Analysis
BGPA	Botanic Gardens and Parks Authority
BIF	Banded Iron Formation
BoM	Bureau of Meteorology
CMIC	Canada Mining Innovation Council
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DBCA	Department of Biodiversity, Conservation and Attractions
DEC	Department of Environment and Conservation
DEHP	Department of Environment and Heritage Protection (Queensland)
DIIS	Department of Industry, Innovation and Science
DJTSI	Department of Jobs, Tourism, Science and Innovation
DMIRS	Department of Mines, Industry, Regulation and Safety (WA)
DMP	Department of Mines and Petroleum (WA)
DNA	Deoxyribonucleic Acid
DPaW	Department of Parks and Wildlife
DPIRD	Department of Primary Industries and Regional Development
DPLH	Department of Planning, Lands and Heritage
DRF	Declared Rare Flora
DSO	Direct Shipping Ore
DWER	Department of Water and Environmental Regulation
EFA	Ecosystem Function Analysis
EIA	Environmental Impact Assessment
EPA	Environmental Protection Authority (WA)
EPBC Act	Environmental Protection and Biodiversity Conservation Act 1999
ESA	Ecosystem Services Assessment
GNA	Goldsworthy Northern Areas
IBRA	Interim Biogeographic Regionalisation for Australia
ICMM	International Council on Mining and Metals
IGO	Independence Long Pty Ltd
INAP	International Network for Acid Prevention
ISO	International Standardisation Organisation

ACRONYMS (cont'd)

LCA	Land Capability Assessment
LFA	Land Function Analysis
LGA	Local Gvernment Authority
LiDAR	Light Detection and Ranging
LoM	Life of Mine
LPSDP	Leading Practice Sustainable Development Program
LSA	Land Suitability Assessment
MADM	Multi-Attribute Decision-Making
MCA	Minerals Council of Australia
MCP	Mine Closure Plan
METS	Mining, Equipment, Technology and Services
MGI	Mount Gibson Iron Limited
MLSA	Mined Land Suitability Analysis
MMPLG	Mining Management Program Liaison Group
MOP	Mining Operations Plan
NDVI	Normalised Difference Vegetation Index
NGO	Non-government Organisation
NMDS	Non-metric multidimensional scaling
NRM	Natural Resource Management
NSW	New South Wales
OTU	Operational Taxonomic Unit
OSA	Overburden Storage Area
PAF	Potentially Acid Forming
PCA	Principal Component Analysis
PCQ	Point-Centred Quarter technique
PMLU	Post-mining Land Use
R&D	Research and Development
RCP	Rehabilitation and Closure Plan
ROM	Run-of-mine
RSC	Research Steering Committee
SER	Society for Ecological Restoration
SERA	Society for Ecological Restoration Australasia
SIMPER	Similarity Percentages
SMART	Specific Measurable Achievable Relevant Time-bound
SWOT	Strengths, Weaknesses, Opportunities and Threats
TIRE	Department of Trade & Investment Resources & Energy (NSW)
TOPSIS	Technique for Order Preference by Similarity to Ideal Situation
TSF	Tailings Storage Facility
TSS	Total Soluble Salts
UAV	Unmanned Aerial Vehicle
UWA	University of Western Australia
WA	Western Australia
WABSI	Western Australian Biodiversity Science Institute
WAIO	Western Australian Iron Ore
WRL	Waste Rock Landform

1 Introduction

1.1 Completion criteria

Mining is a temporary land use and whole-of-life planning for resource projects that enables the delivery of mutually beneficial post-mining land uses is important to the future progress of the sector (Commonwealth of Australia 2018). The development of acceptable and achievable completion criteria is a necessary part of mine closure planning and fundamental to the successful transition of mined land to a future use. Completion criteria have been defined in the mining context as **agreed standards or levels of performance that indicate the success of rehabilitation and enable an operator to determine when its liability for an area will cease** (LPSDP 2016b).

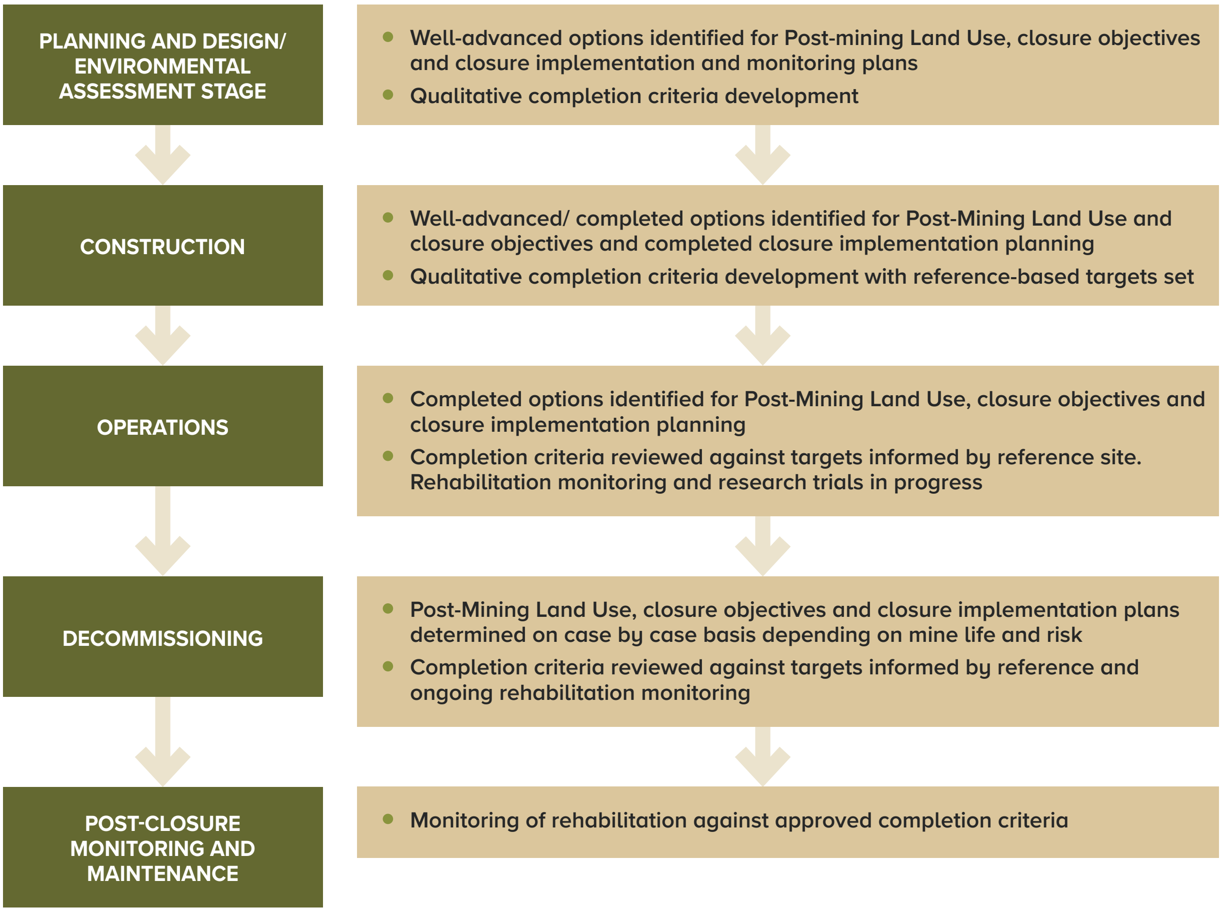
Once achieved, completion criteria demonstrate to the mining company, regulators and other stakeholders that financial assurances and liabilities can be removed. Relinquishment from obligations (where it is legally possible to do so, noting some obligations are not relinquishable – e.g. the Contaminated Sites Act 2003) can ultimately occur if the area is in a state where risks of deleterious environmental, health and safety impacts are at an acceptable level, and the agreed future land use can commence. This is recognised in the Western Australian ***Guidelines for Preparing Mine Closure Plans*** (DMP & EPA 2015) that state:

> *"Relinquishment of a tenement requires formal acceptance from the relevant regulators that all obligations under the Mine Closure Plan associated with the tenement, including achievement of completion criteria, have been met and, where required, arrangements for future management and maintenance of the tenement have been agreed to by the subsequent owners or land managers (e.g. pastoralist, Aboriginal community or land-management agency)."*

While considerable progress has been made in mine closure and rehabilitation planning in Western Australia (WA) (Environment and Communications References Committee 2018), there remains a need to build capacity and understanding of how to best measure rehabilitation success and to set practical outcomes and measurable completion criteria.

Planning for mine closure should occur across the life of mine phases. As a key aspect of the mine closure planning process, the development of completion criteria should be considered from approval stage with activity continuing post closure (Figure 1.1).

Throughout the life of mine there are opportunities for continual refinement to ensure completion criteria are robust and will best demonstrate that closure objectives have been met. Monitoring and the associated use of completion criteria provides a mechanism for adaptive management and refined risk assessments. This is particularly important as continual improvement in rehabilitation techniques will occur over time and proponents should actively include this in their mine closure planning (DMP & EPA, 2015).



Source: Modified from DMP & EPA (2015) Mine Closure Guidelines

FIGURE 1.1 The stages of mining and associated development of completion criteria as defined by the Western Australian mine closure planning process

1.2 Project scope and purpose

This report has been designed to extend information provided in best practice guides, such as the Leading Practice Sustainable Development Program (LPSDP) for the *Mining Industry – Mine Closure* handbook (LPSDP 2016d). The intent of the report is to support the development and implementation of completion criteria and associated monitoring programs as outlined in the *Guidelines for Preparing Mine Closure* Plans (DMP & EPA 2015). The guidelines have been developed by the Western Australian Department of Mines and Petroleum (DMP, now Department of Mines, Industry, Regulation and Safety (DMIRS)) and the Environmental Protection Authority (EPA) to meet the respective objectives of the Western Australian regulatory requirements:

> *"The Department of Mines and Petroleum's (DMP) principle closure objectives are for rehabilitated mines to be (physically) safe to humans and animals, (geo-technically) stable, (geo-chemically) non-polluting/ non-contaminating, and capable of sustaining an agreed post-mining land use."*
>
> *"The Environmental Protection Authority's (EPA) objective for Rehabilitation and Decommissioning is to ensure that premises are decommissioned and rehabilitated in an ecologically sustainable manner."*

The Department of Mines, Industry Regulation and Safety (DMIRS) and the EPA require the following information to be included in a Mine Closure Plan:

- Completion criteria that will be used to measure rehabilitation success;
- Completion criteria that will demonstrate the closure objectives have been met; and
- Completion criteria developed for each domain which consider environmental values.

Mine Closure Plans are regularly reviewed over the life of a mine, with updates on the further refinement and development of completion criteria. This provides direction for the monitoring of information required to develop robust criteria and considering trajectory of rehabilitation management actions.

1.3 Terminology and definitions

In this document, the term 'rehabilitation' is defined as the return of disturbed land to a safe, stable, non-polluting/ non-contaminating landform in an ecologically sustainable manner that is productive and/or self-sustaining, and is consistent with the agreed post-mining land use (DMP & EPA 2015). This description fits the general practice of design and construction of landforms and soil profiles together with revegetation as described in the LPSDP handbook (LPSDP 2016e), that is typical of almost all Australian mine sites, and is distinct from 'ecological restoration' (definition in Table 1.1).

A feature of any discussion of completion criteria for mine rehabilitation is the differences in terminology used to describe various elements of a completion criteria framework, or differences in meaning for the same terminology. Predictably, these differences in terminology can be found between different countries and jurisdictions, but also exist between mining operations, and their stakeholders within Western Australia. For this review, we have drawn on language from guidance published by Western Australia (DMP 2016), Queensland (DEHP 2014) and New South Wales (NSW) (TIRE 2013), the Australian LPSDP series (LPSDP 2016d,e) and the National Standards for the Practice of Ecological restoration Australiasia (SERA 2017).

