MAULES CREEK COAL MINE

MINE SITE REHABILITATION PLAN

Edition	Rev.	Comments	Date
1	0	Draft for internal review	22 November 2014
1	1	Initial Revision for submission and approval by DotE	16 December 2014
1	2	Incorporation of DotE Comments	1 December 2015
1	3	Incorporation of DotE Comments	1 August 2016

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1 INTRODUCTION

1.1 BACKGROUND

The purpose of this document is to address the requirements for a Mine Site Rehabilitation Plan (MSRP) as specified in Conditions 25 to 27 in the Maules Creek Coal Mine (MCCM) Commonwealth approval (i.e. EPBC 2010/5566) issued under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Its particular emphasis is the rehabilitation of mine landforms to effectively restore potential habitat for the Regent Honeyeater (*Anthochaera phrygia*), the Swift Parrot (*Lathamus discolour*), the Greater Long-eared Bat (*Nyctophilus corbeni*) (referred to herein as the South-eastern Long-eared Bat as per the contemporary common name for the species) and the White Box – Yellow Box – Blakely's Red Gum Grassy Woodland and derived Native Grassland Critically Endangered Ecological Community (referred to herein as the Box-Gum Woodland CEEC).

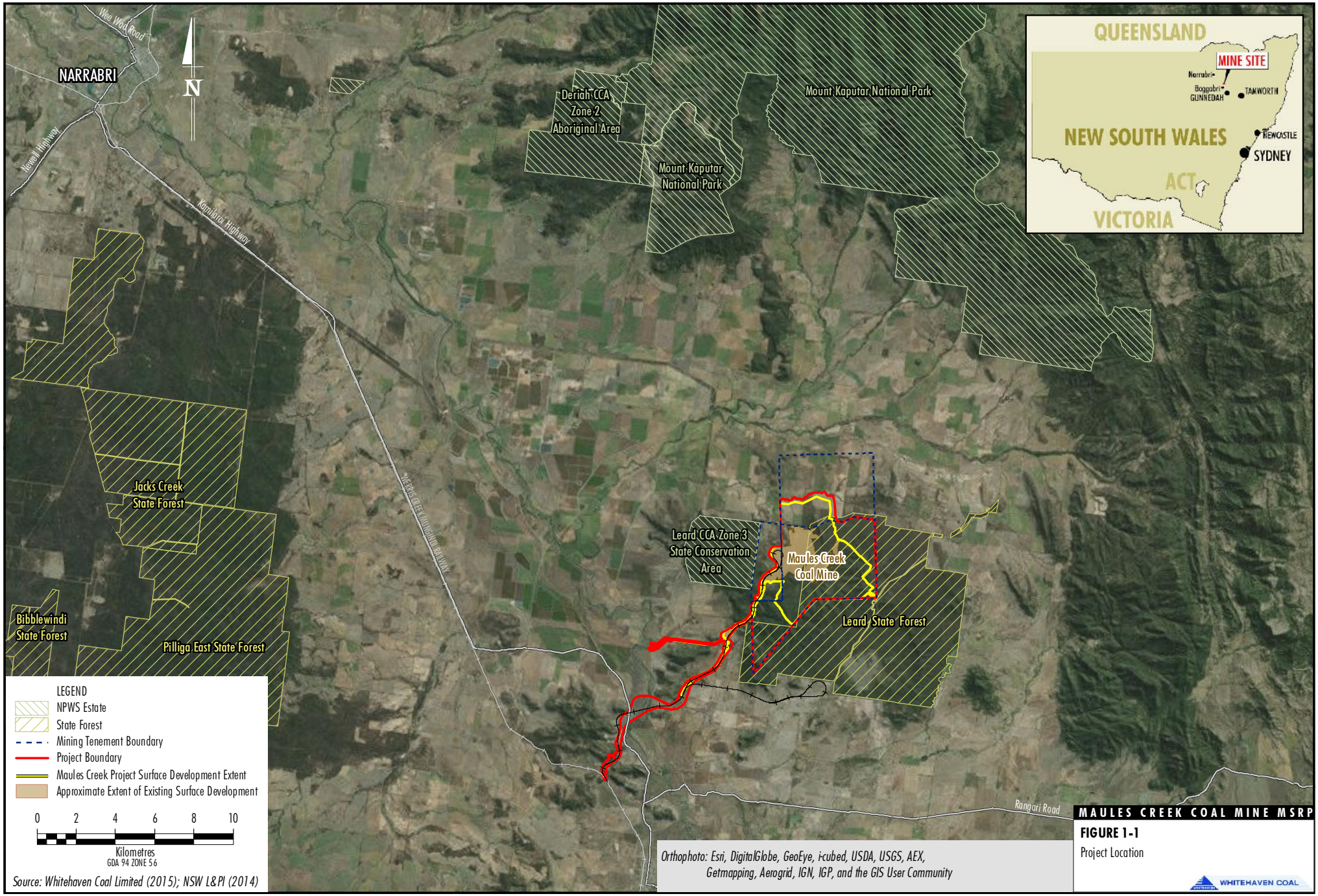
Due to the early development stage of the MCCM (i.e. the operations phase only commenced in mid-2015), none of the major mine landforms (i.e. the overburden emplacement area and backfilled sections of the open cut) have been developed to the extent where rehabilitation activities can commence. As a result, this version of the MSRP focuses more on the initial development activities such as soil stripping, stockpiling and rehabilitation planning.

Subsequent revisions of the MSRP will include more detail on the implementation and monitoring of rehabilitation activities as the mine progresses. It is also expected that the findings of relevant research programs (e.g. the Box-Gum Woodland CEEC and threatened species research required under Conditions 15 and 16 of Commonwealth approval EPBC 2010/5566) and on-site monitoring programs and rehabilitation research activities will be used to refine rehabilitation practices at the MCCM.

This MSRP will be periodically reviewed (i.e. at least every five years from approval of Edition 1) and updated during the life of the MCCM in order to incorporate details of the planned progressive rehabilitation activities, and improvements to soil management measures and rehabilitation practices. In the meantime, annual reports will be prepared and provided to the Commonwealth Department of the Environment (DotE). These reports will describe the management actions undertaken during the reporting period, the outcome of the actions, and the mechanisms to be used to facilitate continuous improvement.

1.2 LOCATION, OWNERSHIP AND OVERVIEW OF MCCM ENVIRONMENTAL APPROVALS

The MCCM is located on the northwest slopes and plains of New South Wales (NSW), approximately 18 kilometres (km) north-east of Boggabri. Further afield are the regional centres of Narrabri and Gunnedah which are situated approximately 35 km and 55 km from the MCCM respectively. Figure 1-1 shows the regional location of the MCCM.



MAULES CREEK COAL MINE MSRP

FIGURE 1-1

Project Location

WHITEHAVEN COAL

WHC-14-23 MSRP_201B

The ownership of the MCCM currently lies with Maules Creek Coal Pty Ltd (MCC), a joint venture between Aston Coal 2 Pty Limited (Whitehaven Coal Limited [Whitehaven]) (75%), ITOCHU Coal Resources Australia Maules Creek (ICRA MC) (15%) and J-Power Corporation Pty Limited (10%).

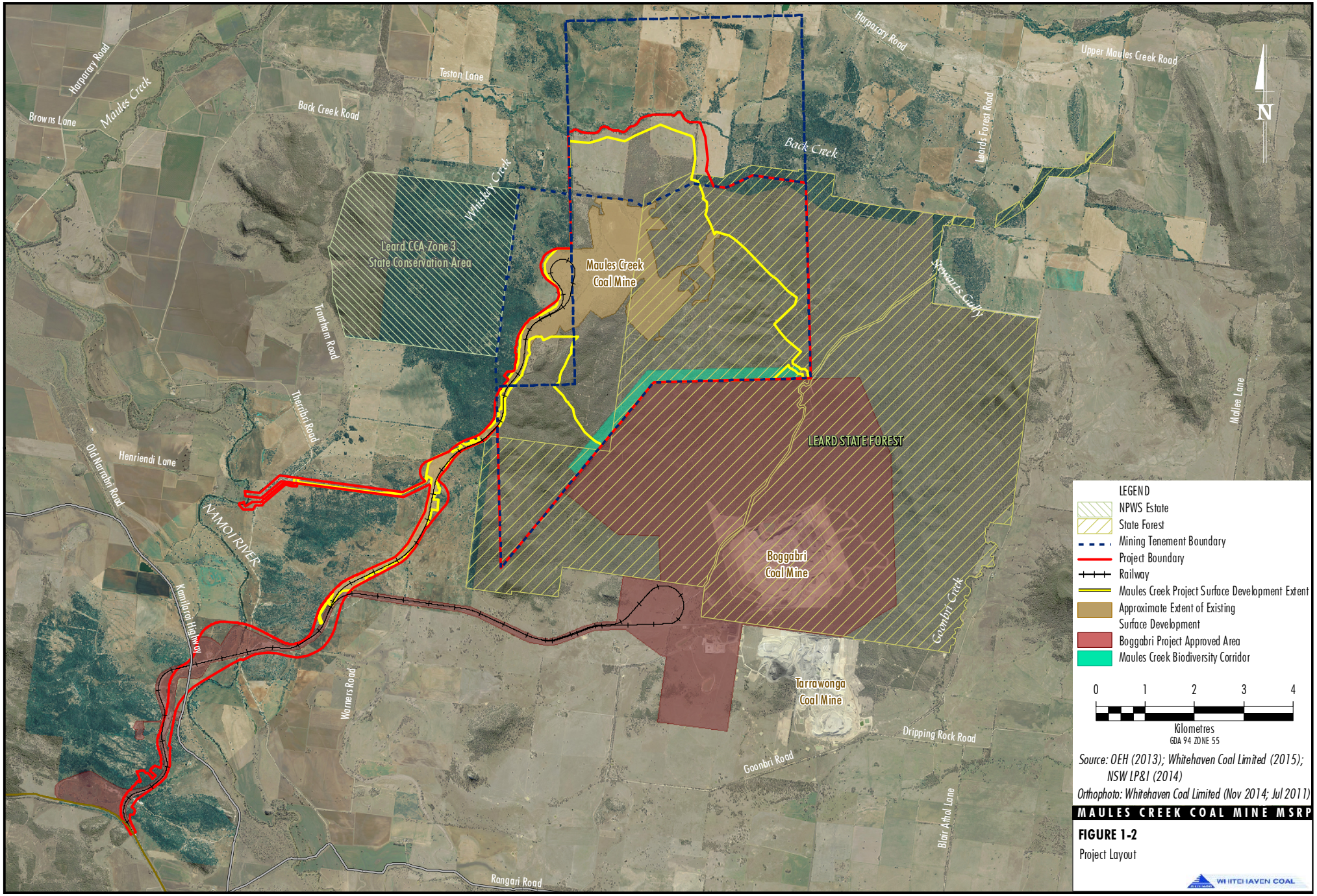
An Environmental Assessment for the Maules Creek Coal Project (referred to herein as the Project EA) was prepared by Hansen Bailey (2011) and was assessed under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) in 2012 and 2013. The NSW Planning Assessment Commission (PAC), as a delegate for the NSW Minister for Planning and Infrastructure, issued the State environmental approval for the MCCM on 23 October 2013 (i.e. Project Approval PA 10_0138). The Commonwealth environmental approval (i.e. EPBC 2010/5566) was granted on 11 February 2013 by the Commonwealth Minister for Sustainability, Environment, Water Population and Communities (herein referred to as 'the Minister').

1.3 PROJECT OVERVIEW

The environmental approvals for the MCCM allow for the construction and operation of an open cut coal mine until the end of December 2034. In particular, the approvals authorise the following activities.

- construction and operation of an open cut mining operation extracting up to 13 million tonnes per annum (Mtpa) run-of-mine (ROM) coal to the Templemore Seam;
- open cut mining fleet including excavator/shovels and fleet of haul trucks, dozers, graders and water carts using up to 470 permanent employees;
- construction and operation of a Coal Handling and Preparation Plant (CHPP) with a throughput capacity of 13 Mtpa ROM coal;
- construction and operation of a Tailings Drying Area;
- construction and operation of a rail spur, rail loop, associated load-out facility and connection to the Werris Creek to Mungindi Railway Line;
- construction and operation of a Mine Access Road;
- construction and operation of administration, workshop and related facilities;
- construction and operation of water management infrastructure including a water pipeline, pumping station and associated infrastructure for access to water from the Namoi River;
- installation of supporting power and communications infrastructure; and
- construction and operation of explosive magazine and explosives storage areas.

The Project Boundary (as defined by PA 10_0138), and the Maules Creek Project surface development extent are shown in Figure 1-2.



Source: OEH (2013); Whitehaven Coal Limited (2015); NSW LP&I (2014)

Orthophoto: Whitehaven Coal Limited (Nov 2014; Jul 2011)

MAULES CREEK COAL MINE MSRP

FIGURE 1-2

Project Layout

WHITEHAVEN COAL

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Construction of the MCCM commenced on 23 December 2013 and was completed in 2015. The operations phase of the MCCM commenced in June 2014, and first coal was first transported from the MCCM via the rail spur in December 2014. The CHPP was constructed and commissioned by mid-2015.

1.4 RELATIONSHIP BETWEEN THIS DOCUMENT AND OTHER MCCM MANAGEMENT PLANS

This document has been specifically prepared to satisfy the requirements of Conditions 25 and 27 of Commonwealth approval EPBC 2010/5566. These conditions, and other relevant conditions, are discussed further in Section 2.

The State approval PA 10_0138 also contains conditions pertaining to the rehabilitation of the MCCM (i.e. Conditions 71 to 74 of Schedule 3), including a requirement to prepare a Rehabilitation Management Plan (RMP). At the request of NSW Division of Resources and Energy (DRE), the RMP requirements in State approval PA 10_0138 are addressed in the MCCM Mining Operations Plan (MOP). The current MOP for the MCCM covers the period from 15 February 2016 to 1 January 2018 (MOP Revision 3).

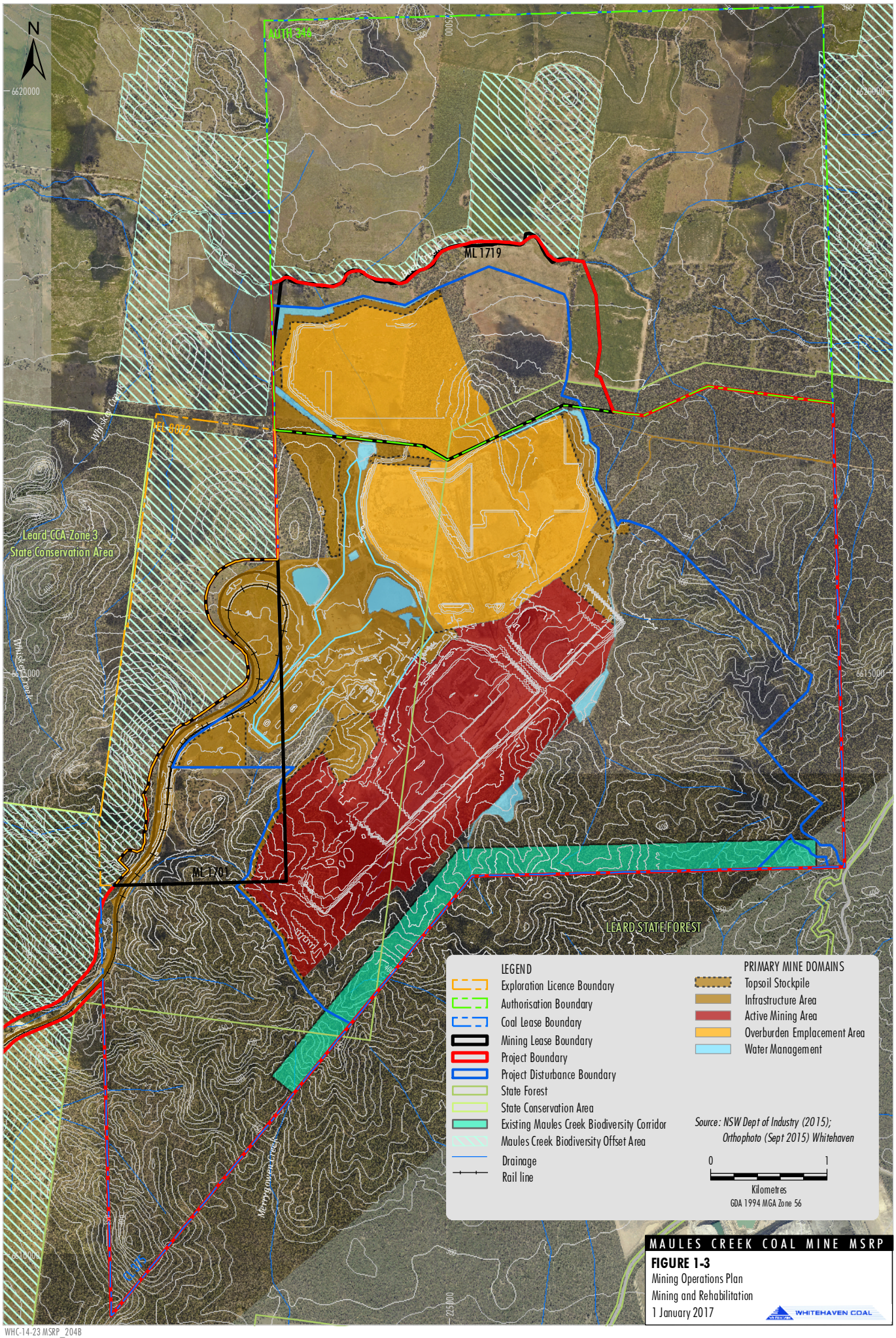
This MSRP has been prepared to be consistent with the rehabilitation component of the MOP, however as described previously it is a stand-alone document that is primarily designed to satisfy the requirements of Commonwealth approval EPBC 2010/5566.

Figures 1-3 and 1-4 represent the early operational phase of the MCCM (i.e. Years 2017 and 2018). Figure 1-5 shows the proposed final rehabilitation and post-mining land use at the conclusion of the 21 year mine life, as depicted in the MOP.

This MSRP has also been designed to closely integrate with the MCCM Biodiversity Management Plan (BMP) (required under Condition 53 of Schedule 3 of State approval PA 10_0138) and the Offset Management Plan (required under Condition 17 of EPBC 2010/5566). The focus of this MSRP is the rehabilitation of mining areas within the Project Boundary. The focus of the BMP/Offset Management Plan is to provide a consolidated plan for the management of flora and fauna within the Project Boundary and the conservation management of the MCCM biodiversity offset areas. This MSRP contains summaries and/or references to these other plans and documents where appropriate.

1.5 INDEPENDENT REVIEW OF THIS DOCUMENT

Condition 28 of Commonwealth approval EPBC 2010/5566 requires the MSRP to be subject to an independent review by a qualified ecologist prior to being submitted to the Minister for approval. For this MSRP, the independent review was conducted by Dr David Freudenberger of ANU Enterprise Pty Ltd. A copy of a letter indicating the findings of the review of this MSRP is contained in Appendix A.



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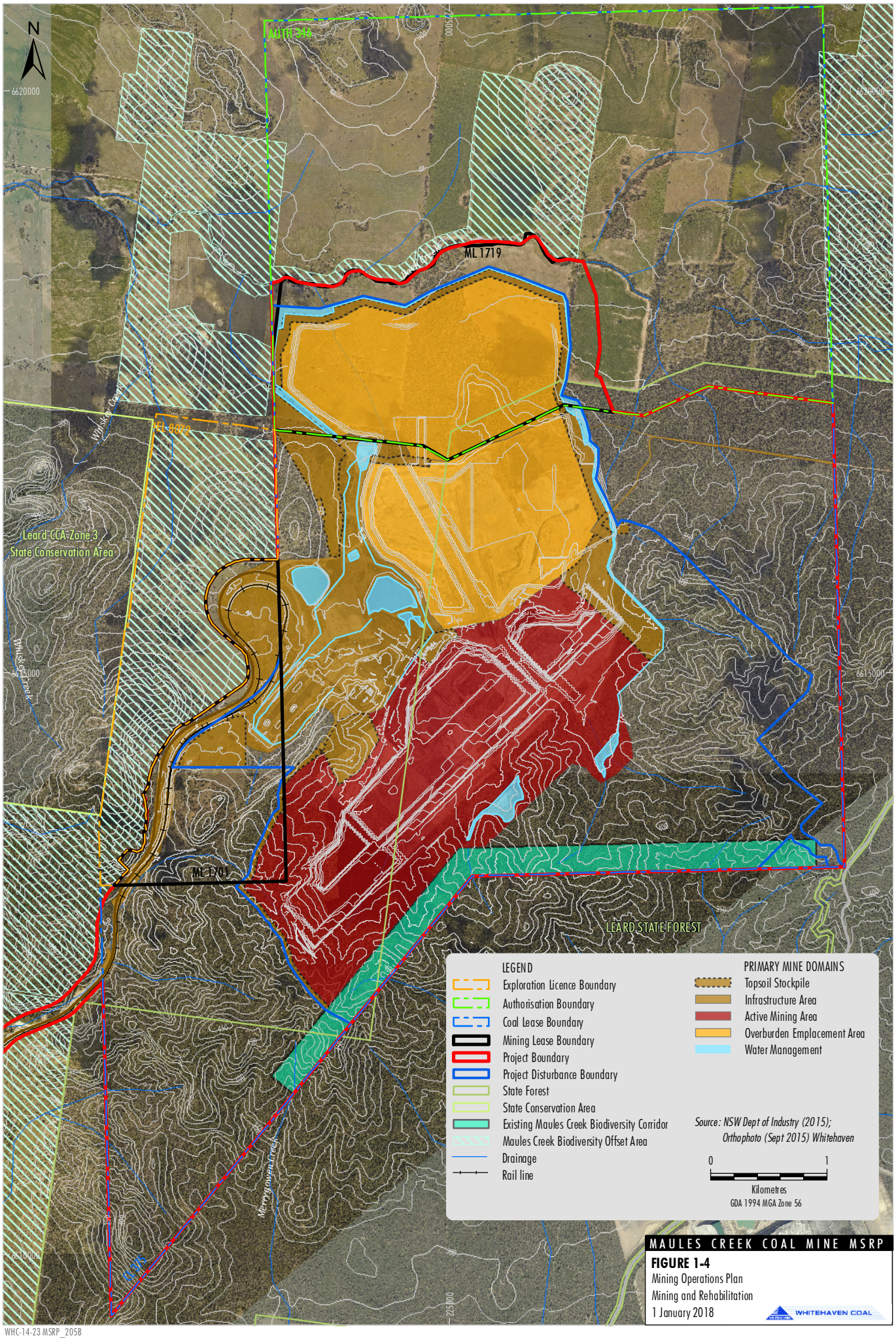

MAULES CREEK COAL MINE MSRP

FIGURE 1-4

Mining Operations Plan
Mining and Rehabilitation
1 January 2018

WHITEHAVEN COAL

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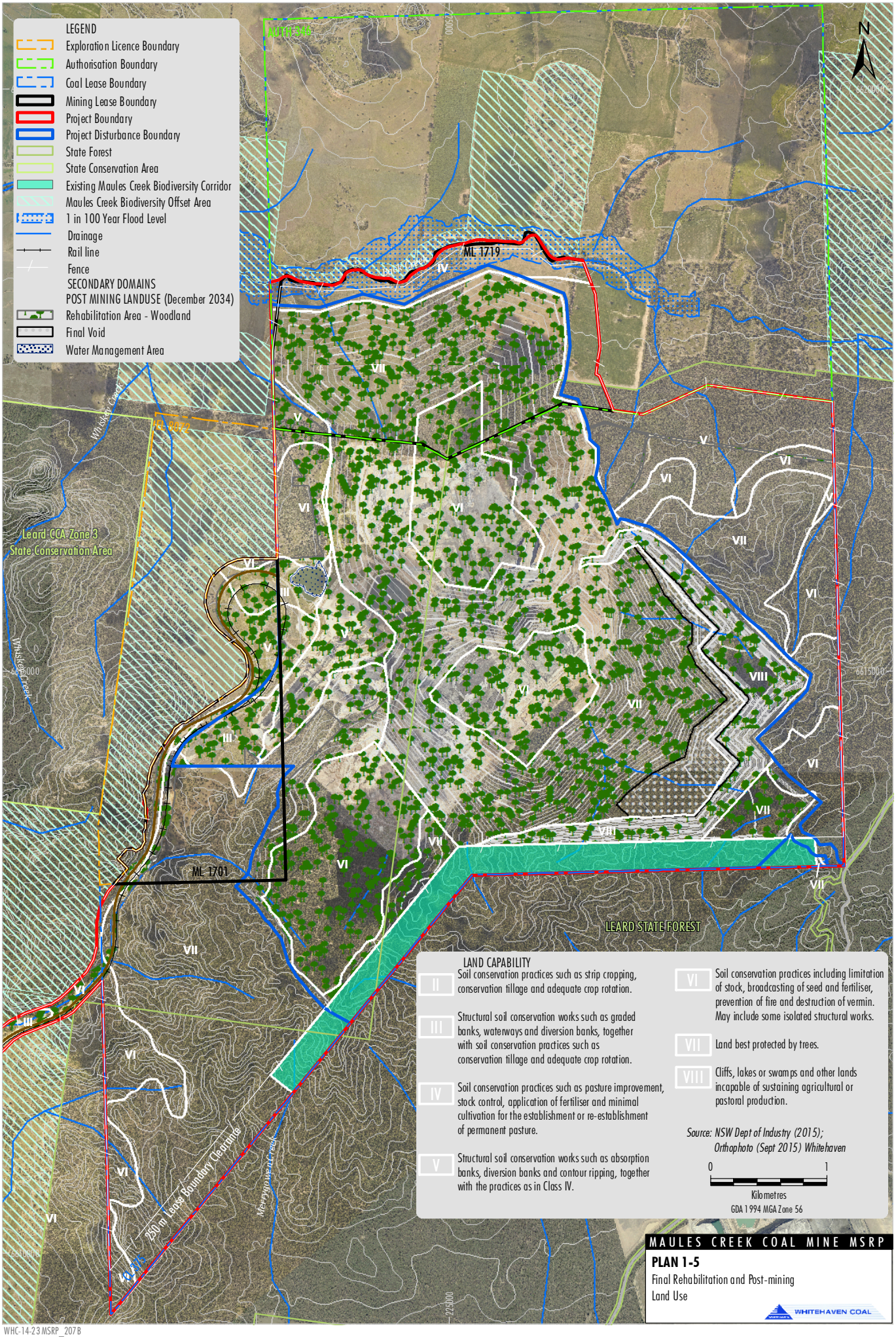

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1.6 STRUCTURE OF THIS DOCUMENT

The structure of this plan is as follows:

- Section 1 Provides background information on the MCCM including its location and ownership, a project overview, and discusses the relationship between this MSRP and other management plans.
- Section 2 Discusses the particular EPBC Conditions applicable to this MSRP.
- Section 3 Describes the rehabilitation strategy and objectives for the MCCM.
- Section 4 Describes the soil management procedures that will be adopted at the MCCM during the operation and rehabilitation of the mine site.
- Section 5 Provides details of the vegetation communities to be rehabilitated and the timing of progressive rehabilitation.
- Section 6 Provides an assessment of potential risks to successful management of rehabilitation, including weed invasion, and describes the contingency measures that will be implemented to mitigate these risks.
- Section 7 Describes the rehabilitation monitoring and reporting process that will be adopted to enable adaptive management and continuous improvement.
- Section 8 Describes the process that will be used to review, audit and review the implementation of this MSRP during the life of the MCCM.
- Section 9 Provides a list of references contained in this MSRP.

2 APPROVAL CONDITIONS RELEVANT TO REHABILITATION OF THE MCCM

2.1 COMMONWEALTH

EPBC 2010/5566 conditions that are relevant to the rehabilitation of the MCCM are presented in Table 2-1. Where applicable, cross references are provided to the relevant section of this MSRP (or separate document) where the requirements of the conditions have been addressed.