TABLE 1.1 Definitions of key terminology

Term	Definition	Source(s)
Aspect	A key theme or element of rehabilitation that needs to be addressed in order to meet the mine site's closure objectives. Also known as 'Environmental factor'.	Adapted from DMP & EPA 2015
Attribute	A specific parameter that can be quantified, or task that can be verified to have been achieved. Forms the basis for a criterion. Also known as 'Indicator' or 'Performance indicator'.	Adapted from DMP & EPA 2015; McDonald *et al.* 2016
Auditing	The process whereby the site's level of rehabilitation performance – as reflected in the monitoring data - is compared with the standards agreed in the completion criteria.	
Closure	A whole-of-mine-life process, which typically culminates in tenement relinquishment. It includes decommissioning and rehabilitation.	DMP & EPA 2015
Closure objectives	Required outcomes, for each aspect, that will allow return of disturbed land to a safe, stable, non-polluting/ non-contaminating landform in an ecologically sustainable manner that is productive and/or self-sustaining and is consistent with the agreed post-mining land use. Closure objectives should be i) realistic and achievable; ii) developed based on the proposed post-mining land use(s); and iii) as specific as possible to provide a clear indication on what the proponent commits to achieve at closure. They may include, but should not be limited to, compliance, landforms, revegetation, fauna, water, infrastructure and waste.	
Completion	The goal of mine closure. A completed mine has reached a state where mining lease ownership can be relinquished and responsibility accepted by the next land user.	DMP & EPA 2015

Table 1.1 continues following page...

TABLE 1.1 Definitions of key terminology

Term	Definition	Source(s)
Completion criteria	Agreed standards or levels of performance that indicate the success of rehabilitation and enable an operator to determine when its liability for an area is able to cease. A *criterion* is a condition to be achieved for a particular attribute that is critical in achieving the objective. Where possible, criteria should be quantitative and/or capable of objective verification. Also known as 'completion, closure, success or performance criteria', 'indicator', 'standard' or 'target'. Sometimes presented as separate indicator (what to measure) and standard (the level to be achieved).	
Data monitoring	The collection and interpretation of information that is necessary to assess the progress towards meeting completion criteria.	
Ecological restoration	The process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed.	SERA 2017
Monitoring	The observation and checking of the progress or quality of performance over a period of time.	
Objective	See closure objective.	
Post-mining land use (PMLU)	Term used to describe a land use that occurs after the cessation of mining operations.	DMP & EPA 2015
Reference	A suite of conditions that serve to inform the level of performance to be used in the definition of completion criteria. References should provide indication on measurable targets for those attributes that will define completion criteria. For each mine site, one or more references can be used.	
Rehabilitation	The return of disturbed land to a safe, stable, non-polluting/non-contaminating landform in an ecologically sustainable manner that is productive and/or self-sustaining consistent with the agreed post-mine land use.	DMP & EPA 2015
Relinquishment	A state when agreed completion criteria have been met, government "sign-off" achieved, all obligations under the *Mining Act 1978* removed and the proponent has been released from all forms of security, and responsibility has been accepted by the next land user or manager.	DMP & EPA 2015
Corrective action	Changes made to a nonconforming site to address the deficiency. May also be referred to as 'remedial action' or 'active management'.	ANZMEC & MCA 2000
Revegetation	Establishment of self-sustaining vegetation cover after earthworks have been completed, consistent with the post-mining land use.	DMP & EPA 2015
Verification	The method used to confirm that the identified standard for the criterion has been achieved. Verification may rely on quantitative measurements or could be a process of certification, for example in terms of compliance with an approved design.	

2 The completion criteria framework

2.1 The Framework

The aim of the Framework is to provide greater consistency for mining companies to develop risk-based completion criteria and monitoring. In addition, it aims to support the regulators by providing greater consistency in the development of mine closure plans across companies, locations and commodities. The framework will also provide a common set of definitions, processes and methods. For the wider community and environment, a better process will assist in leading to a greater number of mines being closed and ultimately, relinquished.

2.2 Framework outline

The framework identifies six key components (Figure 2.1) in the development of, and assessment against, completion criteria: 1) selection of post-mining land uses (PMLUs); 2) aspects and closure objectives; 3) selection of references; 4) selection of attributes and risk-based prioritisation; 5) development of completion criteria; and 6) monitoring. Additional key factors to consider are briefly discussed (e.g. federal and state planning, change management, learnings and innovation, consideration of offsets). Within each major component, several sub-steps are also required (Figure 2.2).

In some cases, the framework may be used as a linear pathway to develop risk-based completion criteria, whereas in others, it may be more appropriate to consider and develop a number of the components consecutively, or in an alternate order. Examples of the different approaches to using the framework are presented in Figure 2.1. For clarity and consistency, this document presents the framework as the linear process (Figure 2.1a) but acknowledges that the development of completion criteria, and monitoring progress towards achieving them, is an iterative process that involves multiple stakeholders and continuous refinement, measurement and re-definition along the lifecycle of a mine. The framework also allows for application across multiple spatial domains within a mine site, recognising that in some situations different potential PMLUs, closure objectives and completion criteria may be developed across a single site.

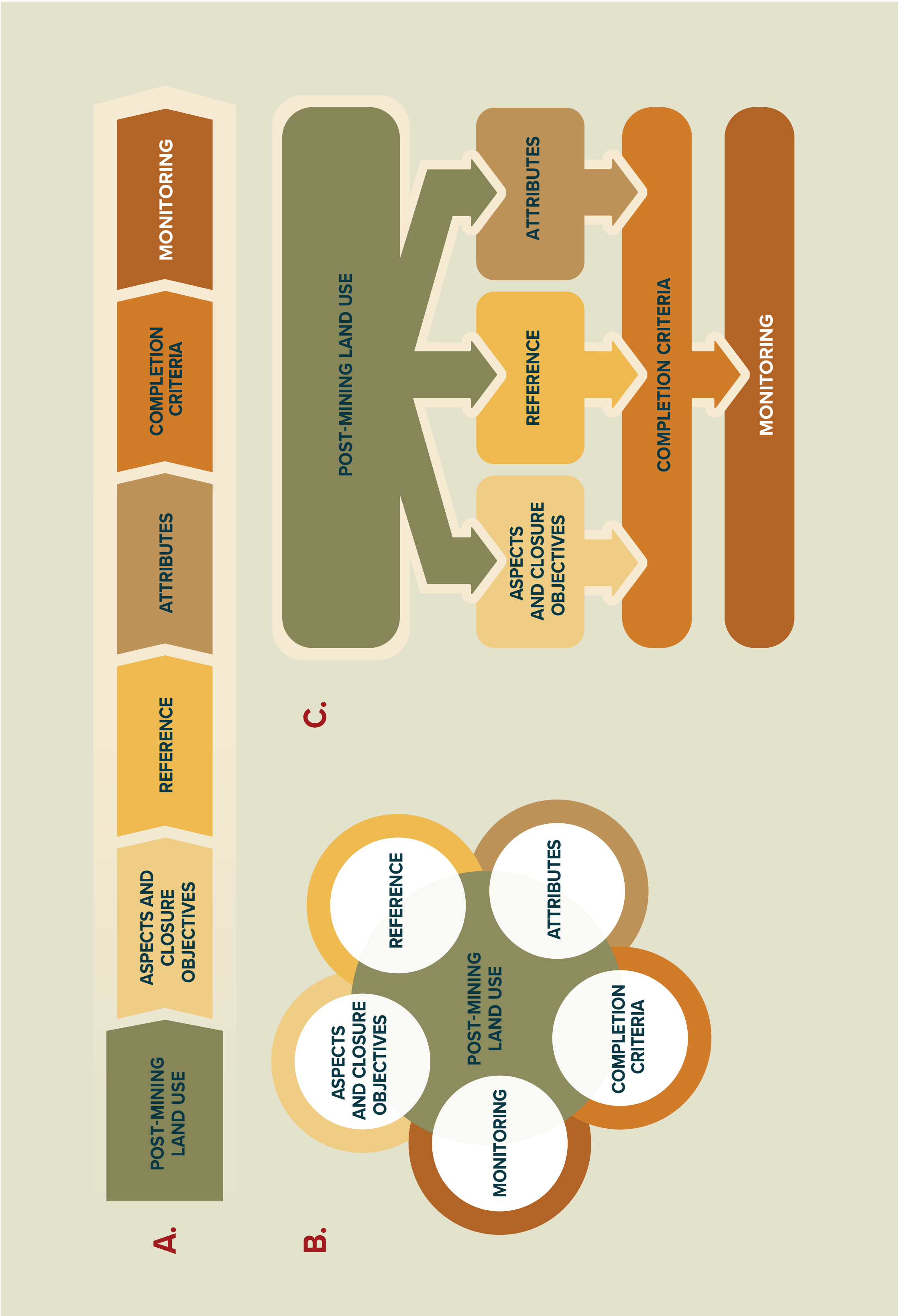


FIGURE 2.1 Six key components to the development and assessment against completion criteria. a) Linear process, b) Consecutive approach, c) Combination of linear and consecutive approach.

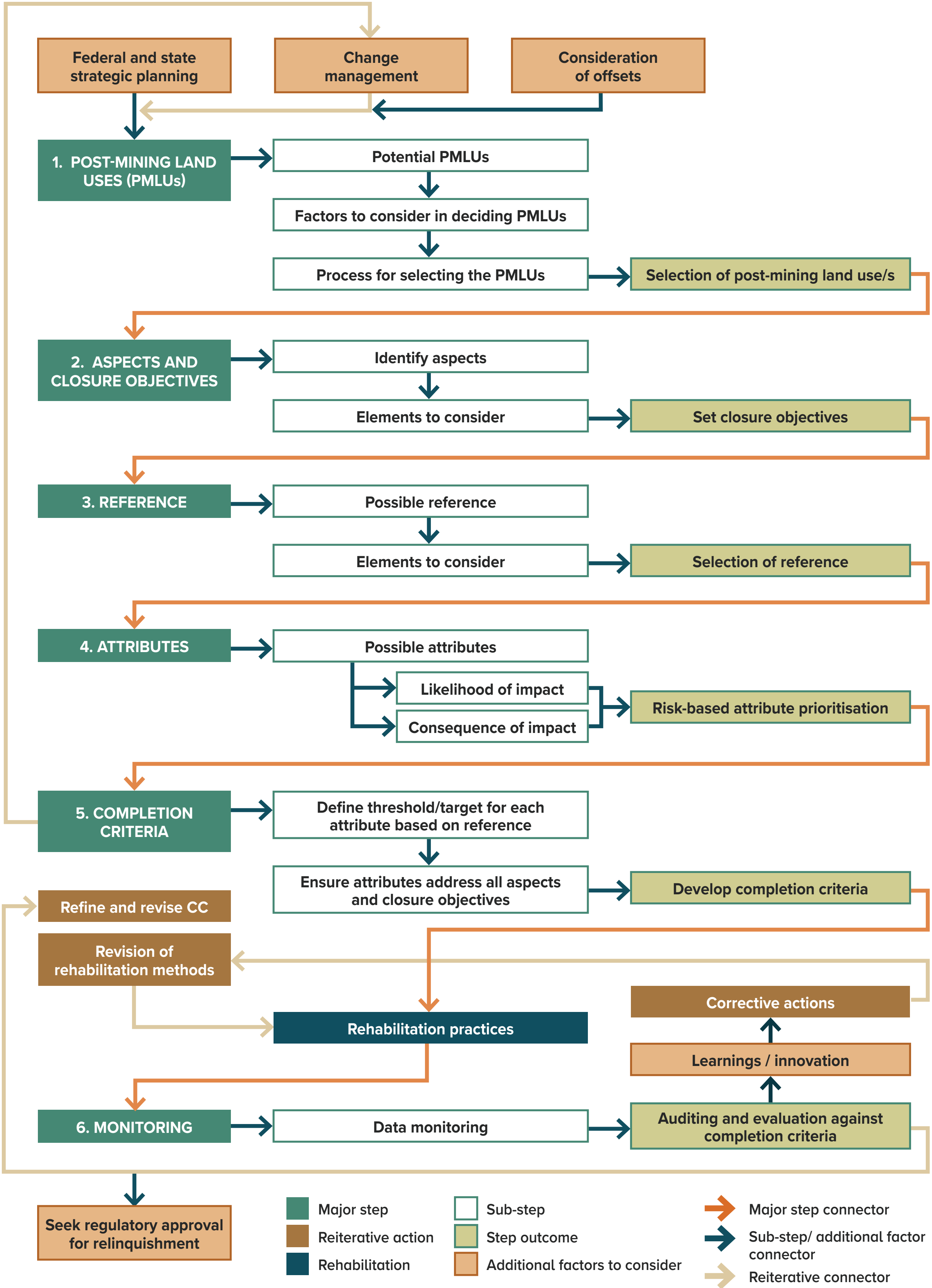


FIGURE 2.2 Framework for the definition of completion criteria (linear approach)

2.3 Federal and state planning

Prior to the definition of site-specific completion criteria, it is important to establish if there is any federal or state strategic planning over the covenanted area that may dictate what the PMLUs will be. If not already understood, mining proponents should inform themselves about strategic land planning schemes through consultation with DMIRS, DWER, EPA and DPLH. In Western Australia, this may include but not be limited to DMIRS, DWER & EPA; DPLH as well as relevant development commissions and local councils.