Table 2-1
EPBC Act Rehabilitation-Related Approval Requirements

Applicable Condition	Requirement	Comment
Condition 25	*To mitigate the impacts to the White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland and the habitat of the regent honeyeater, swift parrot and greater long-eared bat, the person taking the action must, within 12 months of the commencement of construction, submit to the Minister for approval a mine site rehabilitation plan for the progressive rehabilitation and revegetation of no less than 1665 ha of native forest and woodland (less the portion included in the biodiversity corridor identified in condition 3) in the project area including 544 ha using species consistent with a White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland Ecological Community. This approved mine site rehabilitation plan must be implemented.*	This MSRP
Condition 26	*The person taking the action must:* *a. Rehabilitate the site to be consistent with the proposed rehabilitation strategy as provided in the Environmental Assessment and, as required under the NSW State Government approval dated 23 October 2012 (Application 10_0138); and* *b. Not replace top soil and sub soil layers at a depth less than the minimum depths determined through pre-stripping soil surveys as described in condition 27(c).* *Note: the NSW state government Project Approval dated 23 October 2012 (application number 10_0138) conditions require pre-stripping soil surveys and inventories to inform the availability, rehandling, stockpiling and management of soils, and maximising the salvaging of soil to be used, in the rehabilitation of the site.*	Section 3 Section 4.1
Condition 27	*The mine site rehabilitation plan must include, at a minimum, the following information:* *a. targets and performance indicators to achieve effective restoration of potential habitat for the regent honeyeater, swift parrot and greater long-eared bat and White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland ecological community, including weed management;* *b. details of the vegetation communities to be rehabilitated and the timing of progressive rehabilitation (commencing as soon as practicable following disturbance);* *c. detailed soil depths surveys and analysis to inform the effective placement and restoration of soils across the disturbance sites and soil sampling at no less than one sample point per 20 ha of each soil type identified. Sampling must identify; type, depth, water holding capacity, structure and physio-chemical properties of each of the soil and subsoil layers;*	Section 3.7, Section 7.6 Section 5 Section 4.2

Table 2-1 (Continued)
EPBC Act Rehabilitation-Related Approval Requirements

Applicable Condition	Requirement	Comment
Condition 27 (Cont.)	*d. processes and methodology for the removal, storage and re-layering of the top soil and sub layers underlying the disturbed sites being prepared for rehabilitation. These processes and methodologies must ensure the replacement of top soil and sub soil layers:* • *meet the minimum depth requirements determined from sampling outcomes as identified in condition 27(c); and* • *replicate other existing soil parameters including, but not limited to, soil type, water holding capacity, structure and physio-chemical properties.* *e. a process to report annually to the department the rehabilitation management actions undertaken and the outcome of those actions, and the mechanisms to be used to identify the need for improved management;* *f. a description of the potential risks to successful management and rehabilitation on the project site, including weed invasion, and a description of the contingency measures that would be implemented to mitigate these risks;* *g. details of long-term management and protection of the mine site, including details of the commitment of funds to achieve this.*	Section 4.1 Section 8 Section 6 and 7.6 Sections 5 and 7
Condition 28	*The mine site rehabilitation plan must be subject to an independent review by a qualified ecologist prior to being submitted to the Minister for Approval. The findings of the independent review must be published on the proponent's website.*	Section 1.5
Condition 29	*Note: for consistency, the person taking the action may develop a single mine rehabilitation plan to align with the requirements, including timing of reporting, of the NSW State Government approval dated 23 October 2012 (Application 10_0138) and this approval. The Offset Management Plan and the Rehabilitation Management Plan need to be substantially integrated for achieving biodiversity objectives for the rehabilitated mine-site.* *The person taking the action must undertake rehabilitation to ensure that final landform provides the optimum opportunity for the successful restoration of native forest and woodland including the critically endangered White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland ecological community.* *Note: for consistency, the proponent may develop a single mine rehabilitation plan to align with the requirements of the NSW Government and this approval. The Offset Management Plan and the Rehabilitation Management Plan need to be substantially integrated for achieving biodiversity objectives for the rehabilitated mine-site.*	Section 1.4
Condition 30	*The person taking action must undertake rehabilitation to ensure the final void and landform minimises the extent of any resulting pit lake, avoids salt scalding and ensures that drained waters do not adversely affect the downstream environment and avoids any impacts on matters of national environmental significance.* *Note: the State approval conditions for the project 10_0138 require the preparation and implementation of an updated Final Void and Mine Closure Plan that considers interactions with the adjoining mines, including interaction between final voids, opportunities for integrated mine planning with adjoining mines to minimise environmental impacts, all reasonable and feasible landform options for the final void (including filling) and predicted hydrochemistry and hydrogeology (including long-term groundwater recovery and void groundwater quality).*	Sections 1.1 and 3.5

A description of each Matter of National Environmental Significance referenced in Conditions 25 and 27 of Commonwealth approval EPBC 2010/5566 is provided below.

Regent Honeyeater

The Regent Honeyeater (*Anthochaera phrygia*) has not been previously recorded in Leard State Forest. The nearest record of the species is approximately 29 km to the north (Birds Australia, 2014). The Regent Honeyeater mainly inhabits temperate woodlands and open forests of the inland slopes of south-east Australia (DotE, 2016; Office of Environment and Heritage [OEH], 2016). This species can undertake large-scale nomadic movements in the order of hundreds of kilometres (OEH, 2016). In NSW the distribution is very patchy and mainly confined to the four main breeding areas and surrounding fragmented woodlands (DotE, 2016).

Most records of this species come from box-ironbark associations, but it also occurs in forests and woodlands of yellow gum, swamp mahogany and riverine woodlands (DotE, 2016). It has a particular preference for blossoming Eucalypts and Mistletoe which provide nectar flows (DotE, 2016). The Regent Honeyeater is a generalist forager, which mainly feeds on the nectar from a wide range of Eucalypts and Mistletoes (DotE, 2016; OEH, 2016). It also feeds on arthropods, occasionally supplemented with fruit (DotE, 2016). When nectar is scarce; lerp and honeydew comprise a large proportion of the diet (OEH, 2016). Insects make up about 15% of the total diet and are important components of the diet of nestlings (OEH, 2016).

There are four known key breeding areas, three of them in NSW - Capertee Valley, Hunter Valley and Bundarra-Barraba regions (DotE, 2016).

Swift Parrot

The Swift Parrot *(Lathamus discolor)* has not been previously recorded in Leard State Forest. The nearest record of the species is approximately 40 km to the south (OEH, 2014).

The Swift Parrot breeds in Tasmania during spring and summer, migrating in the autumn and winter months to south-eastern Australia from Victoria and the eastern parts of South Australia to south-east Queensland (Saunders and Tzaros, 2011; OEH, 2016). In NSW it mostly occurs on the coast and south-west slopes (Saunders and Tzaros, 2011; OEH, 2016).

The Swift Parrot is dependent on flowering resources across a wide range of habitat in its wintering grounds in NSW (Saunders and Tzaros, 2011). On the mainland they occur in areas where Eucalypts are flowering profusely or where there are abundant lerp (from sap-sucking bugs) infestations (Saunders and Tzaros, 2011; OEH, 2016).

South-eastern Long-eared Bat

The Greater Long-eared Bat (south-eastern form) (*Nyctophilus timoriensis*) is now known as the South-eastern Long-eared Bat (*Nyctophilus corbeni*).

The South-eastern Long-eared Bat is known to occur in the locality of the MCCM. The distribution of the South-eastern Long-eared Bat coincides approximately with the Murray Darling Basin with the Pilliga Scrub region being a distinct stronghold for this species (OEH, 2016). Overall, the distribution of the South-eastern Long-eared Bat spans the western slopes and plains of NSW with the exception of the Darling Riverine Plains Bioregion, the Hay Plains in the Riverina Bioregion and the north-western semi-arid corner of NSW (Turbill and Ellis, 2006).

The South-eastern Long-eared Bat inhabits dry woodlands and the River Red Gum communities of major watercourses (Van Dyck and Strahan, 2008). The species is quite flexible in its roost selection, but has a predilection for tree hollows, exfoliating bark or dense foliage (Lunney *et al.,* 1988).

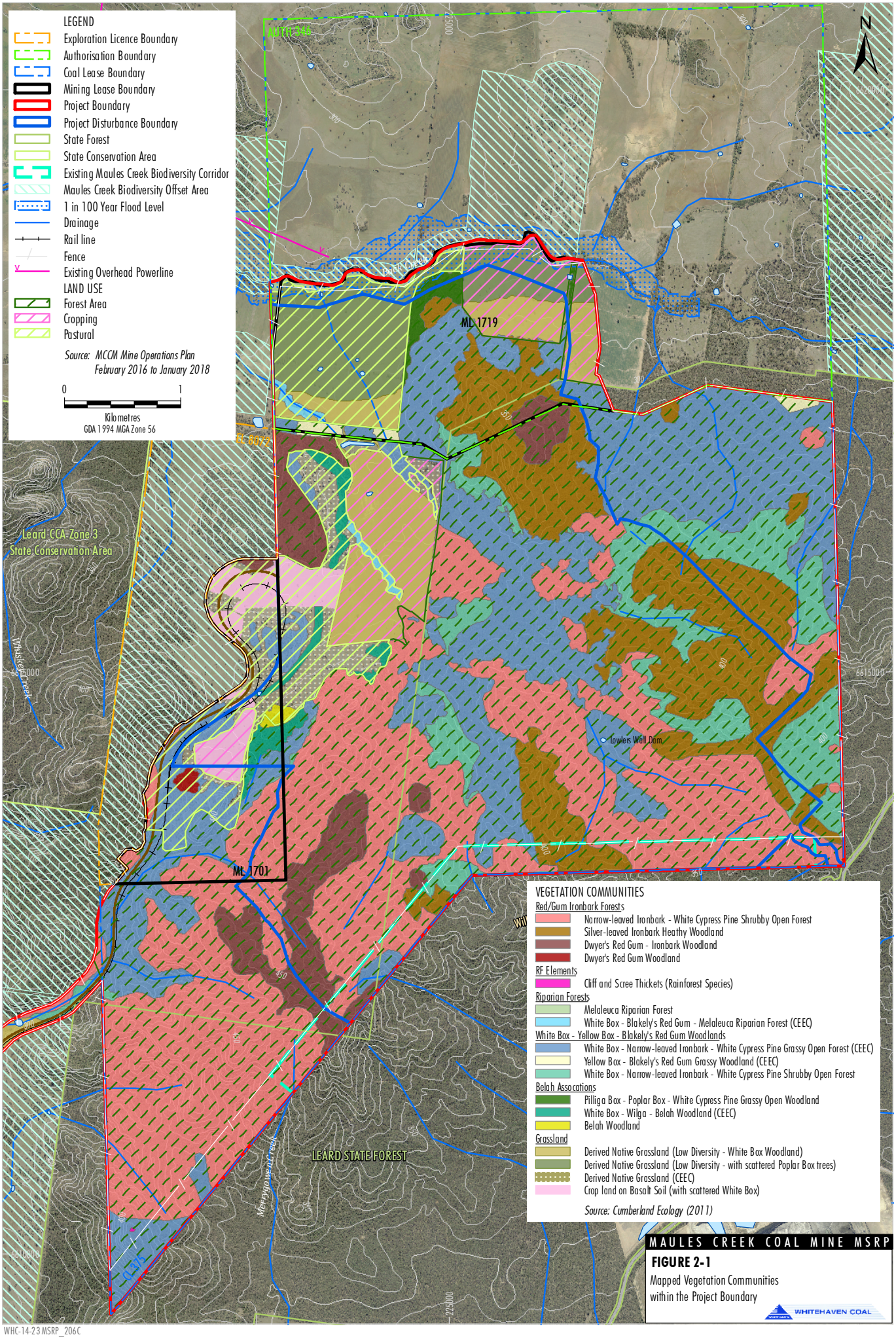
The South-eastern Long-eared Bat forages for large moths and beetles over water or in arid habitats (Hall and Richards, 1979; Richards, 1983). It may use the understorey to hunt non-flying prey (especially caterpillars and beetles) or hunt on the ground (OEH, 2016).

Box-Gum Woodland CEEC

The Box-Gum Woodland CEEC is represented in the MCCM Project Boundary by the following vegetation communities (Cumberland Ecology, 2011):

- White Box - Narrow-leaved Ironbark - White Cypress Pine grassy open forest;
- White Box – White Cypress Pine grassy woodland;
- Yellow Box - Blakely's Red Gum grassy woodland;
- White Box - Wilga - Belah woodland;
- White Box - Blakely's Red Gum - Melaleuca riparian forest; and
- Derived Native Grasslands.

Figure 2-1 shows the location of these, and other non-threatened vegetation communities, in the Project Boundary as mapped during the Project EA flora surveys (Cumberland Ecology, 2011).



MAULES CREEK COAL MINE MSRP

FIGURE 2-1

Mapped Vegetation Communities within the Project Boundary

WHC-14-23 MSRP_206C

2.2 STATE

State approval PA 10_0138 includes several conditions relevant to the rehabilitation and closure of the MCCM, which are repeated below. As described in Section 1.4, the MOP has been prepared to address the requirements of Condition 73 of Schedule 3 of the State Approval PA 10_0138 (i.e. preparation of a RMP). This MSRP has been prepared to be consistent with the rehabilitation component of the MOP, however, is a stand-alone document that is primarily designed to satisfy the requirements of Commonwealth approval EPBC 2010/5566.

Condition 39 of Schedule 3 of State Approval PA 10_0138

The Proponent shall:

(a) develop a detailed soil management protocol that identifies procedures for

- *Comprehensive soil surveys prior to soil stripping;*
- *Assessment of top-soil and sub-soil suitability for mine rehabilitation; and*
- *Annual soil balances to manage soil handling including direct respreading and stockpiling;*

(b) maximise the salvage of suitable top-soils and sub-soils and biodiversity habitat components such a bush rocks, tree hollows and fallen timber for rehabilitation of disturbed areas within the site and for enhancement of biodiversity offset areas;

(c) ensure that coal reject or any potentially acid forming interburden materials must not be emplaced at elevations within the pit shell or out of pit emplacement areas where they may promote acid or sulphate species generation and migration beyond the pit shell or out of pit emplacement areas;

(d) ensure that no water can drain from an out of pit emplacement area to any watercourse or to any land beyond the lease boundary; and

(e) ensure that the coal barrier between the final void and any future surrounding mining operations minimises exchange of any contained groundwaters in the pit shell.

Condition 71 of Schedule 3 of State Approval PA 10_0138

The Proponent shall rehabilitate the site to the satisfaction of the Executive Director Mineral Resources. This rehabilitation must be generally consistent with the proposed Rehabilitation Strategy described in the Project EA and comply with the objectives in Table 17 (of PA 10_0138).

Condition 72 of Schedule 3 of State Approval PA 10_0138

The Proponent shall rehabilitate the site progressively, that is, as soon is reasonably practical following disturbance. All reasonable and feasible measures must be taken to minimise the total area exposed for dust generation at any time. Interim rehabilitation strategies shall be employed when areas prone to dust generation cannot yet be permanently rehabilitated.

Note: it is accepted that some parts of the site that are progressively rehabilitated may be subject to further disturbance at some later stage of the development.

Condition 73 of Schedule 3 of State Approval PA 10_0138

The Proponent shall prepare and implement a Rehabilitation Management Plan to the satisfaction of the Executive Director, Mineral Resources. This plan must:

(a) be prepared in consultation with the Department, Forests NSW, NOW, OEH, Namoi CMA and Council;

(b) be submitted to the Executive Director, Mineral Resources within 6 months from the date of this approval;

(c) be prepared in accordance with any relevant DRE guideline;

(d) describe how the rehabilitation of the site would be integrated with the implementation of the biodiversity management plan;

(e) include detailed performance and completion criteria for evaluating the performance of the rehabilitation of the site, and triggering remedial action (if necessary);

(f) describe the measures that would be implemented to ensure compliance with the relevant conditions of this approval, and address all aspects of rehabilitation including mine closure, final landform, and final land use;

(g) include interim rehabilitation where necessary to minimise the area exposed for dust generation;

(h) include a program to monitor, independently audit and report on the effectiveness of the measures, and progress against the detailed performance and completion criteria; and

(i) build to the maximum extent practicable on the other management plans required under this approval.