2.4 Component 1 – Post-mining land uses (PMLUs)

The PMLUs need to be considered early on in the planning stage, and it is recommended that they are identified and agreed upon before approval of new projects (DMP & EPA 2015). While the most common PMLU for Western Australian mines is to revert to pre-mining land use, such selection should be based on a thorough examination of all possible options. Alternative post-mining land uses should not be ruled out, as it may achieve a beneficial outcome for the key stakeholders in some circumstances. Where the opportunity presents, mining companies may also consider repurposing the use of the land for other beneficial uses if the legislation allows and relevant stakeholders and regulators agree. Hence, this framework proposes that PMLUs are selected through a process involving three steps: identification of potential PMLUs; factors to consider in the selection of PMLUs; and a systematic decision-making process. Early-stage processes may consider multiple PMLUs scenarios within the framework as part of an approach that provides greater flexibility, as it does not preclude the change of one PMLU to another.

2.4.1 Potential PMLUs

At the early stages of mine closure planning, all potential PMLUs should be considered. State, national and international guidelines (DEHP 2014; DMP & EPA 2015; Heikkinen *et al.* 2008), as well as academic articles (Cowan *et al.* 2010; Kaźmierczak *et al.* 2017) prescribe a series of requirements that PMLUs should fulfil. While there is not one set of commonly accepted guidelines, there is consistency in proposing that PMLUs must be:

- Relevant to the tenure;
- Relevant to the environment where the mine operates, considering, for example, natural conditions, terrain configuration, vegetation and water bodies;
- Considerate of historical commitments at the site and at a regional scale;
- Achievable in the context of land capability and safeguarded against physical, chemical and biological hazards;
- Acceptable to key stakeholders, including regulators, local authorities and indigenous groups;
- Ecologically sustainable and, where appropriate, economically productive; and
- Within any other legislative constraints.

Based on the review undertaken and consultation with stakeholders, this framework proposes the use of the Australian Land Use and Management (ALUM) classification (ABARES 2016) for the definition of PMLUs (summarised in Table 2.1). This has several advantages. First, it provides a comprehensive and concise definition of land uses. Second, it makes the definition of PMLUs consistent with other land planning institutions, not only in Western Australia, but also applicable across Australia. Third, as definitions of land use change overtime, this framework will always remain up-to-date by referring to the latest ALUM classification, which is periodically updated.

Photo courtesy: Stacey Williams

The ALUM classification system provides a nationally systematic, logical and consistent method to present land use information across Australia in a hierarchical structure. There are six primary classes of land uses included in the classification: conservation and natural environments; production from relatively natural environments; production from dryland agriculture and plantations; production from irrigated agriculture and plantations; intensive uses; and water. The hierarchical system identifies the minimum level of classification required, but also allows higher level of land use to be assigned if appropriate — see Figure 1 in ABARES (2016). The classification system supports the classification of land for users that are interested in process and outputs as well as allocation of primary and ancillary land uses. At times, there may be mine features that are unable or highly unlikely to have a beneficial next land use. The ALUM classification also provides a categorisation for this, 'Extractive Industry not in use', which may be appropriate for certain areas within a site. Areas assigned to this class would need to be justified, accurately defined and, as with other PMLUs, agreed upon with regulators and stakeholders. There may also be PMLUs that are desirable, but not specifically listed under the ALUM classification. In these scenarios, the PMLU can still be proposed with the most appropriate ALUM class assigned and then further detail provided to stakeholders and regulators as appropriate (e.g. carbon farming could be classified under, 'production native forests, other forest production', in Table 2.1 below).

TABLE 2.1 Summary of Australian Land Use and Management classification

Primary class	Definition	Secondary classes
1. Conservation and Natural Environments	Conservation purposes based on maintaining the essentially natural ecosystems present.	Nature conservation; Managed resource protection; Other minimal use
2. Production from Relatively Natural Environments	Primary production with limited change to the native vegetation.	Grazing native vegetation; Production native forests
3. Production from Dryland Agriculture and Plantations	Primary production based on dryland farming systems.	Plantation forests; Grazing modified pastures; Cropping; Perennial horticulture; Seasonal horticulture; Land in transition
4. Production from Irrigated Agriculture and Plantations	Primary production based on irrigated farming.	Irrigated plantation forests; Grazing irrigated modified pastures; Irrigated cropping; Irrigated perennial horticulture; Irrigated seasonal horticulture; Irrigated land in transition
5. Intensive Uses	Land subject to extensive modification, generally in association with closer residential settlement, commercial or industrial uses.	Intensive horticulture; Intensive animal production; Manufacturing and industrial; Residential and farm infrastructure; Services; Utilities; Transport and communication; Mining; Waste treatment and disposal
6. Water	Water features.	Lake; Reservoir; River; Channel/aqueduct; Marsh/wetland; Estuary/coastal waters

Source: ABARES 2016

2.4.2 Factors for selecting PMLUs

The Western Australian Guidelines for Preparing Mine Closure Plans (DMP & EPA 2015) provide a hierarchical guide that prioritises natural ecosystems before alternative land uses. While the majority of mine closure plans in Western Australia follow such instruction (MINDEX 2017), sometimes the previous land use is no longer achievable or appropriate. In such situations, setting unrealistic goals against unachievable PMLUs may lead to poor closure standards being achieved and an inefficient use of resources (McCullough, 2016). Thus, when selecting the PMLUs, it is critical to take into consideration all elements that may constrain or favour the various PMLUs options. Once formal approval has been obtained, industry is legally obliged to comply with that requirement. A summary of factors to be considered in the selection of PMLUs is presented in Table 2.2.

TABLE 2.2 Factors to consider in the selection of PMLUs

Factors	Definition
Land tenure	Existing land tenure that specifies what the PMLUs will be.
Legislative constraints	Conditions pertaining to any relevant legislation and Acts.
Strategic planning	Local and regional land planning schemes by relevant authorities such as Department of Primary Industries and Regional Development; Department of Planning, Lands and Heritage; Pilbara Development Commission.
Pre-mining conditions	Conditions of the area prior to mining.
Acceptability to key stakeholders	Feedback received through continuous stakeholder engagement.
Heritage (natural, cultural or historical)	Impact associated with the PMLUs on heritage and agreement with relevant government departments and stakeholders.
Physical, chemical and biological hazards (anthropogenic and naturally occurring)	Hazardous materials, unsafe facilities, contaminated sites, radioactive materials, among others.
Consistency with other mines in the area	PMLUs proposed by other nearby mines where applicable and justified as the most acceptable approach.
Compatibility with surrounding area	Integration of the PMLUs with the surrounding landscape in terms of aesthetics, land capability, etc. taking into account the changes occurred over the life of mine.
Feasibility/viability	PMLUs should be achievable in the context of post-mining land capability.
Added value	Value generated as a result of the PMLUs.

2.4.3 Processes for selecting the PMLUs

Existing frameworks in Australia (ANZMEC & MCA 2000; DMP 2016; LPSDP 2016d) indicate that PMLUs should be agreed through consultation with key stakeholders and must take into account any existing obligations or commitments made. These conversations should be informed by a decision-making process to identify the most suitable PMLUs (Table 2.3). There are a number of decision-making frameworks available to assist in this process including Multi-Attribute Decision-Making (MADM) and Mined Land Suitability Analysis (MLSA), Benefit-Cost Analysis (BCA), Land capability assessment (LCA)/Land suitability assessment (LSA) or Ecosystem Services Assessments (ESA) (Table 2.3).

Decision-making frameworks for selecting PMLUs may integrate a variety of environmental, social or economic values. These may range, for example, from local priorities to overall societal welfare. Certain methods, like LCA or ESA, are more focussed on environmental and ecosystem values, while stakeholder consultation tends to prioritise socio-economic considerations. MADM and BCA allow the incorporation and weighting of the multiple values impacted by PMLUs.

TABLE 2.3 Approaches for the selection of PMLUs

Decision-making processes	Definition
Direct consultation with stakeholders and regulators	PMLUs selected in accordance with stakeholders' preference and/or policy requirements
Multi-attribute decision-making (MADM) and Mined Land Suitability Analysis (MLSA)	Systematic methodology to evaluate, compare and rank project alternatives against a set of criteria. Criteria-weighting and options-evaluation are often carried out using analytical hierarchy process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)
Benefit-Cost Analysis (BCA)	A transparent and systematic decision-making framework to evaluate all the costs and benefit impacts of a project on society. By expressing all impacts in the same unit, the positive and negative effects of a project can be compared
Land capability assessment (LCA) or Land suitability assessment (LSA)	A five-class system based the capacity of land to sustain specific land uses such as cropping, irrigated agriculture and forestry
Ecosystem Services Assessments (ESA)	Evaluation of the conditions and processes through with natural ecosystems, and the species that make them up, sustain and fulfil human life. Categorises ecosystem services in supporting, provisioning, regulating, and cultural services

2.4.4 Consideration of offsets

An environmental offset is an offsite action or actions to address significant residual environmental impacts of a development or activity. An offset can either be direct (an action designed to provide for on-ground improvement, rehabilitation and/or conservation of habitat) or indirect (actions aimed at improving scientific or community understanding and awareness of environmental values that are affected by a development or activity) (Government of Western Australia 2011). Environmental offsets may be factored into the approvals process and, thus, are a key consideration for the selection of the PMLUs. Offsets in the form of on-ground management include revegetation (establishment of self-sustaining vegetation cover) and restoration (the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed) (Government of Western Australia 2014; McDonald *et al.* 2017). The objective of environmental offsets through on-ground management actions result in tangible improvement to environmental values in the offset area and thus may be correlated to the PMLUs for that area if it falls within a mining company's tenement.

2.5 Component 2 – Identifying aspects and defining closure objectives

2.5.1 Identifying aspects

ASPECT: An aspect is a key theme or element that needs to be addressed during closure.

Following selection of the PMLUs, aspects relevant to a site need to be identified for closure objectives to be developed. A typical mine site in Western Australia may identify 10–15 relevant aspects, while complex sites may require more. Aspects may include, but are not limited to, those as listed in Table 2.4, e.g. compliance, landforms, revegetation, fauna, water, infrastructure and waste.

2.5.2 Defining closure objectives

CLOSURE OBJECTIVE: Closure objectives provide a clear indication on what the proponent commits to achieve at closure.

The closure objectives can be developed once the aspects have been identified. Closure objectives define the closure outcomes and should be i) realistic and achievable; ii) developed based on the proposed PMLUs; and iii) as specific as possible to provide a clear indication on what the proponent commits to achieve at closure (DMP & EPA 2015). An example of a closure objective for each aspect is provided in Table 2.4, but it emphasised that each closure objective developed should appropriately detailed to address pertinent issues for the specific site. Examples provided should not be interpreted to be the default for the closure objective. Multiple closure objectives may be required for each aspect and an aspect may be relevant for more than one closure objective.

The compiled set of aspects and closure objectives developed should be site specific and able to satisfy that the site is safe, stable, non-polluting and able to support the agreed end land use, covering all major considerations for mine closure and relinquishment.

TABLE 2.4 Examples of aspects and closure objectives

Aspect	Closure objective
Social	Actively engaged and consulted key stakeholders that have agreement on the post-mining land use.
Physical and surface stability	Creation of safe and stable landform that minimises erosion and supports vegetation.
Mine wastes and hazardous materials	Achieve conditions where contaminants of the site are consistent with the final land use requirements. Minimise the potential for off-site pollution.
Water and drainage	Surface drainage patterns are reinstated and consistent with the regional drainage function.
Soil fertility and drainage	Suitable growth medium is in place to facilitate rehabilitation and agreed post-mining land use.
Flora and vegetation	Restored landscapes that are comparable to reference vegetation communities established through leading practice restoration techniques and within the constraints of the post-mining environment.
Ecosystem function and sustainability	The rehabilitated ecosystem has function and resilience indicative of target ecosystem.

2.6 Component 3 – Establishing a reference

REFERENCE: A suite of conditions that serve to inform the level of performance to be used in the definition of completion criteria.

Once the PMLUs, aspects and closure objectives have been identified, it is necessary to select the reference against which completion criteria will be defined. Data collected from references is used to inform the attributes and standards required for the development of the completion criteria. In addition, such data will be used to demonstrate progress towards meeting completion criteria throughout closure and rehabilitation works. It is important to note that the reference informs the definition of completion criteria by providing an objective assessment of attribute states relevant for PMLUs, but the selection of references is independent of the standard applied in the completion criteria. Reference assessment indicates how attributes perform under reference states, while standard is usually an agreed value expressed relative to these. Approaches to determining the relative values of the reference that will be employed as the completion criterion are described in Section 2.8. Depending on the PMLUs and the specific site, several different approaches to reference identification and use may be suitable (Table 2.5). Relevant to the case of mine sites returning to pre-mining land use, McDonald *et al.* (2017) provide further details on the selection of a reference ecosystem that is based on an actual site or conceptual model.

Pre-disturbance conditions may often be an appropriate reference and thus, can be used when the necessary information is available. Baseline survey information, however, may not reflect current or future conditions within the mine life cycle, and a principle of completion criteria development is that the change in the nature of the site as a result of mining is acknowledged. If sufficiently detailed baseline data is not available, an appropriate analogue site should be identified. The analogue site is an intact area (or combination of areas) that reflects the desired closure outcomes of the mine site. These may include, for example, adjacent or near-by ecosystems of the same vegetation type, other mining sites with similar characteristics or existing areas with the same agreed PMLUs that have achieved the agreed objective and completion criteria.

In cases when baseline conditions and analogue sites are not available or appropriate, alternative methods may be used. For example, reference conditions that can be defined based on closure outcomes that can be achieved using leading practices. Such conditions are defined based upon laboratory experiments, in situ field trials, industry standards and best-available rehabilitation techniques. Importantly, references based on leading practices must be evidence based and ascertain that the benchmarks are demonstrable examples of best practice and outcomes. In these circumstances, mining proponents must provide sufficiently detailed information regarding which best practices they intend to adopt and how these will be carried out at the specific mine site. The selection of best practices and expected rehabilitation outcomes must be justified to the level of detail and accuracy that will satisfy regulators' requirements.

Particular challenges exist for pit lakes, which are unlikely to have relevant references or analogues due to their depth, bathymetry and/or catchment area. Solutions to this challenge are only starting to be developed (Blanchette & Lund 2016). Relevant references or analogues for river diversions and modified rivers are difficult to find due to high local variability and cumulative impacts. A proposed approach to filling this knowledge gap is provided in Blanchette & Lund (2017) and Blanchette *et al.* (2016).

When the PMLUs are not for conservation or natural environments, a reference may be defined based on a site of the same designated PMLUs. An example may be a residential development of renewable energy plant, which can serve as models for the rehabilitated site post-mining.

Importantly, more than one reference may be used to inform the definition of completion criteria, where justified. It is possible that performance levels for certain attributes are mirrored in one set of references (e.g. groundwater quality in baseline conditions), yet other elements find a more appropriate reference elsewhere (e.g. vegetation cover based on 'leading practice'). Thus, conceptual models are synthesis of several references, including analogue sites, field indicators, historical data and trajectory models.

Mine closure plans should include documentation and justification of the processes used in the identification and selection of references. This documentation should include how and why a decision was identified to be more appropriate than other alternatives.

TABLE 2.5 Possible reference for post-mining land use

References	Definition
Baseline conditions	Conditions present at the site prior to mine use.
Analogue site	Adjacent or near-by sites from which the necessary attributes to can be quantified to develop completion criteria for the sites agreed upon PMLUs.
Leading-practice outcome	The conditions that most closely define the values desired for the site and that can be realistically achieved. Such conditions are defined based on laboratory trials, on-site trials, basis of design, industry standards and demonstrated effective leading-practice techniques.
Other alternative sites	Example sites for alternate PMLUs, such as renewable energy farm or residential development.
Conceptual model	Synthesis of several data-based references including existing sites, field indicators and historical and predictive records.

Photo courtesy: Dean Revell

2.7 Component 4 – Attributes

2.7.1 Attribute identification

ATTRIBUTE: A specific parameter that can be quantified, or task that can be verified to have been achieved.

A large number of attributes may be used in the definition of completion criteria, with this framework presenting a sub-selection of those most recommended (Table 2.6), given their ease of monitoring and adequacy as rehabilitation performance indicators. While extensive, the lists provided are not exhaustive and additional attributes may be appropriate, based on specific site requirements.

In the development of a MCP, Table 2.6 may serve as a reference for proponents to select those attributes that are specifically relevant to their particular mine site. Selected attributes should be measurable and their metrics comparable to the targets derived from the reference. While attributes are grouped relative to aspects, it should be noted that certain attributes may be relevant to more than one aspect, e.g. slope of waste dumps may affect drainage, waste and physical stability. Consequentially, a single attribute may provide evidence towards multiple closure objectives, whilst several attributes may be required to demonstrate progress towards a single closure objective.

TABLE 2.6 Recommended attributes applicable for the definition of completion criteria*

Aspect	Possible attributes	Type**
Water and drainage	Design and construction of landforms and drainage features	P
	Quality, quantity and fate of surface water flow	Q
	Integrity of drainage structures	Q/C
	Connectivity with regional drainage (lakes & rivers)	Q
	Pit lake bathymetry	P/Q
	Pit lake sediment quality	Q
	Pit lake water quality	Q
	Surface water quality, quantity and timing	Q
	Surface water chemistry and turbidity	Q
	Aquatic biota (algae, macrophytes; invertebrate and vertebrate fauna)	Q
	Riparian vegetation	Q
	Surface water chemistry and turbidity	Q
	Groundwater chemistry	Q
Mine waste and hazardous materials	Landform design and construction	P
	Particle size and erodibility	Q
	Strength	Q
	Acid, alkali or salt production potential	Q
	Total and soluble metals and metalloids	Q
	Spontaneous combustion potential	Q
	pH and electrical conductivity	Q
	Radiation	Q
	Asbestiform minerals	Q/P
	Design and construction of containment structures for hostile wastes	P
	Physical integrity of containment structures for hostile wastes	Q
	Dust	Q
	Sediment quality	Q
Physical and surface stability	Soil coarse fraction content	Q/P
	Soil fraction particle size analysis (texture)	Q
	Hydraulic conductivity	Q
	Sodicity, slaking and dispersion	Q
	Soil strength	Q
	Surface resistance to disturbance	Q
	Erosion rills, gullies, piping	Q
	Sediment loss	Q
	Placement of appropriate surface materials	P/Q
	Earthworks as designed	P
Soil fertility and surface profile	Bulk density, depth of ripping and soil strength	Q/P
	Aggregate stability	Q
	Water infiltration	Q
	Plant-available water	Q
	Soil profile as designed	P/Q
	Electrical conductivity	Q
	Nutrient pools (N, P, K, S)	Q
	Plant-available nutrients; cation exchange capacity	Q
	Heavy metal bioavailability	Q

Table 2.6 continues following page...

TABLE 2.6 Recommended attributes applicable for the definition of completion criteria*

Aspect	Possible attributes	Type**
Flora and vegetation	Numbers of species and quantities of viable seed in seed mix	P
	Number of seedlings planted	P
	Vegetation cover	Q
	Species richness	Q
	Vegetation composition	Q
	Litter cover	Q
	Presence/abundance of keystone, priority or recalcitrant species	Q/C
	Presence of key functional groups	Q/C
	Community structure – presence of all strata	Q/C
	Weed species presence and abundance	Q/C
	Aquatic biota (algae, macrophytes; invertebrate and vertebrate fauna)	Q
	Riparian vegetation establishing	Q
Flora / fauna	Constructed habitat features (breeding and refuge)	P
	Vegetation and litter habitat (foraging, breeding and refuge, in general or for conservation significant species)	Q
	Presence of keystone or significant species	Q/C
Ecosystem function and sustainability	Rainfall capture and infiltration	Q
	Soil microbial function – solvita, respiration	Q
	Presence of different successional groups	Q/C
	Indicator species group richness and composition	Q
	Plant growth, survival, rooting depth, physiological function	Q
	Plant species reproduction and recruitment: flower, seed production, seedbanks	Q
	Capability for self-replacement: seedbanks, seedlings mature 2nd generation	Q
	Connections with nearby systems in place, functioning: corridors; pollinator, gene movement	Q/P
	Key threats absent or managed: feral grazers, predators, pathogens, weeds, etc.	Q/C/P
	Resilience to disturbance (such as fire, drought, extreme weather events)	Q
Social / economic	Recreation opportunities provided, maintained	P
	Heritage values protected	P
	Aesthetics (visual amenity)	P
	Access and safety	P
	Infrastructure removed	P
	Sustainability of utilities	P
	Social progress: health, education, employment, livelihoods and incomes	P/Q

* Not all possible attributes are appropriate for every site, and other attributes not listed may be appropriate.

** **Type:**

P = installed/built as planned – a process for emplacing these attributes is approved initially and then certified as and when constructed;

C = categorical – the feature is required to be present or absent;

Q = quantitative – the attribute can be measured and compared against a numerical target.

2.7.2 Risk-based attribute prioritisation

Early stages of mine closure planning should consider a broad range of attributes relevant for the definition of completion criteria. Given that completion criteria should be site specific, not all possible attributes will be used at every site. Among those attributes that are deemed relevant for the definition of completion criteria, some attributes may be more critical than others by posing a greater risk to the fulfilment of closure objectives. This section presents a risk-based attribute prioritisation process, which provides a systematic tool for decision making aimed at a) discerning which attributes should be used to define completion criteria and b) ranking the criticality of selected attributes.

In some instances, the risk-based prioritisation process may rank attributes as very ‘low priority’, meaning that the attribute poses no, or very low, risk to the fulfilment of closure objectives. In such cases, subject to agreement from the regulator, these may be excluded from the list of completion criteria. An example may be ‘impact on heritage’ in an area where no heritage sites exists.

On the other hand, those attributes that may pose a risk to the fulfilment of closure objectives as a result of mining activities should be considered in the definition of completion criteria. While companies have an obligation to meet their agreed completion criteria, it is important to recognise that some criteria may be more critical than others. In order to develop an efficient and effective suite of completion criteria, it is advisable that such efforts are prioritised based on the criticality of each attribute. Thus, attributes identified as ‘high priority’ should be monitored and audited with a greater level of detail and higher frequency compared to ‘medium or low priority’ attributes. As an example, a mine site could be within a river catchment that supports a rich community of water-dependent ecosystems where the PMLU is nature conservation. The site may, thus, be subject to completion criteria based on ‘surface water quality’ and ‘construction of fauna habitat features’. Both heavily polluted surface water and an insufficient number of habitat features would result in failure to meet completion criteria. Nonetheless, the former poses a much greater risk for closure outcomes i.e. the site being non-polluting and able to support a self-sustaining, agreed PMLU.