Note: In particular the Biodiversity Management Plan and Rehabilitation Management Plan need to be substantially integrated for achieving biodiversity objectives for the rehabilitated mine-site.

Condition 74 of Schedule 3 of State Approval PA 10_0138

The Proponent shall prepare and implement an updated Final Void and Mine Closure Plan (as a component of the overall Rehabilitation Management Plan required under Condition 73 of Schedule 3 of PA 10_0138) to the satisfaction of the Executive Director, Mineral Resources, following consultation with the Director-General. A draft plan must be prepared and submitted to the Executive Director, Mineral Resources by the end of December 2020 and a final plan must be prepared and submitted to the Executive Director, Mineral Resources by the end of December 2026. Each version of the plan must:

(a) be subject to independent review and verification by suitably qualified, experienced and independent person/s (including a groundwater expert) whose appointment has been approved by the Director-General;

(b) identify and consider:

- *Options for continued mining beyond current project life;*
- *Interactions with the final landform of adjoining mines (including any direct or indirect interaction between final voids);*
- *opportunities for integrated mine planning with adjoining mines to minimise environmental impacts of the mines' final landforms;*
- *all reasonable and feasible landform options for the final void (including filling);*

- *predicted stability of the proposed landforms; and*
- *predicted hydrochemistry and hydrogeology (including long-term groundwater recovery and void groundwater quality);*

(c) include a detailed proposed landform design; and

(d) demonstrate that the proposed final landform:

- *satisfies the relevant objectives in Table 17 (of PA 10_0138);*
- *minimises the extent of any resulting pit lake;*
- *avoids salt scalding;*
- *maximises the capacity of emplaced spoil to drain to the natural environment; and*
- *ensures that drained waters do not adversely affect the downstream environment.*

3 REHABILITATION STRATEGY

3.1 OVERVIEW

The Rehabilitation Strategy for the MCCM is described in Section 7.16 of the Project EA (Hansen Bailey, 2011). The State and Commonwealth approvals both specify that the rehabilitation of the MCCM must be consistent with the Rehabilitation Strategy (i.e. Condition 26 of EPBC 2010/5566 and Condition 71 of Schedule 3 of PA 10_0138). The Rehabilitation Strategy includes a description of the following elements:

- rehabilitation objectives;
- rehabilitation techniques;
- final landform and rehabilitation domains;
- decommissioning;
- rehabilitation completion criteria; and
- management and mitigation.

Sections 3.3 to 3.6 summarise the key elements of the Rehabilitation Strategy. Figure 1-5 shows the broad final landform and rehabilitation concept for the MCCM as depicted in the MOP (Revision 3). The concept is consistent with the one depicted in the Project EA, however it should be noted that it will be refined in future revisions of the MOP and this MSRP during the mine life.

Section 3.2 provides a description of the current status of rehabilitation at the MCCM.

3.2 CURRENT STATUS OF REHABILITATION

As described in Section 1.4, the current MOP (Revision 3) for the MCCM covers the period from 15 February 2016 to 1 January 2018.

The DRE's Mining Operations Plan Guidelines (DRE, 2013) require each MOP to provide details of the status of rehabilitation at each domain as at the commencement of the MOP (i.e. an outline of activities that have occurred to date). It must also describe the rehabilitation activities proposed to be implemented over the MOP term on a domain by domain basis. The rehabilitation information must also be shown pictorially.

No rehabilitation of the main mine landforms has occurred to date, and none is scheduled to occur during the period covered by the MOP (i.e. up to the end of 2017). This is because the out-of-pit overburden emplacement area will not be sufficiently developed (i.e. no outer batter areas will be complete and available), and the progressive infilling and re-profiling of the open cut will not have commenced.

It is expected that subsequent revisions of the MOP will include more information on the progressive rehabilitation of the MCCM, as parts of the out-of-pit overburden emplacement area and open cut infill areas are finalised and become available. Notwithstanding, Section 5 of this MSRP includes a description of the rehabilitation schedule for the MCCM based on the current mine plan and conceptual mine closure plan.

3.3 REHABILITATION OBJECTIVES

The key rehabilitation objective of the MCCM is the establishment of native forests and woodlands with a conservation final land use. Condition 25 of Commonwealth approval EPBC 2010/5566 requires rehabilitation within the Project Boundary to include no less than 1,665 hectares (ha) of native forest and woodland in the project area, including 544 ha using species consistent with a Box-Gum Woodland CEEC. The current broad final landform and rehabilitation concept for the MCCM is shown on Figure 1-5. The 'woodland' vegetation depicted on the figure occupies an area of approximately 2,264 ha. The smaller sub-set that will be rehabilitated using species consistent with a Box-Gum Woodland CEEC (i.e. minimum of 544 ha) has not yet been specifically identified and is therefore not shown on the figure. It is intended that this detail will be provided in subsequent revisions of this MSRP and the MOP during the mine life.

Overall, the key goal of the rehabilitation activities is to create landforms that are safe, stable, provide adequate post-mining drainage, and have a shape that is consistent with the types of naturally occurring landform features that occur in the region.

Rehabilitation will be undertaken generally in accordance with the *Strategic Framework for Mine Closure* (Australian and New Zealand Minerals and Energy Council Minerals Council of Australia, 2000) and the *Mine Closure and Completion* (DITR, 2009a) and *Mine Rehabilitation* (Department of Industry, Tourism and Resources [DITR], 2009b) Handbooks. It will also consider the *National Recovery Plan for White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* (Department of Sustainability, Environment, Water, Population and Communities, 2010).

Condition 71 of Schedule 3 of State approval PA 10_0138 includes a table (i.e. Table 17), which lists the overall rehabilitation objectives for the MCCM. These are repeated below in Table 3-1.

Table 3-1
Rehabilitation Objectives

Feature	Objective
Mine Site	• Safe, stable and non-polluting. • Constructed landforms drain to the natural environment.
Final Void	• Minimise the size and depth of the final void as far as is reasonable and feasible. • Minimise the drainage catchment of the final void as far as is reasonable and feasible.
Surface Infrastructure	• To be decommissioned and removed, unless the Executive Director Mineral Resources agrees otherwise.
All land, other than the final void	• Restore ecosystem function, including maintaining or establishing self-sustaining ecosystems comprised of: – local native plant species; and – a landform consistent with the surrounding environment, in accordance with the Revised Biodiversity Offset Strategy and the BMP (i.e. Conditions 45 and 53 of Schedule 3 of State approval PA 10_0138 respectively).
Community	• Ensure public safety. • Minimise the adverse socio-economic effects associated with mine closure.

Note: If seasonally and commercially available, non-native self-sterile plants may be used for stabilisation and dust suppression purposes on a temporary basis, if required.

3.4 REHABILITATION TECHNIQUES

The Rehabilitation Strategy for the MCCM, as described in Section 7.16 of the Project EA, states that the following broad rehabilitation techniques will be used. Further details of the rehabilitation methods that will be adopted at the MCCM, including surface preparation, revegetation and maintenance activities, are provided in Section 5.

3.4.1 Land Disturbance Protocol

The Rehabilitation Strategy states that the MCCM Land Disturbance Protocol (LDP) will be applied prior to the clearing of any native vegetation, in particular pre-strip clearing activities in advance of mining. The LDP will be used to manage the clearing process and to document all licensing, safety and management requirements.

A LDP form for the MCCM is an environmental checklist that must be completed for each stage of clearing by personnel responsible for the clearing activities, the relevant technical expert (e.g. Electrical Engineer to confirm no presence of cables, etc.) and signed off by MCC's Environmental Officer or a delegate.

3.4.2 Rehabilitation Techniques

The Rehabilitation Strategy states that vegetation and topsoil will be removed prior to mining activities occurring, because the topsoil contains a valuable native vegetation seed bank that will be used to enhance the rehabilitation works. Where practical, soil will be immediately spread over rehabilitation areas to enhance the rehabilitation outcomes. Where stockpiling is required, measures to protect its quality by retaining soil microbes and maintaining a viable soil seed bank will be implemented as described in Section 4.1.

The geochemical impact assessment undertaken for the Project EA (Hansen Bailey, 2011) concluded that with the implementation of appropriate management measures, there is a low risk of acid bearing overburden material forming. The Rehabilitation Strategy states that overburden materials that are most suitable for plant growth will be spread over the surface areas of the overburden emplacement areas prior to the application of soil where possible.

Section 5 provides further detail of the rehabilitation methods to be used at the MCCM, including the surface preparation works.

3.4.3 Revegetation Techniques

The Rehabilitation Strategy states revegetation works will generally be carried out when climatic growth conditions are optimal, and that they will involve direct native seeding and/or supplementary tube stock planting.

It also states that native groundcover vegetation will be established to prevent raindrop and sheet erosion from occurring, and in the event that native grass cover is initially insufficient to stabilise sloped areas due to slow growth rates, introduced self-sterile ground covers (if seasonally and commercially available) may be used to supplement plantings. Natural seed germination from the soil seed bank will be assisted with direct seeding and where applicable, seed will be treated to enhance germination rates. Planting of tube stock will supplement areas of low success rates from the natural regeneration from the seed bank and direct seeding. The seed used for direct seeding and for growing tube stock will be sourced from healthy, large and accessible populations that are located near the MCCM where possible. Local endemic (adapted) species will be preferentially used, however consideration will be given to the use of a high quality seed source further from the site over a low quality more local seed source.

Section 5 provides further detail of the revegetation methods that will be adopted at the MCCM to achieve effective restoration of potential habitat for the Regent Honeyeater, Swift Parrot and South-eastern Long-eared Bat and the Box-Gum Woodland CEEC.

3.5 FINAL LANDFORM AND REHABILITATION DOMAINS

The Rehabilitation Strategy for the MCCM, contained a description the final landform concept, including a description of the major rehabilitation 'domains' that will be created over the mine life. The domains were identified based on their physical characteristics, location and proposed post-mining land use.

As part of the development of the initial mine plans and preparation of the MOP, Whitehaven has refined the domains into the following primary and secondary categories (Table 3-2).

Table 3-2
Primary and Secondary Rehabilitation Domains

Primary/Operational Domains	Code	Secondary/Post Mining Land Use Domains	Code
Infrastructure Area	1	Rehabilitated Woodland	A
Overburden Emplacement Area	2	Water Management	B
Water Management Infrastructure	3	Final Void	C
Open Cut at Year 21	4		
Stockpiled Material	5		

Source: MCCM MOP – 1 March 2014 to 1 March 2016.

The main domains for the MCCM are shown on Figures 1-3 and 1-4 and include:

- Domain 1A – Infrastructure area with a post mining land use of rehabilitated woodland;
- Domain 2A – Overburden emplacement area with a post mining land use of rehabilitated woodland;
- Domain 3B – Water management infrastructure;
- Domain 4C – Residual open cut at Year 21 (i.e. final void); and
- Domain 5A – Stockpiled material (vegetation and topsoil) with a post mining land use of rehabilitated woodland.

A brief description of the domains is provided below.

Domain 1A - Infrastructure Area

The Infrastructure Area Domain (1A) is located in an area that, prior to mining, consisted of cleared agricultural land, woodlands and isolated pockets of remnant vegetation and derived grassland, and incorporated an area of the Namoi River floodplain (Figure 2-1). This domain includes the CHPP, site administration offices, equipment and maintenance sheds, loading facilities, coal stockpiles, mine access road and the transport corridor between the mine infrastructure area and the Boggabri Coal Mine rail spur. Figures 1-3 and 1-4 show the locations of infrastructure as depicted in the mine plans in the MOP.

Upon mine closure, mine-related infrastructure will be decommissioned and the landscape rehabilitated (Figure 1-5). A key rehabilitation objective for this domain will be to stabilise the batters and slopes surrounding this infrastructure to a final landform that minimises potential erosion and sedimentation issues in downstream waterways.

The final land capability of this domain will incorporate a mixture of classes including Class III, V and Class VI lands. A substantial area of this domain adjoins land that contains remnant native vegetation that is adjacent to, or will form part of, the MCCM biodiversity offset areas (Figure 1-5). The rehabilitation strategy for this domain will, where practical, revegetate the decommissioned areas of the mine access road and rail spur corridor to maximise its ecological contribution to the biodiversity offset areas. It is envisaged that this domain will include a significant proportion of the 544 ha area to be rehabilitated with species consistent with a Box-Gum Woodland CEEC (i.e. as required by Condition 25 of Commonwealth approval EPBC 2010/5566). Specific details will be provided in subsequent revisions of the MOP and this MSRP as the mine proceeds.

Domain 2A - Overburden Emplacement Area

The overburden emplacement area Domain (2A) consists of the areas within the Project Boundary used for overburden emplacement (i.e. the out-of-pit overburden emplacement area as well as the infilled sections of the open cut). The rehabilitation objective for this domain is to develop a free draining final landform designed to integrate with the surrounding catchments by channelling water towards natural drainage lines of Back Creek. Figure 1-5 shows the conceptual design of the overburden emplacement area as depicted in the MOP (Revision 3).

The domain will be progressively rehabilitated over the life of the mine. This will assist in minimising the mine disturbance area that is open at any one time and will reduce the environmental impacts of the mining operations (i.e. reduced dust emissions, visual impacts, and biodiversity).

The final shape of the overburden emplacement area will be designed to integrate with the surrounding undisturbed topography as much as possible. The final rehabilitated batters will have a maximum overall slope of 10 degrees, which will assist in maximising the long term stability and sustainability of the landform. The final batter slope and top surface configuration of the overburden emplacement area landform will be a key factor in determining which areas will be rehabilitated with species consistent with a Box-Gum Woodland CEEC (i.e. the minimum 544 ha required under Condition 25 of Commonwealth approval EPBC 2010/5566). Generally speaking, it is expected that only the flatter areas and shallower parts of the overburden emplacement area will be used for this purpose.

Domain 3B - Water Management Infrastructure

The Water Management Domain (3B) will be situated immediately adjacent to the Infrastructure Area Domain and will include the various dams, channels and bunds used to manage and contain water runoff from this area. The primary objective for this domain will be to construct and stabilise the water management structures so that they can used during the mine life and post closure (where necessary) to meet the water management objectives for the MCCM (i.e. segregation and containment/treatment of dirty water, and diversion of clean water around mine disturbance areas).

Domain 4C - Open Cut at Year 21 with Final Void

Based on the currently approved 21 year mine life for the MCCM, the final void will be located in the southern and eastern portion of the Project Boundary and will have a catchment area of approximately 887 ha with an approximate surface area of 170 ha. Figure 1-5 shows the final void conceptual design as depicted in the MOP (Revision 3).

The Rehabilitation Strategy states that at the conclusion of mining the pit walls of the final void will be blasted to a slope of approximately 37 degrees. Catchment areas that are not free draining will report to the final void.

Condition 74 of Schedule 3 of State approval PA 10_0138 (refer to Section 2.2) requires the proponent to prepare and implement a Final Void and Mine Closure Plan, as a component of the overall RMP (required under condition 73 of Schedule 3 of State approval PA 10_0138). A draft of the Final Void and Mine Closure Plan is required to be submitted to the Executive Director of DRE by the end of December 2020, and a final plan must be submitted by the end of December 2026.

The Final Void and Mine Closure Plan must identify and consider:

- options for continued mining beyond the 21 year mine life;
- interactions with the final landform of adjoining mines;
- opportunities for integrated mine planning with adjoining mines to minimise environmental impacts;
- all reasonable and feasible landform options for the final void (including filling);
- the predicted stability of the proposed landforms; and
- predicted hydrochemistry and hydrogeology (including long-term groundwater recovery and void groundwater quality).

It must also include a detailed proposed final landform, and demonstrate that it:

- satisfies the relevant rehabilitation objectives (Table 3-1);
- minimises the extent of any resulting pit lake;
- avoids salt scalding;
- maximises the capacity of emplaced spoil to drain to the natural environment; and
- ensures that drained waters do not adversely affect the downstream environment.

These requirements are consistent with the conditions of Commonwealth approval EPBC 2010/5566 (i.e. Condition 30 requires the person undertaking the rehabilitation to ensure that the final void and landform minimises the extent of the resulting pit lake, avoids scolding and ensures that drained waters do not adversely affect the downstream environment and avoids any impacts on matters of national environmental significance).

In order to maintain consistency between documents, and to satisfy all the requirements of Commonwealth approval EPBC 2010/5566, this MSRP will be revised as necessary to be consistent with the Final Void and Mine Closure Plan, once it has been prepared.

Domain 5A - Stockpiled Material Domain

The Stockpiled Material Domain (5A) incorporates the MCCM soil and vegetation stockpiles. Section 4.1 provides details of the soil stripping and stockpiling processes that will be adopted. The BMP provides details of the methods and processes for salvaging, stockpiling and reusing vegetation that is cleared during the land clearing process (i.e. for reuse as habitat features in rehabilitation areas). Salvaged vegetative material may include hollow trees, woody ground debris (to be reused as either fallen or standing debris), and trees and fallen logs without hollows. Large flat or creviced rocks may also be collected and stockpiled for later reuse.

The soil and vegetation stockpiles will be used progressively during the mine life. They will be located in available land within the Project Boundary, and will be accessed as required to stockpile material and to reclaim it for use in rehabilitation. Once the stockpile areas are no longer required, the disturbance areas will be rehabilitated into native forests and woodlands. While in place, the soil stockpiles will be managed in accordance with the Soil Management Protocol (refer to Section 4) and the vegetation stockpiles will be managed in accordance with the BMP.

3.6 DECOMMISSIONING

Decommissioning and removal of all infrastructure items from the mine site will take place during the mine closure phase. Any infrastructure including dams, levee banks, roads and buildings, which is beneficial for future use by post mine landowners, will be left in place in accordance with the relevant stakeholder or landowner agreements. Decommissioning of the mine infrastructure area will include removal of equipment and infrastructure, remediation of any land contamination, ripping, topsoiling (if necessary) and seeding.

3.7 REHABILITATION PERFORMANCE INDICATORS AND COMPLETION CRITERIA

The Project EA (Hansen Bailey, 2011) included a table of preliminary rehabilitation criteria, and indicated that the criteria will be further developed and agreed in consultation with the relevant government agencies and community. It also stated that these criteria will continue to be revised and developed to demonstrate that the rehabilitation objectives have been achieved, and that the achievement of the completion criteria will be monitored and reported to relevant stakeholders. The preliminary rehabilitation completion criteria have been reviewed and revised in light of the Commonwealth and State approvals that have now been issued for the MCCM.

The Condition 27 (a) of Commonwealth approval EPBC 2010/5566 requires targets (completion criteria) and performance indicators for restoration of habitat and weed management. Table 3-3 provides completion criteria (i.e. end of mine life) and performance indicators.

Table 3-3
Rehabilitation Performance Indicators and Completion Criteria (Targets)

Objectives	Performance Indicators	Completion Criteria/Targets
Phase – Decommissioning of Infrastructure		
All mine-related infrastructure removed from the site and disposed of at an appropriate facility, relocated to another Whitehaven site, or sold.	Communications, power supply, water supply, and water management services and infrastructure removed.	All infrastructure components dismantled and/or removed from the site unless otherwise agreed with the Administering Authority and landholder.
	Offices, workshops and other buildings removed.	
	Fuel, chemical, explosive storage tanks and containers removed.	
	Roads and rail Infrastructure removed.	
All hazardous materials removed and contaminated areas remediated.	Hazardous materials such as hydrocarbons, chemicals and explosives removed from site.	All hazardous materials removed from the site and appropriately disposed of.
	Areas where hazardous materials have been stored or transferred have been assessed for contamination and remediated if required.	Land contamination assessments and remediation (if necessary) conducted in accordance with the relevant legislative requirements.
Groundwater bores and piezometers decommissioned and sealed if no longer required for monitoring or water supply purposes.	Groundwater bores and piezometers stand pipes removed and sealed.	Bentonite seal installed, standpipe and piezometer ‘cap’ removed and cement grout installed to the surface.
Phase – Landform Establishment		
Mine landform integrates and generally blends in with surrounding landscape and is stable.	Vegetative cover.	Vegetative cover (i.e. native shrub, grass, tree species and/or leaf litter) at least 80% of the minimum vegetative cover of each stratum at analogue sites.
	Minimal active erosion.	Absence of gullies >300 millimetre (mm) wide or deep, or gullies stable.
		Absence of tunnel erosion intake or outlets points.

Table 3-3 (Continued)
Rehabilitation Performance Indicators and Completion Criteria (Targets)

Objectives	Performance Indicators	Completion Criteria/Targets
Mine landform integrates and generally blends in with surrounding landscape and is stable. (Cont.)	LFA Stability Index (Tongway and Ludwig 2011; or equivalent).	LFA soil stability Index based on key soil surface characteristics including: • Soil cover; • Litter cover; • Cryptogam cover; • Crust brokenness; • Erosion type and severity; • Deposited materials; • Surface coherence (resistance to disturbance); and • Slake test. The LFA Soil Stability Index of rehabilitated landforms will be similar to reference (analogue) woodland conditions
	LFA Nutrient Recycling Index (Tongway and Ludwig 2011; or equivalent).	LFA Index for Nutrient cycling is based on key soil surface characteristics including: • Surface roughness; • Cryptogram cover; • Litter cover, depth origin and decomposition ; and • Perennial grass basal and tree and shrub foliage cover. The LFA Nutrient Cycling Index of rehabilitated landforms will be similar to reference woodland conditions

Table 3-3 (Continued)
Rehabilitation Performance Indicators and Completion Criteria (Targets)

Objectives	Performance Indicators	Completion Criteria/Targets
Mine landform integrates and generally blends in with surrounding landscape and is stable. (Cont.)	LFA Infiltration Index (Tongway and Ludwig 2011; or equivalent)	LFA Infiltration index based on key soil surface characteristics including: • Perennial plant cover; • Litter cover, depth origin and decomposition; • Surface roughness; • Slake test; and • Soil texture. The LFA Infiltration Index of rehabilitated landforms will be similar to reference (analogue) woodland conditions
Water quality non-polluting and appropriate for conservation end land use.	Water quality.	Oil/grease 10 milligrams per litre (mg/L).
		pH between 6.5 and 8.5 as per the Maules Creek Environmental Protection Licence (EPL) 20221.
		Total Suspended Solids (TSS) 50 mg/L.
Phase – Growth Medium Development		
Growth media is suitable for establishing desired vegetation communities.	Soils ameliorated to sustain native ecosystems.	Presence of woody debris (logs with hollows salvaged from clearance activities) and rocks similar to analogue sites (at least 80% of the analogue sites).
		Topsoil respread to the depth and layering based on the results of the pre-disturbance soil testing program (Section 4.1).
		Appropriate soil ameliorants (e.g. gypsum, fertilisers, mulch) have been applied.
Phase – Ecosystem Establishment		
Native ecosystems established consistent with desired vegetation communities.	Woody vegetation diversity.	The species diversity of established shrubs and trees is similar to that of the analogue sites (at least 80% of the analogue sites).
		Number of weeds species and surface area cover analogue sites.

Table 3-3 (Continued)
Rehabilitation Performance Indicators and Completion Criteria (Targets)

Objectives	Performance Indicators	Completion Criteria/Targets
Native ecosystems established consistent with desired vegetation communities (Cont.)	Herbaceous diversity	The diversity of herbaceous species of understoreys and native grasslands is similar to analogue sites (at least 80% of the analogue sites).
	Woody vegetation density.	The stem density of established shrubs and trees is similar to that of the analogue sites (at least 80% of the analogue sites).
Establishment of fauna habitats.	Presence of a heterogeneous and structurally complex habitat development.	LFA Habitat Complexity Index based on key characteristics including: • Canopy cover; • Shrub cover; • Ground vegetation cover; • Amount of litter, logs and rocks; and • Free available water.
Phase – Ecosystem Development		
Ecosystem health.	Vegetation is in a condition comparable to that of the analogue communities.	The percentage of the tree population in a healthy condition is similar to that of the analogue sites (at least 80% of the analogue sites)
		The presence of reproductive structures such as buds, flowers or fruit.
Ecosystem structure.	Vegetation is developing in structure and complexity comparable to that of analogue communities.	Projected foliage cover provided by perennial plants in the 0.5 – 2 m vertical height stratum.
		Projected foliage cover provided by perennial plants greater than 6 m vertical height stratum.
Ecosystem composition.	Vegetation is comprised by a range of growth forms comparable to that of the analogue communities.	The number of tree species comprising the vegetation community is similar to that of the analogue sites (at least 80% of the analogue sites).
		The number of shrub species comprising the vegetation community is similar to that of the analogue sites (at least 80% of the analogue sites).

Table 3-3 (Continued)
Rehabilitation Performance Indicators and Completion Criteria (Targets)

Objectives	Performance Indicators	Completion Criteria/Targets
Ecosystem composition (Cont.)	Vegetation is comprised by a range of growth forms comparable to that of the analogue communities (Cont.)	The number of herbs or forbs species comprising the vegetation community is similar to that of the analogue sites (at least 80% of the analogue sites).
		The number of grass species comprising the vegetation community is similar to that of the analogue sites (at least 80% of the analogue sites).
Phase – Relinquishment		
Unrestricted fauna movement across the rehabilitation.	Presence of a range of fauna assemblages throughout the rehabilitation.	Species diversity within each key fauna groups (birds, bats, reptiles) similar to an analogue community of similar post disturbance condition.

Regent Honeyeater, Swift Parrot and South-eastern Long-eared Bat and the Box-Gum Woodland CEEC

The performance indicators and completion criteria (targets) in Table 3-3 are also relevant to the re-establishment of potential habitat for the Regent Honeyeater, Swift Parrot and South-eastern Long-eared Bat and the Box-Gum Woodland CEEC. The Regent Honeyeater, Swift Parrot and South-eastern Long-eared Bat all use woodland and forest habitats that will be established on the post-mine landforms in accordance with Condition 25 of Commonwealth approval EPBC 2010/5566. Of the 1,665 ha of woodland and forest habitats that will be established on the post-mine landforms, 544 ha will be revegetated with species consistent with Box-Gum Woodland CEEC in accordance with Condition 25 of Commonwealth approval EPBC 2010/5566.

Analogue Sites

As described in Section 7.4, transects will be established in adjacent undisturbed (analogue) communities to track the rehabilitation progress, predict self-sustainable values and compare the rehabilitation and analogue sites. At a minimum, revegetated communities will be of similar (at least 80%) or higher quality than an analogue site at the time of Project relinquishment.

As described in Section 5.1, no rehabilitation of the main mine landforms has occurred to date, and none is scheduled to occur during the period covered by the MOP (Revision 3) (i.e. up to the end of 2017). Analogue sites will be established by the end of 2017 (before rehabilitation of the main mine landforms has occurred) to refine the completion criteria (targets) in Table 3-3.

Monitoring

The quality of rehabilitation will be monitored annually using Ecosystem Function Analysis (EFA) or a similar systems-based approach. EFA is a CSIRO developed method used to provide indicators of rehabilitation success and allows the assessment of ecosystem sustainability through the plotting of development trajectories. It is divided into three modules: Landscape Function Analysis (LFA); vegetation composition and dynamics; and habitat complexity.

The LFA component is a quantitative tool for assessing ecosystem function, which focuses on the dynamics of resource mobilisation, transport, deposition, utilisation and loss of soil condition. The vegetation composition and dynamics component of EFA monitoring provides a quantitative assessment of species composition, density and cover. The habitat complexity component of EFA provides an index of the development of available habitats for fauna and includes measurements of vegetation cover, ground habitat (litter, logs, rocks) and the availability of water.

Further detail of the MCCM rehabilitation monitoring program is provided in Section 7.3.

Trigger Action Response Plan

The performance of the rehabilitation will be monitored against the performance indicators provided in Table 3-3. If performance criteria are not being met, the Trigger Action Response Plan (TARP) for rehabilitation at the MCCM (Section 7) will be implemented where required. For example, remedial measures for managing poor vegetation growth or weeds are provided in Section 7.

Review

The performance indicators and completion criteria (targets) in Table 3-3 may be revised subject to the results from the rehabilitation monitoring programme. In accordance with Condition 36 of the Commonwealth approval EPBC 2010/5566, if MCC wishes to carry out any activity otherwise than in accordance with the MSRP (as it pertains to Commonwealth approval EPBC 2010/5566), MCC will submit a revised MSRP to DotE for the Minister's written approval.

4 SOIL MANAGEMENT

4.1 SOIL MANAGEMENT PROTOCOL

Soil management procedures have been developed and are documented in the MCCM Soil Management Protocol. These procedures enable soil resources within disturbance areas to be characterised, stripped, stockpiled and reused appropriately.

The soil management procedures have been developed to meet the requirements of the State and Commonwealth approvals for the MCCM. In particular, the requirements of Condition 39 of Schedule 3 of PA 10_0138 (i.e. preparation of a soil management protocol), and Conditions 26(b), 27(c) and 27(d) of EPBC 2010/5566 (refer to Table 2-1).

A list of the procedures/management measures contained in the MCCM Soil Management Protocol is provided below, along with a brief overview of the coverage of the document. In the event of an inconsistency between this MSRP and the Soil Management Protocol, the latest version of the Protocol should be used.