The risk-based prioritisation process also provides an opportunity to consider individual attributes and completion criteria within the context of closure objectives being met and a holistic understanding of rehabilitation success. In response to this need, this section proposes a method for attribute prioritisation, based on a systematic, risk-based ranking system. As the Life of Mine (LoM) progresses, the criticality of attributes is likely to change and, thus, the risk-based ranking should be periodically re-assessed.

> **The priority of each attribute is defined based upon *the risk of the attribute preventing the fulfilment of the closure objective.***

Photo courtesy: DBCA

An example of the attribute prioritisation process follows the structure of commonly used risk management approaches (ISO 2018; LPSDP 2016g) where risk levels are categorised through a matrix of maximum reasonable likelihoods and consequences. Likelihoods and consequences are rated on a 1–5 scale (e.g. rare to almost certain and insignificant to catastrophic, respectively), based on qualitative and semi-quantitative parameters. Several guidelines (Australian Government 2014; LPSDP 2016g) and international standards, such as ISO 31000 (ISO 2015, 2018), provide generic frameworks for identification and management of risks using the likelihood-consequence method. Because risk should be evaluated based on specific circumstances, there are no universal definitions of qualitative ratings (e.g. likely) or thresholds for semi quantitative indicators (e.g. frequency of occurrence).

Therefore, for the purpose of risk-based attribute prioritisation, the definition of likelihood and consequences levels should be specific to each attribute type, and in accordance with international standards listed above, as well as the company's own risk management policies. Examples of definitions of risk likelihood (Table 2.7), consequence (Table 2.8) and categorisation (Table 2.9) are provided below. The risk rating of each attribute provides an indication of the level of detail required in the definition of completion criteria and the type and intensity of monitoring required (Table 2.10). An example of the risk-based attribute prioritisation is provided in Table 2.12. The tables provided below should be reviewed and considered if they are appropriate for a particular site. Currently, there is no standardised risk rating specifically defined towards fulfilment of mine completion criteria — although this may warrant development. Additional examples of risk frameworks can be found in DMP & EPA (2015) *Guidelines for Preparing Mine Closure Plans* and *LPSDP Risk Management* (LPSDP 2016g).

TABLE 2.7 Example of the definitions of likelihood levels for attribute prioritisation

Level	Rating	Description	Probability of occurrence	Frequency of occurrence
5	Almost Certain	Common or frequent event; expected/ proven to occur in most circumstances	> 90%	Monthly occurrence
4	Likely	Has been known to occur; expected/ proven to occur in many circumstances	50 to 90%	Yearly occurrence
3	Possible	Has happened in the past; expected/ proven to occur in some circumstances	20 to 50%	1 in 10 year occurrence
2	Unlikely	Not likely to occur; expected/proven to occur in infrequent circumstances	1 to 20%	1 per 25 year occurrence
1	Rare	Very rare; expected/proven to occur in under rare circumstances	≤ 1%	1 per 100 occurrence

Photo courtesy: DBCA

TABLE 2.8 Example of the definitions of consequence by attribute type

Risk type	Specific risk type	1 – Insignificant	2 – Minor	3 – Moderate	4 – Major	5 – Catastrophic
Health and Safety	Minor injury or illness (first aid or medical treatment)	< 10 individuals	< 100 individuals	< 1,000 individuals		
	Major injury or illness (Medium term, largely reversible); Restricted work injury; Lost Time Injury < 2 weeks	1 individual	< 10 individuals	< 100 individuals	< 1,000 individuals	
	Serious bodily injury or illness (e.g. fractures) and/or Lost Time injury > 2 weeks			1 individual	< 10 individuals	> 10 individuals
	Fatality; or severe irreversible disability (Permanent Disabling Injury) or illness				1 individual	> 1 individual
Legal and compliance		Minor legal issues, non-compliances and breaches of legislation	Breach of legislation with investigation or report to authority with prosecution and/ or moderate fine possible	Major breach of legislation with punitive fine. Significant litigation involving many weeks of senior management time	Major litigation costing $10m+. Investigation by regulatory body resulting in long-term interruption to operations. Possibility of custodial sentence	Major litigation or prosecution with damages of $50m. Custodial sentence for company Executive. Prolonged closure of operations by authorities
Property/ infrastructure	Cost to repair/ replace (and lost revenues)	Approximate range from $0 to $0.1 million	Approximate range from $0.1 to $1 million	Approximate range from $1 to 10 million	Approximate range from $10 million to $100 million	Approximate range from $100 million to $1 billion
Environmental	Environmental impact	Negligible reversible environmental impact requiring very minor remediation	Minor reversible environmental impact requiring minor remediation	Moderate, reversible environmental impact with short-term effect requiring moderate remediation	Serious environmental impact with medium term effect requiring significant remediation	Disastrous environmental impact with long-term effect requiring major remediation

Table 2.8 continues following page...

TABLE 2.8 Example of the definitions of consequence by attribute type (cont'd.)

Risk type	Specific risk type	1 – Insignificant	2 – Minor	3 – Moderate	4 – Major	5 – Catastrophic
Environmental ***(continued)***	Ecosystem function	Alteration or disturbance to ecosystem within natural variability. Ecosystem interactions many have changed but it is unlikely that there would be any detectable change outside natural variation occurrence	Measurable changes to the ecosystem components without a major change in function (no loss of components or introduction of new species that affects ecosystem function). Recovery in < 1 year	Measurable changes to the ecosystem components without major change in function (not loss of components or introduction of new species that affects ecosystem function). Recovery in 1-2 years following completion of Project construction	Measurable changes to the ecosystem components with a major change in function. Recovery (i.e. within historic natural variability) in 3 to 10 years following completion of Project construction	Long-term and possibly irreversible damage to one or more ecosystem functions. Recovery, if at all, greater than 10 years following completion of Project construction
	Habitat or communities	Altercation or disturbance to ecosystem within natural variability. Area of habitat affected or removed <1 %	Reestablishment in < 1 year. Area of habitat severely affected or removed < 5 %	Reestablishment in < 2 years. Area of habitat severely affected or removed < 30 %	Reestablishment in < 10 years. Area of habitat severely affected or removed <90%	Reestablishment in > 10 years. Area of habitat severely affected or removed > 90%
	Species and/or groups of species (including protected species)	Population size or behaviour may have changed but it is unlikely that there would be any detectable change outside natural variation/occurrence	Detectable change to population size and/or behaviour, within no detectable impact on population viability (recruitment, breeding, recovery) or dynamics. Recovery < 1 year	Detectable change to population size and/or behaviour, within no detectable impact on population viability (recruitment, breeding, recovery) or dynamics. Recovery < 2 years	Detectable change to population size and/or behaviour, within no detectable impact on population viability (recruitment, breeding, recovery) or dynamics. Recovery < 10 years	Local extinctions are imminent/immediate or population no longer viable. Recovery > 10 years

Table 2.8 continues following page...

TABLE 2.8 Example of the definitions of consequence by attribute type

Risk type	Specific risk type	1 – Insignificant	2 – Minor	3 – Moderate	4 – Major	5 – Catastrophic
Social	Amenity – Recreation (water sports. Fishing, beach going)	Short-term interruptions in recreational use (1-2 days)	Restricted activities within a localised area for short periods (months)	Communities totally or partially restricted from recreational activities for up to 2 years	Communities totally or partially restricted from recreational activities for 2 to 10 years	General community unable to pursue recreational activities for over 10 years
	Amenity- Sensory/Perception (visual, noise, odour)	Short-term (<1 year) impact on the perceived amenity of the site as a place to live or visit. The region's attractiveness as a place to live is not changed	Short-term (<1 year) impact on the perceived amenity of the site as a place to live or visit. The region's local attractiveness as a place to live is negatively changed	Medium term (1-2 years) impact on the perceived amenity of the site as a place to live or visit. The region's wide attractiveness as a place to live is negatively changed	Long-term (>2 years) community perception that the area is significantly damaged. The region's wide attractiveness as a place to live is negatively changed	Very long term (>10 years) community perception that the area has experienced major damage and has become a place to be avoided
	Media coverage and public reaction	No media coverage. No community complaints	Local media coverage. Complaint to site and/ or regulator	Local media coverage over several days. Persistent community complaints	National media coverage over several days. Community / NGO legal actions	Prominent negative International media coverage over several days
	Company's reputation and local economy	No impact	No impact	Negative impact on local economy	Significant negative impact on share price for weeks. Impact on local economy	Significant negative impact on share price for months
	Non-aboriginal heritage within State/Commonwealth site	No measurable alterations to existing natural or human processes already impacting on heritage sites	Detectable impact with heritage values remaining largely intact	Partial reduction in intrinsic heritage value	Substantial reduction in intrinsic heritage value	Complete loss of heritage intrinsic value
	Non-aboriginal heritage within non-State/Commonwealth site	No measurable alterations to existing natural or human processes already impacting on heritage sites	Partial reduction in intrinsic heritage value	Substantial reduction in intrinsic heritage value	Complete loss of heritage intrinsic value	

Table 2.8 continues following page...

TABLE 2.8 Example of the definitions of consequence by attribute type

Risk type	Specific risk type	1 – Insignificant	2 – Minor	3 – Moderate	4 – Major	5 – Catastrophic
Social ***(continued)***	Aboriginal heritage	No measurable alterations to existing natural or human processes already impacting on Indigenous heritage sites	Partial removal of one or more Indigenous archaeological sites in a specific area within the mine site	Complete removal of one or more Indigenous archaeological sites in a specific area within the mine site	Complete removal of multiple Indigenous archaeological sites in several areas within the mine site	Complete removal of multiple Indigenous archaeological sites across the entire mine site
	Tourism	Limited and short-term (<1 year) reduction in tourist visits with no impact on local businesses	Short-term (<1 year) reduction in tourism use	Medium term (2-10 years) reduction in tourism use	Permanent reduction in tourism use with businesses viability becoming compromised	Permanent loss of attractiveness as a tourist site with significant negative impact on local businesses
	Cost to property (AUD)	<10k	10k – 300k	300k – 2m	3m – 30m	30m

Source: Adapted from LPSDP (2016g)

Photo courtesy: Lesley Gibson

TABLE 2.9 Example of qualitative risk rating matrix

	Likelihood	Consequence					Risk rating
		1 Insignificant	2 Minor	3 Moderate	4 Major	5 Catastrophic	
5	Rare	VL1	VL2	L3	M5	M10	Very Low
4	Unlikely	VL2	L4	L6	M7	H11	Low
3	Possible	L3	L6	M9	H12	H15	Moderate
2	Likely	L4	M8	H12	H16	E20	High
1	Almost certain	M5	M10	H15	E20	E25	Extreme

TABLE 2.10 Relevant actions based on attribute risk rating

Risk rating	Action relevant to management of risk[1]	Action relevant to completion criteria and monitoring
Extreme	Immediate action and formal documentation required. This level of risk is not tolerable, senior management responsibility and formal documentation required. Closure plan needs to implement new controls or detail investigative tasks designed to reduce residual risk to a level acceptable to all stakeholders. Upgrade corporate procedures / instructions if required.	The mine closure plan should list quantitative completion criteria, including details on performance indicators, targets and thresholds. Monitoring at early stages is required, should be comprehensive and occur at a frequency able to rapidly detect if adaptive management is required.
High	This level of risk is not tolerable, senior management responsibility and formal documentation required. Mine closure plan needs to implement new controls or detail investigative tasks designed to reduce residual risk to a level acceptable to all stakeholders. Upgrade corporate procedures / instructions if required.	The mine closure plan should list quantitative completion criteria, including details on performance indicators, targets and thresholds. Monitoring at early stages is highly recommended, should be comprehensive and occur at a frequency able to rapidly detect if adaptive management is required.
Moderate	Management responsibility must be specified in documents, this level of risk is acceptable provided all possible efforts have been made to implement proposed controls. Assess adequateness of existing controls in conjunction with key stakeholders, upgrade corporate procedures / instructions if required.	The mine closure plan may include detailed or indicative completion criteria. Monitoring at early stages is recommended, should be comprehensive and occur at a frequency able to detect if adaptive management is required.
Low	This level of risk acceptable with standard management procedures / instructions that incorporate annual internal review.	Indicative criteria to be included in the mine closure plan, with further (quantitative) detail required in later versions. Some monitoring should be undertaken.
Very Low	Manage by routine procedures; accept risk.	Attribute should be mentioned in mine closure plan to inform indicative qualitative completion criteria. Attributes with risk rating equal to one (1) may be excluded from list of completion criteria.

Source: Doray Minerals Limited 2012

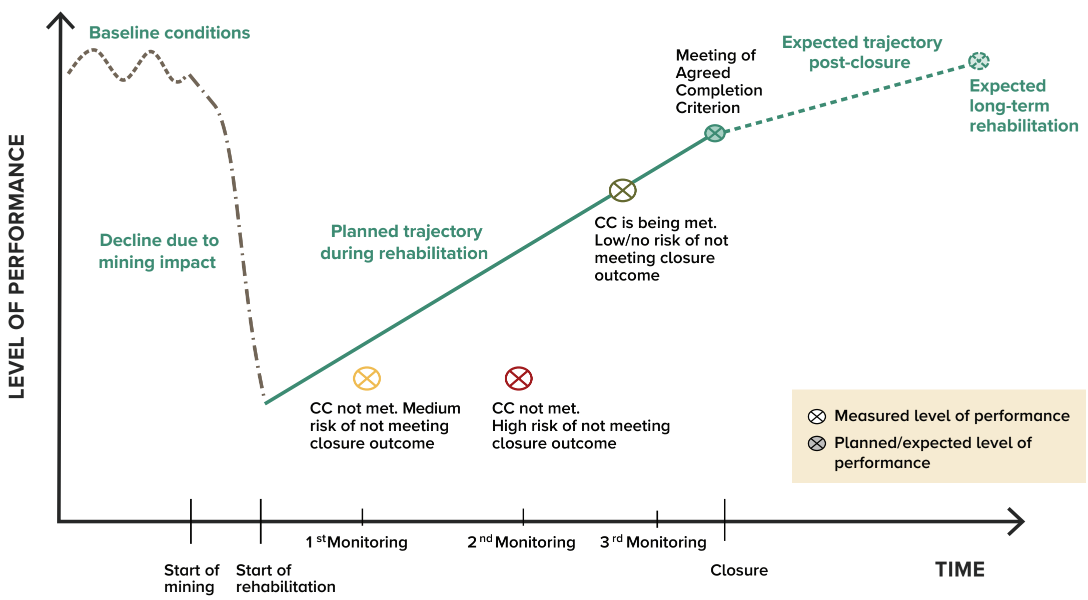
2.8 Component 5 – Completion criteria

COMPLETION CRITERIA: Agreed standards or levels of performance that indicate the success of rehabilitation and enable an operator to determine when its liability for an area can cease.

Once attributes have been selected and prioritised (following Step 4), a completion criterion may be defined by setting a target that will allow the fulfilment of closure objectives. Targets are informed by the reference value for the attribute and must be set to levels that makes them attainable for the particular site and, where appropriate, within a specified timeframe, recognising that the outcome must be supportive of the agreed PMLUs. At the same time, standards must be high enough to ensure that, once they are met, the risk of no-fulfilment of closure objectives is brought down to low or zero.

In early stages of mine closure planning, it is often not known what the attainable and necessary levels of performance will be at time of closure. Hence, information from reference sites (selected in Step 3) may provide an evidence-based indication of the adequate standards for each attribute. For instance, if the agreed PMLUs is to revert to previous land use, then standards should be set at similar levels to those in the baseline conditions. Importantly, standards present in natural ecosystems may take a long time to be reinstated post-disturbance however, decisions will need to be made that the ecosystem is developing towards or has developed to a satisfactory level. Therefore, where appropriate, completion criteria should be time-bound, meaning that targets must be associated to a certain point in time. Defining completion criteria in a time-bound manner is a useful tool given that the same targets at different points in time can reflect very different levels of performance. For example, a vegetation cover of 25% of the mean of the baseline site three years after seeding may be an indication that the vegetation closure objective is likely to be met. Conversely, 25% of the baseline vegetation cover 10 years post replanting most probably points at a failure to fulfil the closure objective. Understanding a systems trajectory and how the indicator is performing relative to this is important when evaluating monitoring data (Figure 2.3) (Adapted from Grant 2006).

However, the same performance level later in time (2nd monitoring round) constitutes a significant gap between the planned and measured level of performance and may trigger corrective rehabilitation actions. Risk levels associated with each of these points are discussed in Step 6. Setting targets to establish a trajectory in a specific region or site may initially be challenging, with rates of rehabilitation yet to be established. Confidence in appropriate targets over time will increase with monitoring and experience. It should be recognised that the gradient or shape of a trajectory line may also not be linear, with alternatives being a curved or step-wise progression depending of the type of completion criteria to be achieved or alternatively may change all together as more data becomes available. Thresholds are another option which may be incorporated to allow for some variability in monitoring values over time and to incorporate trigger points at which further investigation into rehabilitation progressions is warranted.



Source: Adapted from Grant (2006)

FIGURE 2.3 Example of a trajectory approach for the definition of completion criteria

Completion criteria being time-bound also means that certain criteria must be achieved at specific times (e.g. early in the LoM) in order to allow attainment of successive criteria. For instance, correct landform construction should be achieved in early rehabilitation stages, thus ensuring that landforms may support successful revegetation as a result of adequate water retention, slope stability, etc. Correct landform construction is particularly important for pit lakes, prior to filling, to ensure that the fundamentals for allowing the lake to develop along a desirable trajectory are established. Planning for all completion criteria needs to be completed early even though the completion of various criteria may be successional. The time-lines to meet each completion criteria should be determined based on the specific circumstances of every mine site.

Completion criteria will often be defined using numeric targets, especially for parameter-based attributes, such as plant density, slope or soil pH. Targets set should be informed by data derived from the reference(s) to ensure they are meaningful and achievable, with evidence included in the mine closure plan to demonstrate how the numerical values were derived. It is also possible to define completion criteria using task or outcome-based targets as, for example, in the case of qualitative attributes, such as vegetation resilience, heritage, access or safety. In some cases, both quantitative and task-based targets can be used, e.g. landform design and construction (see Table 2.11). Table 2.6 lists quantitative as well as categorical/qualitative and process/task-based criteria.

TABLE 2.11 Examples of numeric and outcome-based completion criteria

Aspect	Attribute	Completion criteria
Flora and vegetation	Plant density	X plants per ha at Y years post start of rehabilitation.
Social	Access and safety	Access to be restricted through fencing and signage.
Mine waste and hazardous materials	Landform design and construction	Landform slope < X°. Landform to be constructed in compliance with design specifications.

Example

Completion criteria should account for spatial variation of targets within the mine sites. For example, different domains or areas may present different characteristics that do not allow the same level of performance to be achieved throughout the site. Definition on completion criteria by domain will assist with progressive rehabilitation, while recognising 'patchiness' or 'heterogeneity' within an area whilst still contributing to the overarching closure objectives.

Another important consideration in the definition of completion criteria is the difference between 'lagging' and 'leading' indicators. Lagging indicators are those that can only be measured after many years into the rehabilitation process e.g. fauna community return. Hence, completion criteria based on lagging indicators may be difficult to achieve, given the time required to assess success. Conversely, leading indicators are those that can be measured at early stages of rehabilitation and provide an indication of future rehabilitation outcomes, such as soil nutrient levels or initial plant populations. A practical example can be found in Alcoa's bauxite mine sites in the jarrah forest, where rehabilitation success is assessed based on four key leading indicators: 9-months stocking rate of Eucalyptus species; 9-month density of legumes; 15-months species richness; and 15-months density of re-sprouter species. Leading indicators can also serve as 'proxies' whereby the attribute of interest is not directly measured, but instead an alternative feature is used in the definition of completion criteria. For instance, Alcoa uses seeding rates and legume plant density as leading/proxy indictors of soil nitrogen. The correlation between the leading indicator/proxy must be clearly articulated and backed up by data in the mine closure plan.

The setting of numeric values which represent the targets of the completion criterion should be informed by the reference value and appropriate for supporting the PMLU. When numerical targets are set, they are not necessarily equal to those in the reference. Informed targets are a part of the key principles of completion criteria. It is important that completion criteria are:

- Agreed;
- Evidence based;
- S.M.A.R.T.;
- Supportive of PMLUs; and
- Achievable given permanent changes to landforms, soils and hydrology.

Several approaches to the setting of the numerical values of targets in relation to the reference may be employed including:

1. The **same as the reference value** (e.g. pre-mining or analogue condition). This may be the ideal approach in many circumstances as it does not involve any subjective judgement but merely represents like for like. This should include an assessment of achievability given changes to landforms, soils and hydrology.
2. **Exceeding the reference** may be appropriate in cases where assessment is required at a point in time and subsequent performance is expected to decline after this assessment time. Tree species density may be one example if, for instance, 8 year old rehabilitation is compared against a mature forest reference.
3. Based on **understanding of risk**. Where risk and control effectiveness are well understood, as may occur for engineering parameters, understanding the acceptable level of risk to delivery of effective PMLUs, including safety elements, may provide objective values for completion criteria targets.
4. Based on **common practice precedent**. An industry-wide or regional standard may already be in place that has proven achievable and acceptable to stakeholders – either an absolute value or a proportion of a reference value.
5. Based on **demonstrated best practice precedent**. A local standard may already be demonstrated for a site or region that has proven achievable and acceptable to stakeholders.
6. Based on **precedent set by previous approvals**. Standards may have been set in previous agreements, specifically in Ministerial statements, and could be applied in equivalent settings.
7. Based on an agreed **proportion of the reference value that is demonstrated** to deliver the support for PMLU required. Research or monitoring may be required to make this case.
8. Based on an agreed proportion of the reference value that is accepted, forming a **likely best guess** or **rule of thumb** that is able to support the PMLU required.

Depending on the monitoring approach, and the level of assessment required, criteria may be expressed as being either higher or lower than a threshold value, within a stated range, or statistically not different from the target value (allowing some sites to lie above while others are below the target).

2.9 Component 6 – Monitoring

The main objective of monitoring in this framework is to assess whether the completion criteria have been fulfilled, or are likely to be so, as per the company's closure plan. For this purpose, monitoring should be linked directly to the completion criteria, allowing any site to be compared with its agreed reference. The second goal of monitoring is to track progress and, thus, it should be such that any site can be compared with itself over time. Existing guidelines (ANZMEC & MCA 2000; DMP & EPA 2015; ICMM 2008; LPSDP 2016d) provide further recommendations on how monitoring should be conducted, yet there is still a need for a clearer framework that will help define more accurate and effective monitoring programs.

Monitoring can be useful or required in a mine closure context for purposes other than assessing completion criteria, but in this review only monitoring that is relevant to completion criteria assessment is considered.

Monitoring should be accurately defined and broken down into separate tasks. What is commonly referred to as monitoring, is comprised of three distinct steps:

- **Data monitoring:** gathering, analysis and interpretation of information;
- **Auditing and evaluation:** systematic review of monitoring information against agreed completion criteria; and
- **Corrective action:** redefinition of a) rehabilitation program, b) completion criteria or c) both.