- **Soil Profile:** Nine soil types/groups were identified within the Project Boundary as part of the baseline soil surveys conducted for the Project EA (Hansen Bailey, 2011). The Soil Management Protocol lists the nine types, their key constraints, and the specific management measures to be adopted for each type, including recommended stripping depths, and suggested soil amelioration and fertiliser rates.
- **Soil Testing Procedure:** Prior to stripping, soil will be sampled to: identify the soil resource prior to stripping; assist with the preparation of a soil balance/inventory to assist with rehabilitation planning; and to determine if the soil requires amelioration. The soil sampling will be undertaken at a minimum sampling frequency of one sample point per 20 ha of each soil type identified, and will include an assessment of soil depth and analysis of soil characteristics. Individual Soil Stripping and Placement Plans will be prepared for each stripping event.
- **Soil Balance:** The Soil Stripping and Placement Plans will document the amount and type of soil stripped from each area. This information will be recorded in a centralised inventory. The soil balance for the MCCM will be updated and reviewed regularly as new surveys are conducted, and progressive stripping and rehabilitation is undertaken.
- **Clearing and Grubbing:** Vegetation clearing will be undertaken using the management practices contained in the BMP. Records of salvaged vegetation (particularly hollow trunks) and large rocks will be retained, and these materials will be used in rehabilitation areas to provide fauna habitat opportunities.

- **Soil Amelioration:** The soil testing results will be used to determine if physical and/or chemical amelioration is required, and the rates and method of application. The Soil Management Protocol provides indicative ameliorant application rates for the nine main soil types/groups found at the MCCM. It is generally not possible to correct soil deficiencies with a single application of fertiliser. As a result, additional soil testing following revegetation will be undertaken to determine further amelioration requirements and rates.
- **Soil Stripping:** The surface 0.15 m of *in situ* soil is biologically active and contains almost all of the nutrients, seeds, and beneficial organisms. In many parts of the Project Boundary, the biologically active layer is likely to be shallower than 0.15 m, however, stripping soil in layers thinner than this is generally not possible with available machinery.

  All soils below the topsoil are defined as subsoils. The Soil Management Protocol provides recommended soil stripping depths for the nine main soil types/groups found at the MCCM. As described in the Soil Management Protocol, subsoil stripping is not recommended for six of the nine soil types found at the MCCM due to their physical and/or chemical limitations. The subsoils of the three soil types that are suitable will be stripped and reused underneath the corresponding stripped topsoil where appropriate and practicable.

  Individual Soil Stripping and Placement Plans will be developed for each area that is to be stripped. Earthmoving plant operators will be supervised to ensure that stripping operations are conducted in accordance with the stripping plan and *in situ* soil conditions. The process summarised below for stripping topsoil should be followed:

  – The area to be stripped of soil will be clearly demarcated and surveyed.
  – Soil will be in a slightly moist condition during stripping.
  – Soil will not be stripped during excessively wet or dry conditions.
  – Where practical, stripped material will be placed directly onto reshaped overburden and spread immediately (if mining sequences, equipment scheduling and weather conditions permit) to avoid the requirement for stockpiling and costs with double handling.
  – As part of the planning process, sufficient area for stockpiling, placement or burial of soil will have been identified and these areas will be accessible.
  – As part of the planning process, temporary drainage, sediment control and structures to prevent erosion will be developed for each area if required.
  – Soil collection will be undertaken by open bowl scrapers or loading into rear dump trucks.

  Where practicable, soil stripped from each vegetation community will be used in areas identified for rehabilitation for the corresponding vegetation community. Where soil cannot be used for rehabilitation immediately it will be stockpiled according to vegetation community type.

  A summary of the available soil stripping information for mine disturbance areas cleared to date is provided in Section 4.2.

- **Soil Stockpiling:** The soil seed bank is an important reserve of native plant seeds and symbiotic soil micro-organisms, which will assist with the preservation of local genetic material and the re-establishment of a similar range and mix of species of the original vegetation in the rehabilitation area. The individual Soil Stripping and Placement Plans for each area will describe the soil stockpiling requirements for each area to be cleared (e.g. stockpile locations, methods, depths and reporting requirements). stockpiling is unavoidable until after 2018, the following process for soil stockpiling will be followed:
  - Where possible, stockpiles will be located in areas away from drainage lines and/or drainage will be diverted around stockpiles to prevent erosion.
  - If required, sediment controls will be installed downstream from stockpiles to prevent contamination of clean water.
  - Stockpile height will be limited to the practicable minimum.
  - New stockpiles will be continually created and old ones will be used in order of age.
  - More erodible materials will be placed on flatter areas to minimise the potential for erosion.
  - The surface of soil stockpiles shall be contour scarified in order to promote infiltration and minimise erosion until vegetation is established.
  - When necessary, stockpiles will be seeded with (if storage times will be less than five years) or native grasses, tree or shrub species to protect the stockpile from raindrop splash erosion, aerate the soil to reduce anaerobic conditions, enhance organic carbon levels and suppress weeds.
- **Characterisation:** Characterisation of subsoil for erosion (primarily dispersion) and agronomic parameters (pH, EC, Cation Exchange Capacity [CEC] and metals) will be undertaken. Sampling will determine if the subsoil is suitable for rehabilitation use or if it requires amelioration or selective handling and placement. The Soil Management Protocol provides the parameters and limits that will be used to classify the suitability of subsoil.

  If not able to be ameliorated, unsuitable subsoil and spoil, including Potentially Acid Forming (PAF) material, will be capped with a minimum of 5 m of suitable inert spoil (compacted depth) or, more appropriately, capped to a depth greater than the minimum rooting depth of the vegetation. The individual Soil Stripping and Placement Plans for each stripping area will identify where unsuitable spoil and subsoil has been placed.

- **Soil Respreading:** Prior to the re-spreading of stockpiled soil, an assessment of weed infestation will be undertaken to determine if individual stockpiles require burial due to their unsuitability as a result of weed infestation. If unsuitable, the stockpiled material will be buried and capped as described above. For all other stockpiled material, the following re-spreading measures will be adopted where appropriate/relevant.
  - When planning soil re-spreading, MCC will consider the information contained in the stockpile inventory (i.e. amount, age, type), climatic conditions, the location and distance of the stockpile from the area to be rehabilitated, the pre-mining vegetation communities (i.e. what communities were growing in the area prior to stripping), and the vegetation communities and final land use proposed for the rehabilitation area.
  - During the removal of soils from the stockpiles, care will be taken to minimise structural degradation of the soils.
  - Material will be spread in even layers at an appropriate thickness, and will consider the soil depth information obtained through the pre-stripping soil sampling. During the life of the MCCM monitoring and research studies will be undertaken to refine the soil depth used in for each soil type and rehabilitation application.
  - All soils will be lightly ripped prior to seeding. This will be conducted on the contour and will be managed to minimise the potential for unsuitable spoil material being ripped up to the surface.
  - Where necessary, slow release fertiliser application will be conducted prior to seeding while the surface is being lightly scarified to create an optimal seed bed. The application rates and types of fertiliser used will be selected to minimise the potential for weed invasion.
- **Monitoring, Responsibility and Reporting:** Implementation of the various stages of soil stripping, stockpiling and reuse will be monitored and periodically reviewed. Where appropriate, management practices will be revised and updated based on operational experience and where improved performance/outcomes are identified.

  The responsibility for overall soil management at the MCCM belongs to Whitehaven. However, all staff and contractors have a responsibility to follow the processes and procedures for managing soils, as outlined in the Soil Management Protocol. All staff and contractors must ensure that they have the necessary permits and approvals in place, including a Soil Stripping and Placement Plan, prior to undertaking works which will disturb soils.

  Soil stripping and placement activities for each work area will be documented in the individual Soil Stripping and Placement Plans, which will be prepared following soil testing and updated following stripping activities to confirm the location of either stockpiled material or the direct placement of material.

  Soil stockpiling and rehabilitation will be assessed and reported annually as part of the MCCM Annual Review.

4.2 SUMMARY OF AVAILABLE SOIL SURVEY AND STRIPPING INFORMATION

Soil Survey

In accordance with the Soil Management Protocol, MCC conducted a soil survey and developed a growth media inventory for the mine landform areas conducted by Landloch Pty Ltd (2014). Soil surveys of the remaining areas of the planned MCCM mine disturbance footprint will be conducted progressively over the mine life prior to the commencement of each stage of land clearing (i.e. as summarised in Section 4.1 and described in detail in the Soil Management Protocol).

The soil survey conducted by Landloch Pty Ltd (2014) covered a 392 ha area, and included the initial development area of the open cut, the initial out-of-pit overburden emplacement area, and associated mine infrastructure (e.g. haul roads, stockpiles and water management infrastructure). The soil survey was undertaken at a density of at least one sample point per 20 ha of each soil type identified. Figure 4-1 shows the sample locations and the five soil landscapes that were identified (i.e. Leard, Blue Vale Slopes, Blue Vale Footslopes, Blue Vale Flats and Hartfell).

Each soil profile class was described, classified and quantified for the purpose of evaluating soil layers as plant growth media for rehabilitation. Soil samples were taken and their physical and chemical properties were analysed. The soil survey report (Appendix B) provides detailed descriptions of each soil profile class that was identified, including an analysis of the observation and laboratory data, and a discussion of the key features and potential management issues to be considered when salvaging soils for re-use as plant growth media.

Soil Stripping

Soil stripping and stockpiling activities have been conducted at the MCCM since construction and development of the mine commenced. The main soil striping areas have been located in the initial open cut development area and the overburden emplacement area. As described in Section 3.2, no rehabilitation of the main mine landforms has occurred at the MCCM to date, and as a result, re-use of stockpiled soil has not yet commenced.

Table 4-1 summarises the volume and type of soil that has been stripped and stockpiled from the main mine disturbance areas.

As per the approved BMP, vegetation clearing at the MCCM will be conducted annually in campaigns during the period from 15 February to 30 April each year, except under exceptional circumstances agreed to by the Secretary of the Department of Planning & Environment (DP&E). The amount of land cleared each year will be restricted to the practicable minimum required for the safe and efficient operation of the MCCM. Soil stripping of the cleared areas will occur when required, and following completion of the necessary pre-stripping soil surveys.

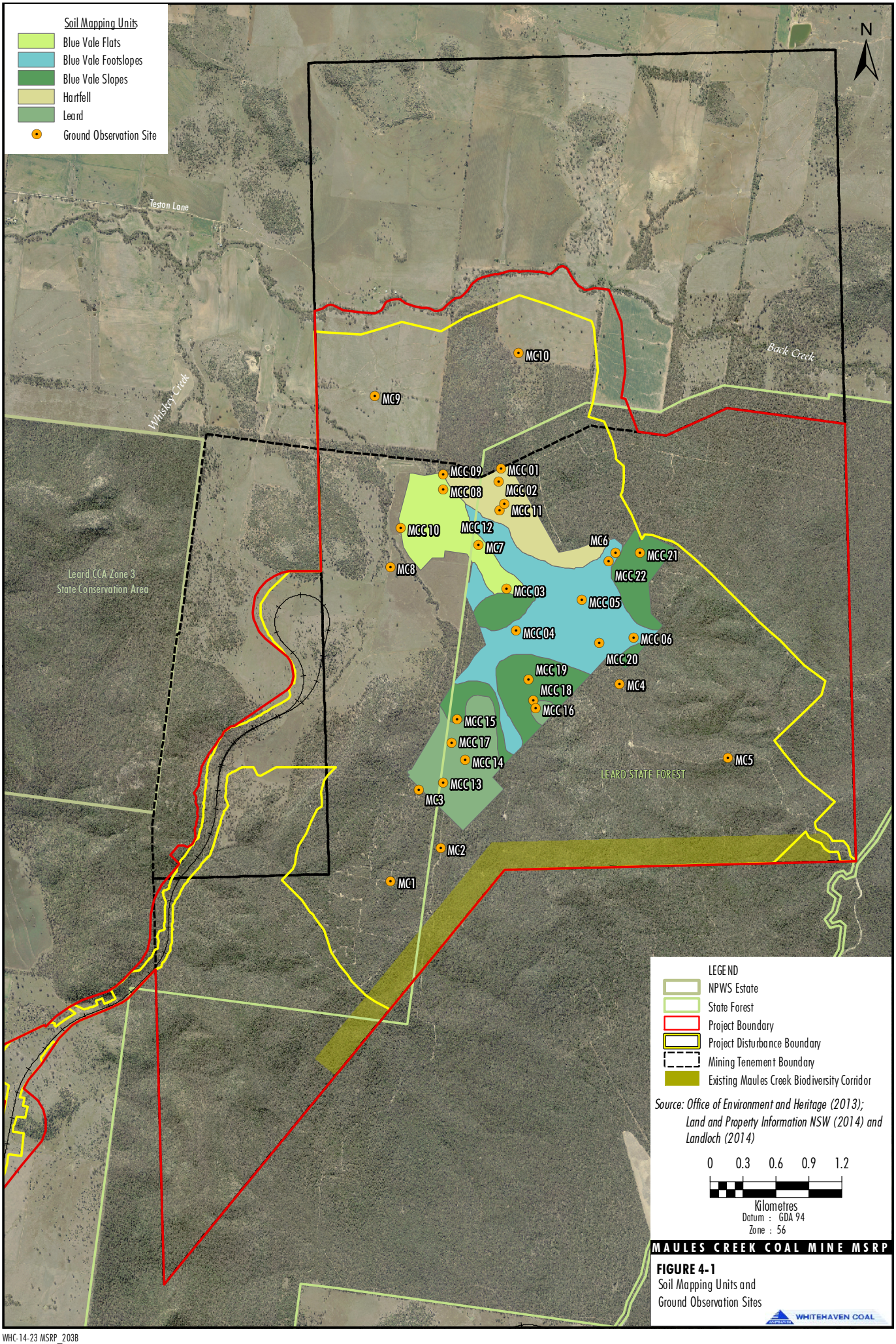


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Table 4-1
Summary of Soil Types and Areas Stripped and Stockpiled at the MCCM

Stockpile Name	Volume* (bcm)	Source Areas	Soil Types
Operations Area 3	131,000	Operation Areas – 1, 3, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	2, 3, 4, 5
Operations Area 4	164,000	Operation Areas – 2, 4, 5, 6 Construction Areas – mine water dam	1, 2, 3, 4a, 4b-1, 4b-2, 4c-3
Ditchfield North	269,000	Construction Areas – magazine, train load-out facility, mine infrastructure area, coal stockpile area, haul road 1, raw water dam	3a, 3b, 4a, 4b-1, 4b-2, 4c-3
Ditchfield South	86,000	Construction Area – coal stockpile area	4c-1

* As at November 2014.
bcm = bulk cubic metres

5 REHABILITATION MANAGEMENT

5.1 REHABILITATION PROGRAM

As described in Section 1.4, the current MOP (Revision 3) for the MCCM covers the period from 15 February 2016 to 1 January 2018.

The DRE Mining Operations Plan Guideline (DRE, 2013) requires each MOP to provide details of the status of rehabilitation at each domain as at the commencement of the MOP (i.e. outline activities that have occurred to date), plus it must also describe the rehabilitation activities proposed to be implemented over the MOP term on a domain by domain basis. The rehabilitation information must also be shown pictorially.

Due to the early construction and development phase of the MCCM, no substantial rehabilitation of the main mine landforms has occurred to date, and none is scheduled to occur during the period covered by the MOP (Revision 3) (i.e. up to the end of 2017). This is because the infilled out-of pit overburden emplacement area will not be sufficiently developed (i.e. no outer batter areas will be complete and available), and the progressive infilling and re-profiling of the open cut will not have commenced.

Future versions of the MOP will include more information on the progressive rehabilitation of the MCCM, as parts of the overburden emplacement area and infilled open cut are finalised and become available. Notwithstanding, the indicative rehabilitation program for the MCCM based on the current mine plan and mine closure strategy is presented in Table 5-1.

Overburden dumping in the out-of-pit overburden emplacement area will be undertaken for the first nine years of mining. Following this, overburden will be used to infill the area directly behind the mining operations in the open cut. The out-of-pit overburden emplacement area is scheduled to be fully developed by the end of Year 10.

Table 5-1
Indicative Schedule of Rehabilitation Activities and Timelines

Location	Rehabilitation Activity	Timeline
OEA - northern and eastern faces.	Rehabilitation	Years 1 to 5
OEA - western face.	Temporary Rehabilitation	Years 1 to 5
OEA - northern and eastern faces.	Rehabilitation	Years 5 to 10
Sediment dam 5.	Temporary Rehabilitation	Years 5 to 10
OEA top section.	Rehabilitation	Years 10 to 15
Southern in-pit emplacement area.	Rehabilitation	Years 10 to 15
Sediment dam 5.	Temporary Rehabilitation Progressive Rehabilitation	Years 10 to 15
OEA - southern and western faces.	Temporary Rehabilitation	Years 10 to 15

Table 5-1 (Continued)
Indicative Schedule of Rehabilitation Activities and Timelines

Location	Rehabilitation Activity	Timeline
Southern in-pit emplacement area - all southern section.	Rehabilitation	Years 15 to 21
East and west face of haul road west of the open cut highwall.	Temporary Rehabilitation	Years 15 to 21
All temporary and remaining in-pit areas.	Rehabilitation	Year 21 to relinquishment
Mine infrastructure area.	Rehabilitation	Year 21 to relinquishment
Mine access road and rail spur corridor.	Rehabilitation	Year 21 to relinquishment

Source: MCCM MOP – 1 March 2014 to 1 March 2016.

Note: OEA = overburden emplacement area. Temporary Rehabilitation is described in Section 5.2.9.

5.2 REHABILITATION METHODOLOGY

5.2.1 Mine Landform Reshaping and Design

The final outer surfaces of the mine landforms will be designed to be safe, stable, provide an adequately drained post-mining landform, and have a shape that is consistent with the types of naturally occurring landform features in the region. They will also be designed to provide a final surface that facilitates revegetation and growth of species that occurred in the native woodland and forest communities that were present prior to the commencement of mining.

In some instances, parts of the mine landforms will be constructed in their final configuration from the outset (e.g. some batters of the out-of-pit overburden emplacement and some cut and fill areas associated with the mine-related infrastructure). However for the majority of the out-of-pit overburden emplacement area and the open cut, the working batters and berms will need to be pushed back/down (or in-filled with overburden in the case of the open cut) to form the final mine landform surface. Micro-relief features and permanent water management structures (e.g. drop structures between batters and final bunds) will also be installed as part of this process. As described in the Rehabilitation Strategy (Section 3.5), the final rehabilitated batters of the overburden emplacement will have a maximum overall slope of 10 degrees, and the walls of the final void will be blasted to a slope of approximately 37 degrees, or less.

The designs of final landforms will be refined as part of the overall mine planning process, in a manner that is consistent with the overall rehabilitation and mine closure concept for the MCCM (Section 3). The MOP will provide detailed descriptions and plans of the landform reshaping activities and final designs for the period covered by each MOP.

5.2.2 Surface Preparation

Rehabilitation of the MCCM will involve replacement of soil in areas where it has been stripped, and surface conditioning in areas where the soil was left *in situ*.

Prior to topsoil is to be respread over subsoil or overburden, the subsoil or overburden surface will be deep ripped to address compaction and to incorporate ameliorants such as gypsum (where applied). Subsoil and/or topsoil will then be spread over the ripped area. The depth and layering of respread soil will be based on the results of the pre-disturbance soil testing program (refer to Section 4.1 for a summary of this program).

The surface of the topsoil will be ripped along the contour to reduce compaction.

A soil seed bank germination test will be undertaken on the re-spread soil to determine if direct seeding is required.

It is expected that the best results will be obtained when ripping of the replaced soil is undertaken when the soil is moist, and when it is undertaken immediately prior to sowing. The respread soil surface will be scarified prior to, or during seeding.

5.2.3 Amelioration of Growing Media

Some soils and mine spoils may have physical and chemical characteristics that will otherwise limit plant establishment and have a high potential for erosion. The pre-disturbance soil testing program will be used to determine whether these materials can be ameliorated (and the required application rates), or whether they should be left and buried within the overburden emplacement areas.

Mine soil and spoils will typically be ameliorated with one or more of the following if required:

- agricultural gypsum (i.e. to treat dispersion, calcium to magnesium ratio, and improve structure and water holding capacity);
- vegetation mulch generated on site (i.e. to increase organic carbon, and improve the soils water holding capacity and soil biota levels); and/or
- fertiliser (e.g. slow-release native plant fertiliser where possible).

Some soils may also contain soil microbes, such as rhizobia bacteria, which assist leguminous species such as *Acacias* and peas to grow and eventually contribute to increasing the nitrogen content of the system, which is often the most growth limiting nutrient in spoil (University of Newcastle [UoN], 2012).

Where topsoil is unavailable or of insufficient quality, subsoil or mine spoil may be able to be ameliorated to form a suitable growing media. The pre-disturbance soil testing program (Appendix B) and the rehabilitation monitoring and research activities will be used to determine whether subsoil amelioration is practicable.

5.2.4 Erosion Control

Erosion control measures will be used at the MCCM rehabilitation areas in order to manage dispersive soils and spoils, provide soil surface cover, and to minimise the creation of concentrated surface water flow conditions. Erosion control works will include, but are not necessarily limited to the measures listed below.

- Amelioration of dispersive spoil to minimise the risk of rill, gully and tunnel erosion and to allow the infiltration of surface water (reduce the amount and velocity of surface water). This will be determined during the soil testing program outlined in the Soil Management Protocol.
- Contour scarification of compacted surfaces to encourage infiltration and surface roughness.
- Use of cover crops including salt tolerant self-sterile annual grasses (if seasonally and commercially available), native grasses and native legumes to minimise raindrop and sheet erosion of reshaped areas.
- Use of inert rock mulches of appropriate stone sizes and cover where effective and appropriate.
- Vehicle access will be predominantly restricted to designated tracks on mine landforms that have been revegetated to minimise ground disturbance (e.g. erosion and/or compaction).
- Engineered temporary channel banks, slope drains and energy dissipaters in areas where concentrated surface flow may occur to reduce erosion if necessary. However, it should be noted that one of the aims of the landform design process will be to minimises the reliance on structural erosion control measures. Drainage and sediment control structures will be designed in accordance with Table 6.1 of *Managing Urban Stormwater: Soils and Construction* Volume 2E – Mines and Quarries (DECC, 2008). Sediment basins and other water storages will not be located on overburden emplacement areas in order to reduce the potential for tunnel erosion.
- Structural erosion controls may be used on overburden emplacement areas if necessary until vegetation cover is sufficient to provide adequate erosion protection.
- In the larger drainage systems such as clean water drains and modified natural drainage systems, erosion control methods such as cross vanes, rock vanes and J-hook vanes will be used to provide channel bed and bank protection.

The management of erosion and sediment control for all mining and associated disturbances is detailed further in the MCCM Water Management Plan, and for initial clearing activities via the LDP, which is contained in the BMP.

5.2.5 Timing of Revegetation Works

Rehabilitation will commence as soon as practicable in 2018 following disturbance in accordance with Condition 27b of Commonwealth approval EPBC 2010/5566 to minimise the potential for erosion and weeds. Section 5.1 provides an indicative schedule of rehabilitation activities and timing.

Where possible, each campaign of rehabilitation works will be completed by early September each year to allow sufficient time for appropriate levels of vegetation cover to establish before the period of potential high erosion hazard rainfall from October to February.

Livestock will be excluded from areas undergoing active revegetation (i.e. planting or seeding).

5.2.6 Revegetation of Domains

Section 3.5 summarises the major rehabilitation domains for the MCCM based on the Rehabilitation Strategy and the MOP as follows:

- Domain 1A – Infrastructure area with a post mining land use of rehabilitated woodland;
- Domain 2A – Overburden emplacement area with a post mining land use of rehabilitated woodland;
- Domain 3B – Water management infrastructure;
- Domain 4C – Residual open cut at Year 21 (i.e. final void); and
- Domain 5A – Stockpiled material (vegetation and topsoil) with a post mining land use of rehabilitated woodland.

Domains 1A, 2A and 5A will be revegetated to woodland. Domains 3B (the water management infrastructure) and 4C (the final void) will not be revegetated.

The upper sections of the Domain 4 final void highwall will be re-contoured and revegetated. The extent to which the remaining blasted sections of the highwall will be able to be revegetated will be determined by the final slope profile. It is likely that native vegetation adapted to steep slopes and skeletal soils can be established via direct seeding in some locations on the final highwall slope.

5.2.7 Vegetation to be Established

All of the remnant native vegetation communities that were mapped in the Project Boundary prior to mining (Figure 2-1) provide potential habitat resources for the Regent Honeyeater, Swift Parrot and South-eastern Long-eared Bat as these species all use woodland and forest habitats (Cumberland Ecology, 2011) . Condition 25 of Commonwealth approval EPBC 2010/5566 requires no less than 1,665 ha of woodland and forest to be established on the post-mine landforms. Woodlands and forests to be established may include, but are not necessarily limited to the following vegetation communities that occur in the Project Boundary (as mapped by Cumberland Ecology, 2011):

- White Box – White Cypress Pine grassy woodland;
- Silver-leaved Ironbark heathy woodland;
- White Box - Narrow-leaved Ironbark – White Cypress Pine grassy open forest;
- White Box - Narrow-leaved Ironbark – White Cypress Pine shrubby open forest; and
- Dwyer's Red Gum – Ironbark woodland.

No less than 544 ha of the post-mine landforms will be revegetated with species consistent with Box-Gum Woodland CEEC in accordance with Condition 25 of Commonwealth approval EPBC 2010/5566. The Box-Gum Woodland CEEC is represented in the Project Boundary by the vegetation communities listed in Section 2.1.

The placement of these vegetation communities will depend on final slopes, drainage and subsoil and topsoil characteristics. Suitably qualified specialists/restoration ecologists will be commissioned to provide direction about the rehabilitation and restoration of the Box-Gum Woodland CEEC, where appropriate.

As described in Section 5.1, future versions of the MOP (i.e. beginning February 2018) will include specific details of the locations and composition of the vegetation communities to be established in rehabilitated areas once the necessary mining planning and design processes have been undertaken. At a minimum, revegetated communities will be similar (at least 80%) or higher quality than analogue sites at the time of Project relinquishment (Section 3.7).

5.2.8 Soil Seed Bank Management

One of the key steps in the successful rehabilitation of native species is the management of the soil seed resource. For example, surveys of rehabilitated areas at the adjacent Boggabri Coal Mine have demonstrated natural regeneration of native species from the topsoil (Boden & Associates, 2011; Parsons Brinckerhoff, 2011).

Soil stripped from each vegetation community will be re-used to rehabilitate areas with the corresponding vegetation communities on appropriate slopes and substrates. This will maximise the likelihood that the soil type on the mine landform will be consistent with the naturally occurring vegetation community. It will also maximise regrowth of the community from the corresponding seed bank contained in the stripped material.

Soil seed bank germination testing will help determine if supplementary revegetation techniques are required at time of soil respreading.

5.2.9 Plant Species Selection for Revegetation

It is anticipated that natural seed germination from the soil seed bank will need to be assisted with direct seeding. Planting of tube stock will also be used to supplement natural regeneration from the seed bank and direct seeding as required. In particular, tube stock may be necessary to ensure the appropriate composition and density of long-lived woody vegetation needed for threatened fauna. A combination of all three techniques is likely to be used in order to achieve the rehabilitation objectives in certain areas.

Seed and tube stock used in revegetation will include a wide variety of grasses (including tussock grass species), herbs, forbs, low shrubs, mid-sized shrubs and tall trees to create structurally diverse habitat.

Local endemic species will be preferentially used, however consideration will be given to the use of a high quality seed sourced further from the site over a low quality more local seed source.

Revegetation species will include the main strata species of each vegetation community (Table 5-2) and species to assist in the initial development of the ecosystem including short lived *Acacia* species to contribute nitrogen to the developing system but not at excessive densities (UoN, 2012). *Acacia* species to be incorporated in the seed mix from vegetation communities include *Acacia decora,* and *A. cheelii*, and will consist of both tree and shrub varieties.

Direct seeding trials will be undertaken to determine the optimum method for vegetation establishment.

Table 5-2
Provisional Species List

Common Name	Scientific Name	Common Name	Scientific Name
Overstorey		***Overstorey***	
* White Box	*Eucalyptus albens*	Narrow-leaved Grey Box	*Eucalyptus pilligaensis*
* Yellow Box	*Eucalyptus melliodora*	Inland Grey Box	*Eucalyptus microcarpa*
* Blakely's Red Gum	*Eucalyptus blakelyi*	Dwyer's Red Gum	*Eucalyptus dwyeri*
Narrow-leaved Ironbark	*Eucalyptus crebra*	Red Stringybark	*Eucalyptus macrorhyncha*
Apple Box	*Eucalyptus bridgesiana*	Angophora species	N/A
Midstorey		***Midstorey***	
*Sticky Hop-Bush	*Dodonaea viscosa* ssp. *Angustifolia*	Silver Wattle	*Acacia dealbata*
*Wilga	*Geijera parviflora*	Hickory Wattle	*Acacia implexa*
Belah	*Casuarina cristata*	White Cypress Pine	*Callitris glaucophylla*
-	*Allocasuarina* spp.	Scant Pomaderris	*Pomaderris queenslandica*
Black Tea-tree	*Melaleuca bracteata*	Buloke	*Allocasuarina leuhmanii*
Understorey		***Understorey***	
*Smooth Darling Pea	*Swainsona galegifolia*	Three-awn Speargrass	*Aristida vagans*
*Barb-wire Grass	*Cymbopogon refractus*	Slender Stackhousia	*Stackhousia viminea*
*Silky Blue-grass	*Dichanthium sericeum*	Yellow Burr-daisy	*Calotis lappulacea*
*Daises	*Brachyscome* spp.	-	*Rostellularia adscendens* var. *adscendens*
*Everlasting Daises	*Chrysocephalum* spp.	Plains Grass	*Austrostipa aristiglumis*
*Kangaroo Grass	*Themeda triandra*	-	*Panicum* spp.
*Wallaby Grass	*Austrodanthonia induta*	-	*Austrodanthonia* spp.
*Winter Apple	*Eremophila debilis*	-	*Bothriochloa* spp.
Blue Trumpet	*Brunoniella australis*	-	*Chloris* spp.