Data monitoring consists of collection and interpretation of information that is necessary to assess the progress towards meeting completion criteria. Data monitoring should be targeted to those indicators that are used in the definition of completion criteria, excluding the need to collect redundant information. Information for the selected indicator needs to be available for the reference to allow auditing. It is important to acknowledge that not all attributes included in the MCP will need to be monitored to the same level of detail and with the same frequency. Hence, the risk-based attribute prioritisation approach (Section 2.7.2) allows the identification of which attributes should be closely monitored. For the purpose of planning of monitoring activities, Table 2.6 can be used as a guide by adding a column summarising indicators, methods and frequency of monitoring for each attribute. Examples of monitoring for completion criteria are provided in Table 2.12. It should be noted that columns in Table 2.12 follow the sequential process defined by the framework. The column 'Monitoring Plan' illustrates examples of proposed monitoring strategies, which often need to be outlined in early version of mine closure plans. As rehabilitation works advance, observable progress (or the lack thereof) should be documented, as exemplified in 'Monitoring results'. Subsequently, the column 'Auditing and Evaluation' illustrates the process whereby the observed level of rehabilitation is compared against the set targets to assess whether criteria have been met or are trending towards the agreed outcomes. Finally, 'Corrective Action' provides examples of the strategies that need to be implemented to meet completion criteria, based upon the monitoring, auditing and evaluation results. Usually, 'Monitoring results', 'Auditing and evaluation" and 'Corrective action' are recorded as part of companies' internal management processes, but not necessarily reported in Mine Closure Plans – unless requested by the regulator.

Auditing is the process whereby the site's level of rehabilitation performance – as reflected in the monitoring data – is compared with the standards agreed in the completion criteria. The difference between the actual and planned performance levels will indicate whether completion criteria are being met and, thus, whether the site is on the right 'trajectory' towards fulfilling closure objectives. Auditing is necessarily time-bound, given that a level of performance can indicate either success or failure, depending on how much time has elapsed since start of rehabilitation or how much time is left before the planned closure date (see Component 5). The risk of each attribute preventing the fulfilment of closure objectives should be re-evaluated following each monitoring round. The process will follow the same approach as described in Component 4, where likelihood and consequences are assessed to determine risk of non-compliance.

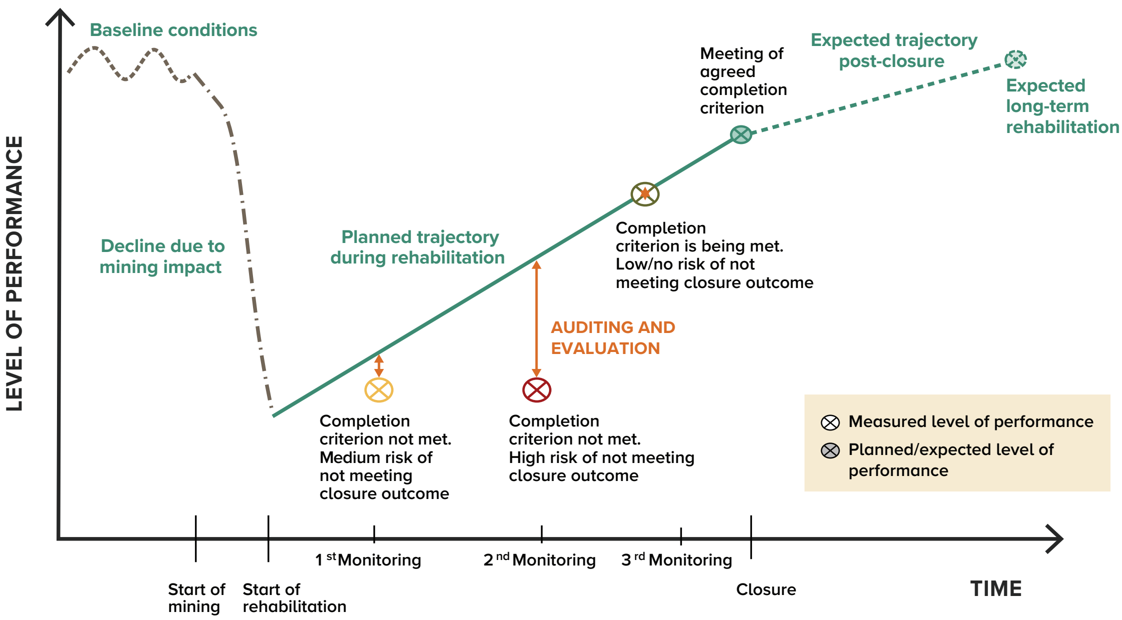


FIGURE 2.4 Auditing and evaluation along the planned rehabilitation trajectory

Finally, corrective actions are the necessary processes to be undertaken that will ensure closure objectives are met, in those cases where a significant risk of non-compliance has been identified. When auditing identifies that there is a risk of not meeting completion criteria, this should trigger investigations into causes of such failure, including questioning whether:

- Rehabilitation practices are not effective and need to be modified including potentially new rehabilitation techniques previously unavailable or considered inappropriate;
- Completion criteria are unachievable and need to be modified; or
- Both rehabilitation practices and completion criteria need to be modified.

While rehabilitation programs should be science-based and thoroughly planned, it is possible that practices are poorly implemented or that the proposed methods are not suitable for the specific mine site. In such cases, an expert assessment should be conducted to redefine a new set of practices aimed at improving the site's rehabilitation performance levels (see example in Figure 2.5).

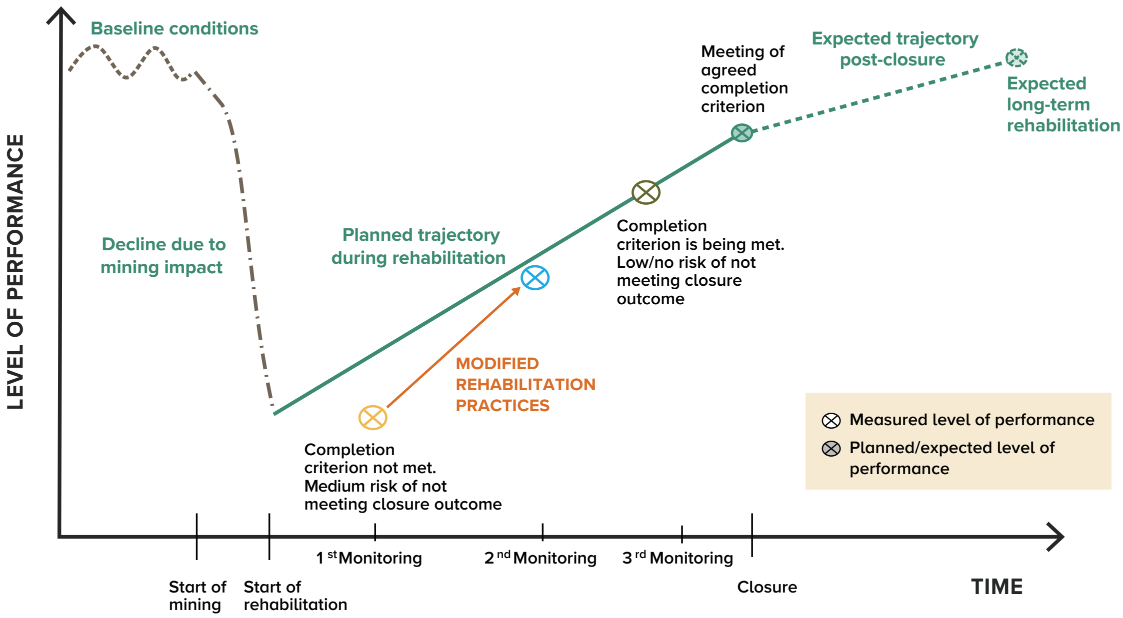


FIGURE 2.5 Corrective Action: Improved Rehabilitation Practices

It is also possible that, as rehabilitation progresses and more monitoring data becomes available, completion criteria initially agreed upon are later understood to be unachievable. For example, climate change impacts may be hard to predict in 20–30 years' time, which means that criteria set using today's knowledge may overestimate what will be feasible at the time of closure. Under these scenarios, companies need to investigate the factors that have influenced failure to meet the completion criteria. A thorough review of available all evidence (data) and science would be required to be provided to the regulators in order to inform the new standards for the redefinition of completion criteria (Figure 2.6).

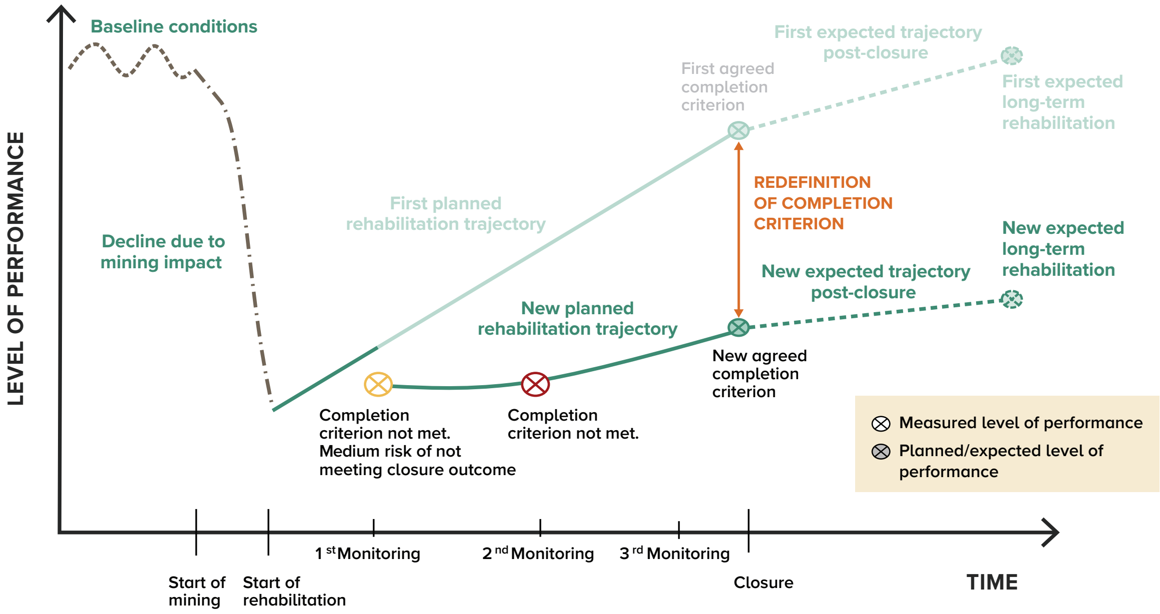


FIGURE 2.6 Corrective action: Redefinition of completion criteria

A third scenario is the situation where completion criteria become unachievable and need to be redefined, but at the same time, improved rehabilitation practices are also required to increase the level of performance of rehabilitation (Figure 2.7). An example may be a mine site where an extreme weather event alters the planned trajectory of rehabilitation. As one interviewee described, based on a real experience in the Pilbara region, planted seeds were ripped away by a severe storm which impacted the planned rehabilitation progress. In such circumstances, the time-specified rehabilitation trajectory may be adjusted, while reseeding and careful management of sprouting plants would be also required.

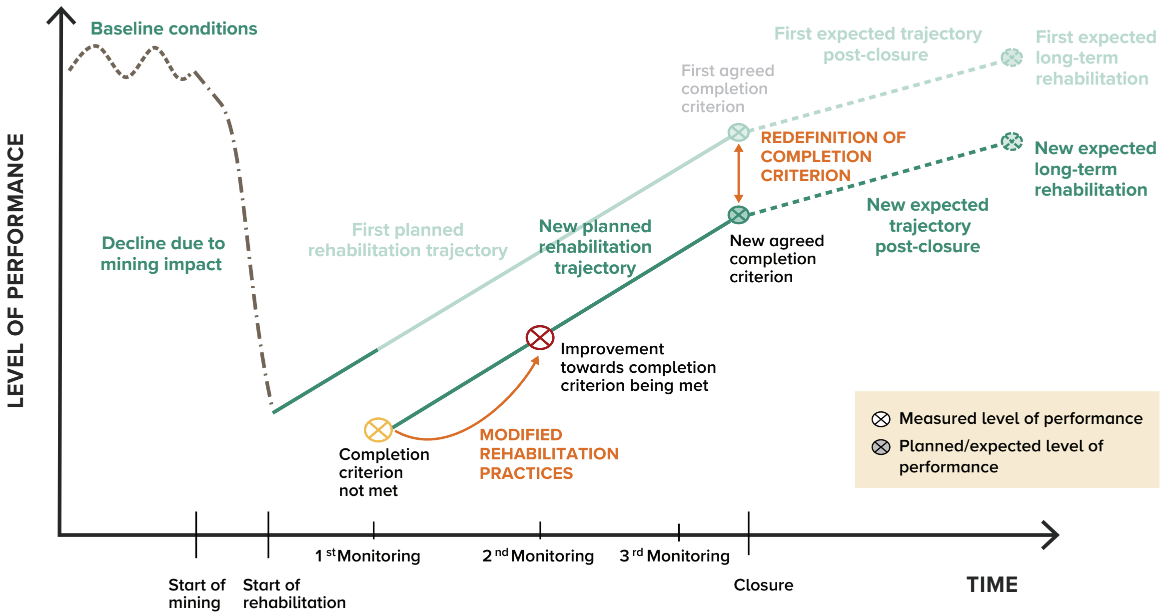


FIGURE 2.7 Corrective action: Modified rehabilitation practices and redefinition of completion criteria

Some completion criteria, such as recovery of groundwater levels or vegetation cover, may be associated with an expected trajectory. By contrast, other criteria, such as the removal of non-transferrable infrastructure, do not follow a trend but are the result of an action undertaken at a certain point in time. It is also important to note that trajectories for certain completion criteria may be more easily defined in environments were weather patterns are predictable and rehabilitation trends are well understood, such as the result of research and data records dating back many years. By contrast, in landscapes suffering from erratic rainfall and periodic droughts, it may be harder to predict the timeframes for certain completion criteria to be met (e.g. vegetation). In such cases, it is advised that mining proponents keep a time-bound record of rehabilitation works that precede plant growth e.g. adequate landform design and construction, erosion management, seeding or planting and pest management. Such records may serve as supporting evidence to the regulator that adequate practices are carried out – albeit with an uncertain outcome.

As discussed above, when completion criteria are not being met or rehabilitation is not trending towards the agreed target, mining proponents should investigate the factors that have influenced such failures. Thus, progress towards meeting each completion criterion should be documented and regularly updated based on the data assimilated from the ongoing monitoring. An assessment of the progress towards whether the completion criteria has been met, is on a trajectory to be met or requires remedial action is required to inform management on projections for resource allocation.

2.9.1 Change management

Inevitably over the life of mine as market conditions, environmental conditions, company structures and government regulations change there may be a requirement for industry to adapt their site-based closure planning. The variables that may instigate change and the implications for this change towards closure can be significant and companies need to be prepared to adapt. Examples of change that may be required include the agreed upon PMLU, completion criteria and/or monitoring techniques and the reiterative process in the framework (Figure 2.2) highlights that adapting to change is possible. If change to the PMLU is required then it may require a revised set of completion criteria to be developed based on a new risk-based attribute prioritisation. However, simpler changes such as the incorporation of new monitoring methodologies may only require an explanatory document to outline how the monitoring results between old and new technologies will be aligned and how progression towards trajectory will still be able to be tracked. Regardless of the level of change, as change occurs, making decisions based on well-documented science and keeping a clear, transparent record of agreements/negotiations with stakeholders will help minimise discrepancies across time and staff and facilitate the update of closure targets.

2.9.2 Learnings and innovation

The quality of rehabilitation in Western Australia has seen significant improvement over recent decades and many companies in the resources sector have worked with research partners and leading consultants to innovate and improve environmental performance and health and safety management processes (Commonwealth of Australia 2018). Examples of the substantial benefits obtained when industry has formed long-term relationships and worked with external experts are evident throughout the state and include large-scale long-term investments (Erickson *et al.* 2016, Stevens *et al.* 2016) as well as smaller-scale projects undertaken in a single or few seasons (Grant *et al.* 1996, Barritt *et al.* 2016, Cross *et al.* 2018a). The demonstrated commitment of industry to improve performance is critical in developing and maintaining a positive social licence to operate (Commonwealth of Australia 2018).

Whether industry chooses to engage with researchers and/or leading consultants or not, the importance of detailed documentation of rehabilitation methodologies, site conditions and performance that are regularly updated, allows the continual improvement of outcomes and efficiencies of resources. It is important that the monitoring data collected across all aspects, attributes and completion criteria are reviewed regularly and procedures updated to ensure site-based activities are in line with leading practice.

TABLE 2.12 Example of completion criteria, monitoring and assessment based on risk-based attributes

Step 1	Step 2		Step 3	Step 4				
PMLUs	Aspects and closure objectives		Reference	Attribute	Risk-based attribute prioritisation			
	Aspect	Closure objectives			Description of risk	Likelihood	Consequence	Risk level
1.1.0 Nature conservation	Ecosystem function and sustainability	The rehabilitated ecosystem is self-sustaining and is indicative of baseline conditions.	Analogue site	Plant species reproduction and recruitment	Established vegetation communities at restoration sites with low fecundity and poor recruitment.	3	4	H12
	Flora and Vegetation	The rehabilitated area has a vegetation community that is commensurate with the baseline conditions.	Baseline conditions	Species richness and cover	Established vegetation community richness and/or cover is inadequate.	3	3	M9
3.2.4 Grazing modified pastures, pasture legume/grass mixture	Social	The visual impact of the rehabilitated mine site compatible with surrounding landscape and acceptable to stakeholders.	Analogue site	Aesthetics (visual amenity)	The post-mining topography does not adequately integrate with the surrounding natural topography. Breach of approval commitments. Visual amenity impact. Local complaints.	2	4	M7
5.2.3. Intensive animal production, poultry farm	Mine Waste and Hazardous Materials	All redundant post-mining and mineral processing infrastructure to be salvaged and disposed of appropriately. Items with beneficial uses post-operations may be left in situ following negotiations with post-closure land users (roads, sheds etc.). Formal transfer of liability to the post-mining landholder has been obtained for any retained infrastructure.	Conceptual Model	Infrastructure	Infrastructure buildings transferred to land owner is not safe with risk of fall from heights, electrocution.	1	4	M5

Note: Examples are not exhaustive in nature and may not be relevant or applicable to sites at all geographical regions. Multiple attributes may be required to demonstrate that a completion criterion has been met. Risk-based attribute prioritisation is based on an initial risk rating; mitigation strategies to reduce risk with a revised risk level could be added at step four. Further, the example layout is time sequential with monitoring occurring at a time occurring post completion criteria development. Additional columns could be added to track monitoring success/progress over several sequential monitoring periods.

Table 2.12 continues following page...

TABLE 2.12 Example of completion criteria, monitoring and assessment based on risk-based attributes

Step 1	Step 5	
PMLUs	**Completion criteria**	**Rehabilitation practices**
1.1.0 Nature conservation	The number of native flora species recorded as naturally recruited juveniles is ±50% that recorded in reference sites, with ±10% surviving to maturity. ±50% of the native species recorded are observed to flower and fruit on the rehabilitation area. Species demonstrated to be actively recruiting represent all strata present in the baseline conditions. The rehabilitated area has been assessed to have the properties of a self-sustaining system by a qualified expert.	Rehabilitation in accordance with MCP. Monitoring of restoration and reference sites for plant fecundity and recruitment rates.
	The vegetation community on the rehabilitation site will have a species richness no less than the 70% of the vegetation recorded in baseline surveys. Total native perennial vegetation cover to be ≥ 20%.	Rehabilitation in accordance with MCP. Monitoring of restoration and reference sites for species richness and cover.
3.2.4 Grazing modified pastures, pasture legume/grass mixture	The post-mining profile will be integrated into the surrounding undisturbed landscape, continuing the gently sloped undulating plain. No slopes greater the 15% will remain at closure. The post-mined land surface will be within ± 1.0 m of the approved rehabilitation design for 95% of the disturbance area.	Engage with stakeholders on final landform designs and obtain endorsement from key stakeholders. Conceptual landform design to reflect natural topographic features.
5.2.3. Intensive animal production, poultry farm	Retained infrastructure will be left in a safe condition and transferred to a legally responsible entity. Retained buildings or infrastructure have been issued the necessary safety compliance certificates or permits. Open pits will be left in accordance with the guidelines on "Safety Bund Walls and Abandoned Open Pits" (DIR, 1997).	Ensure building infrastructure complies with safety standards. Building certificates obtained for structures retained. Electrical safety certificates obtained for retained electrical infrastructure. Additional safety certificates obtained where necessary.

Note: Examples are not exhaustive in nature and may not be relevant or applicable to sites at all geographical regions. Multiple attributes may be required to demonstrate that a completion criterion has been met. Risk-based attribute prioritisation is based on an initial risk rating; mitigation strategies to reduce risk with a revised risk level could be added at step four. Further, the example layout is time sequential with monitoring occurring at a time occurring post completion criteria development. Additional columns could be added to track monitoring success/progress over several sequential monitoring periods.

Table 2.12 continues following page…

Example

TABLE 2.12 Example of completion criteria, monitoring and assessment based on risk-based attributes

Step 1	Step 6			
PMLUs	Monitoring			
	Monitoring plan	Monitoring results during rehabilitation	Auditing and Evaluation	Corrective action
1.1.0 Nature conservation	Qualitative assessment of vegetation communities and health including richness, cover, flowering, fruiting, soil seed bank audit and recruitment at 1, 2, 3 and 5 years. Monitoring of plant health (ecophysiology) over drought period in restoration and at reference. Monitor for structurally dominant species reaching an age sufficient to recover post-fire.	Monitoring quadrats at 2 years after rehabilitation practices: 55% of native perennial species have reached sexual maturity and fecundity rates match the same species from the reference site (±10%). Evidence of grazing recorded for 15% of species. Mean rates of gas exchange (ecophysiological health) of indicator species for plants of similar ages was 30% lower in the rehabilitation site when compared to plants from the reference sites. Soil seed bank viability has reached 30% of that observed at reference.	Criteria not achieved but progressing along a trajectory to reach targets. Impacts of grazing likely to be affecting percentage of plants reaching sexual maturity. Plants in rehabilitation site showing higher levels of stress than at reference.	Installation of fencing to reduce grazing pressure and compaction. Monitor again in 12 months and, if necessary, implement additional remedial actions to improve measures of ecosystem function and sustainability. Review rehabilitation plan and consider irrigation during early plant establishment.
		Monitoring quadrats show at 2 years after rehabilitation practices, species richness is 35% of baseline conditions. Total native perennial cover ranges for 5-15%.	Criteria not achieved. Species richness is low and remedial action is required. Cover is progressing along a trajectory to reach targets.	Options to increase species diversity to be investigated including re-broadcasting of seed and planting of seedlings. Consider irrigation following seeding/planting during early plant establishment to facilitate survival.
3.2.4 Grazing modified pastures, pasture legume/grass mixture	Visual impact evaluation, records of stakeholder endorsement and landform construction report.	Post-mining landform restoration is complete. Rehabilitation land contours integrate with the surrounding areas with the majority conforming with completion criteria targets. Expert review of landscape identified minor instability and erosion risk on south facing slope in Domain 3. The rehabilitated agricultural land is visually compatible with the surrounding landscape (see figures).	Criteria has been achieved for Domain 4 and with minor remedial actions required in Domain 3. Supporting documentation, reports and signed agreements filed in document management system (link to file)	Minor corrective earthworks required in Domain 3, south facing slope to stabilise landform.
5.2.3. Intensive animal production, poultry farm	Inspections of retained features prior to handover. Safety and compliance certificates for retained infrastructure. Signed asset transfer agreement in place prior to transfer of legal responsibility. Review against Decommissioning Plans.	Building and electrical certificates for Industrial shed (Domain 1) obtained March 2018. Written landowner acceptance of retained infrastructure. Certifications filed and located here.	Relevant permits and certificates obtained. Transfer of liabilities completed.	None required.

Note: Examples are not exhaustive in nature and may not be relevant or applicable to sites at all geographical regions. Multiple attributes may be required to demonstrate that a completion criterion has been met. Risk-based attribute prioritisation is based on an initial risk rating; mitigation strategies to reduce risk with a revised risk level could be added at step four. Further, the example layout is time sequential with monitoring occurring at a time occurring post completion criteria development. Additional columns could be added to track monitoring success/progress over several sequential monitoring periods.

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