* Specifically associated with the Box-Gum Woodland.

Temporary Cover

Temporary or interim rehabilitation will be used where required to provide cover to minimise erosion and dust impacts, as well as inhibiting the establishment of weeds. This will involve the application of a temporary cover crop for short term uses, and native grasses for longer term requirements. The species that are used will be selected so as to not be likely to impede the final revegetation of native vegetation, particularly the Box-Gum Woodland CEEC.

5.2.10 Seed Collection, Application and Storage

Native seed collection will be undertaken in the areas to be cleared where practicable, and from the remainder of the MCCM mining tenements. Seed will also be collected from offset properties (where suitable), with no more than 20% of the seed to be taken from any one population to maintain viability (UoN, 2012). The seed collection times and methods will be recorded and a database established to enable regular review and revision of the program.

Seed collection may occur at any time of year to coincide with the optimal seed collection times for each target flora species. As described in the BMP, seed collection, management and storage will be undertaken in consideration of the relevant Florabank guidelines (Florabank, 1999).

Due to the early development phase of the MCCM, specific details of the seed and tubestock supply strategy are yet to be developed (i.e. calculation of the amount and species of seed and tubestock required each year and how the seed and tubestock will be managed to meet the demand). These details will be provided in future editions of the MOP as the mine progresses and rehabilitation activities ramp up.

If seed collection campaigns are undertaken some considerable time prior to sowing, or if there is remaining seed after sowing, the seed will be stored prior to use to maintain germination rates and seed vigour. The length of time that the seed is stored will be kept to a minimum as seed vigour and germination rates can deteriorate over time. High temperature and humidity are the primary causes of seed deterioration over time.

Germination and Viability

Collected seed will be tested for germination rate and viability according to Florabank Guidelines (Florabank, 1999). A seed collection report will be completed by an independent seeding contractor following each collection event.

Seed Preparation and Application

Pre-treatment of seed is often required to mimic the natural process that creates optimal conditions for seed germination.

The rate and depth of seed application will be calculated based on the planned target plant density and species mix. The establishment percentage under field conditions can be affected by temperature, moisture, soil type, sowing depth, insects and disease. The establishment rate of directly sown seed is highly variable (i.e. can be less than 2%) and varies according to field conditions and the sowing operations employed.

Details of application rates for seeds and planting densities for tubestock will be provided in future versions of the MOP.

5.2.11 Habitat Creation for Matters of National Environmental Significance

The rehabilitation of the MCCM will include fauna habitat resources to encourage fauna use.

Regent Honeyeater

The Regent Honeyeater is a generalist forager, which mainly feeds on the nectar from a wide range of Eucalypts and Mistletoes. In consideration of the potential foraging habitat requirements of the Regent Honeyeater, a variety of box, ironbark and gum eucalypt species will be established on the post-mine landforms, including, but not limited to, White Box (*Eucalyptus albens*), Yellow Box (*E. melliodora*), Blakely's Red Gum (*E. blakelyi*), Mugga Ironbark (*E. sideroxylon*), *Allocasuarina* and *Casuarina* species.

Swift Parrot

In consideration of the potential habitat requirements of the Swift Parrot, a variety of winter-flowering box, ironbark and gum eucalypt species will be established on the post-mine landforms, including, but not limited to, White Box (*E. albens*) and Mugga Ironbark (*E. sideroxylon*).

South-eastern Long-eared Bat

The South-eastern Long-eared Bat forages on insects and roosts in tree hollows in the locality surrounding MCCM (Section 2.1). In the short to medium term, the proposed revegetation of box, ironbark and gum eucalypt species can provide potential source of prey.

Hollow limbs salvaged during vegetation clearance at the mine will be installed in select trees without hollows (once the revegetation is sufficiently mature to hold the hollow limb) providing a potential roosting resource.

The success of this hollow salvage program for the South-eastern Long-eared Bat will be assessed as part of the ongoing rehabilitation monitoring program.

Other Habitat Creation

Timber and bush rocks piles will be relocated to rehabilitation areas before, during and after clearing as per the LDP, which is contained in the BMP. Also, vegetative material (cleared at the mine site) will be incorporated into the soil used for rehabilitation or as mulch.

5.2.12 Rehabilitation Maintenance and Contingency Measures

Active management in response to monitoring and research activities in the rehabilitation areas will be completed as required to address any issues of concern identified during monitoring.

Maintenance activities will be developed in response to rehabilitation which is not performing on a case by case basis to ensure that these activities are focussed towards the achievement of rehabilitation objectives and targets. Maintenance works may include the following activities:

- supplementary seeding or planting of vegetated areas;
- application of soil ameliorants;
- weed and pest control;
- de-silting or repair of drainage structures and sedimentation dams; and
- infilling, regrading and revegetation of eroded areas.

Supplementary Seeding

Supplementary seed broadcasting will be undertaken in areas where revegetation success is considered to be sub-optimal. The sufficiency of vegetation establishment will be determined based on monitoring results and the comparison against the appropriate rehabilitation objective and/or completion criteria and their analogue sites. Seed for broadcasting will be treated where necessary prior to broadcasting to maximise germination rates.

Application of Soil Ameliorants

Soil testing will be undertaken to determine if additional amelioration is required. Additional applications of ameliorates may be required to ensure an optimum growing medium. It is generally not possible to correct soil deficiencies by a single application of fertiliser. It is possible, however, to slowly build up a bank of available elements in the soil from which vegetation is able to draw and which is replenished by the eventual death and decay of the plants (i.e. the nutrients are continually recycled through the soil and the vegetation). Since many of the available nutrients are held in the organic soil fraction, this recycling condition cannot be achieved until adequate levels of organic matter have accumulated in the soil (Hannan, 1995).

Soil will be collected and managed on-site in accordance with the Soil Management Protocol in order to maximise the preservation of the soil seed bank and soil microbes.

Weed and Pest Control

Weed management will include the following actions:

- vehicles and equipment minimise the transport of weed seed;
- areas will be inspected regularly for the presence of weed species;

- relevant personnel will be provided with pictures and descriptions of known weed species and asked to report incidental sightings;
- treatment of entire infestations where possible;
- re-treatment of recurring infestations at regular intervals;
- mapping of key weed infestations following monitoring to track progress and focus control activities where necessary; and
- prompt rehabilitation of land post disturbance.

Pest control actions will be undertaken with reference to the appropriate Code of Practice and Standard Operating Procedures (these documents are available on the DotE website).

De-silting or Repairing Drainage Structures, Infill and Regrading

Additional surface stabilisation works will be undertaken as required and may include reshaping, installation of surface stabilisation structures, amelioration of soil, revegetation, fencing and de-silting and repair of drainage structures.

Stabilisation works will be inspected annually and some of the works will be formally monitored as part of the rehabilitation monitoring program (Section 7).

Irrigation

Irrigation of the rehabilitation areas may be required to assist the germination of the plants and to assist the supplementary tube stock planted. Supplementary watering of tube stock at the time of planting can be particularly useful. Irrigation (if required) will be undertaken in consideration of the prevailing weather conditions, soil moisture and plant health. Water availability following seeding has been found to be a major influence on a number of experimental sites (UoN, 2012).

Livestock Management

Livestock will be excluded from areas undergoing active revegetation (i.e. planting or seeding) and all those area with a Land Capability Class unsuitable for grazing (i.e. Classes VI and VII).

5.2.13 Rehabilitation and Mine Closure Financial Provisioning

Whitehaven has a mine site rehabilitation and mine closure provisioning process which is used to estimate the liabilities associated with rehabilitating each of its operations in accordance with the operating approvals, mining lease conditions, applicable mine closure plan and relevant guidelines. The cost estimate includes consideration of mobilisation costs, project management costs, monitoring costs and a contingency. It also includes indexation for inflation where appropriate. The degree of existing disturbance and the status of rehabilitation at the site is factored in to the consideration of rehabilitation and mine closure liability.

This rehabilitation cost estimate is undertaken in line with the development and approval of the MOP, the rehabilitation security is held by the DRE.

MCC will regularly review and revise its rehabilitation and mine closure provisioning for the MCCM during the life of the project, and will provide the necessary security deposits as required by the operating approvals for the mine.

6 RISK ASSESSMENT OF REHABILITATION-RELATED ASPECTS

Condition 27f of Commonwealth approval EPBC 2010/5566 requires the MSRP to provide a description of the potential risks to successful management and rehabilitation on the project site, including weed invasion, and a description of the contingency measures that will be implemented to mitigate these risks. In order to address this aspect, a qualitative risk-based approach has been adopted. The assessment focused on evaluating the likelihood and consequence of environmental impacts associated with rehabilitation occurring and identifying the management measures that will reduce the potential impact.

This approach allowed for the potential interactions between MCCM aspects (or hazards) and environmental factors (or receptors) to be considered on the basis of potential risk, therefore enabling the prioritisation of management measures to achieve an overall acceptable level of environmental risk.

Typically an environmental risk assessment includes:

- establishment of a risk assessment framework (definition of consequences and likelihood and establishment and validation of risk matrix);
- systematic identification of environmental factors, related hazardous events, their causes and environmental aspects;
- initial characterisation of environmental risks based on standard management practices (inherent risk);
- identification of additional management options to reduce risks to acceptable levels; and
- analysis of residual risk following implementation of the additional management options.

The overall environmental risk assessment process used to support this MSRP is shown in Figure 6-1.

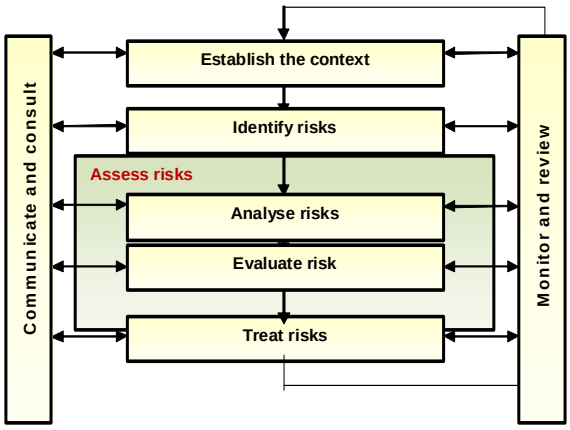

Figure 6-1 – Risk-based Environmental Impact Assessment Process

The aspects and hazards associated with rehabilitation of the MCCM were identified through a review of the conceptual closure design, relevant approval conditions for the MCCM, the baseline studies and environmental impact assessment conducted for the Project EA (Hansen Bailey, 2011) and rehabilitation methods and performance in the Industry and at Whitehaven's other mines.

The aspects and hazards were classified in accordance with the following qualitative definitions:

High Significance

- require high level of mitigation and/or management for potential impact to comply with guidelines and standards; and/or
- direct/permanent loss of environmental attributes of conservation significance and/or social attributes of significance; and/or
- high risk rating.

Medium Significance

- potential impacts require moderate management measures to comply with guidelines and standards; and/or
- potential impacts will be localised and medium term, with moderate loss to environmental attributes of conservation significance and/or social attributes of significance; and/or
- medium risk rating.

Low Significance

- potential impacts will be minor requiring minimal management measures to comply with guidelines and standards; and/or
- potential impacts will be localised and short-term, with minimal loss to environmental attributes of conservation significance and/or social attributes of significance; and/or;
- low risk rating.

The environmental factors and rehabilitation-related aspects considered for the risk assessment undertaken for this MSRP are outlined in Table 6-1.

Table 6-1
Environmental Factors and Hazards

Environmental Factor (Receptors)	Rehabilitation-related Hazard (Stressor)
• Landforms and Closure. • Surface Water. • Groundwater. • Flora and Vegetation. • Fauna. • Soil Resources.	• Clearing and rehabilitation earthworks. • Discharge. • Physical Presence. • Physical Interaction. • Fire. • Leaks and Spills.

The risk assessment process involved the identification of the following for each environmental factor:

- hazard (stressor);
- source of hazard;
- event;
- potential impacts;
- inherent risk;
- proposed controls; and
- residual risk.

A risk assessment framework (including factor-specific definitions of consequences and likelihood and establishment and validation of risk matrix) was used to assess rehabilitation-related risks of the MCCM. The risk assessment framework defines the type and duration of potential impacts based on five categories of consequence (minor, moderate, serious, major and critical). Similarly, there are five categories of likelihood of an event causing a particular impact. Risk is categorised as high, medium or low based on the scoring of likelihood and consequences.

Tables 6-2 and 6-3 were used to assign a consequence factor/ranking[1] and likelihood factor/ranking[2] to each potential impact. The inherent risk ranking was calculated by multiplying the consequence factor and the likelihood factor (Table 6-4).

[1] Consequence is defined as a measure of the expected degree of gain, harm, injury or loss (impact) from the most severe event associated with a risk issue.

[2] Likelihood is defined as a measure of the chance of an impact at that selected level of severity actually being incurred.

Table 6-2
Consequence Factor

Relevant Consequence Criteria	Negligible 1	Minor 2	Moderate 3	Significant 4	Serious 5
Soils and rehabilitated landforms	• Local impacts only, and which can be readily remediated; or • Negligible impact on soil characteristics; or • Local and minor changes in recharge patterns within sub-catchments; or • Disturbance of well-represented landform habitats.	• Local contamination requiring a long-term remediation effort; or • Local, short-term change in soil characteristics; or • Local and major change in recharge patterns within sub-catchments; or • Widespread and minor changes in recharge patterns; or • Local loss of well-represented landform habitat.	• Local contamination that cannot be readily remediated; or • Local, long-term change in soil characteristics; or • Widespread, short-term change in soil characteristics; or • Major widespread changes in sub-catchment recharge patterns; or • Widespread loss of well-represented landform habitats; or • Local loss of a unique landform habitat.	• Widespread contamination requiring a significant long-term remediation effort; or • Widespread, long-term change in soil characteristics; or • Minor changes in regional recharge patterns; or • Widespread loss of a unique landform habitat.	• Widespread contamination that cannot be readily remediated; or • Major changes in regional recharge patterns; or • Regional loss of a unique landform habitat.
Flora and Vegetation	• Local and temporary decrease in abundance of flora or impact on community structure; or • Sub-lethal physiological impacts.	• Widespread, short-term decrease in abundance of flora or impact on community structure; or • Local, long-term decrease in abundance of flora or impact on community structure.	• Widespread, short-term decrease in abundance of flora or impact on community structure; or • local, long-term decrease in abundance of flora or impact on community structure.	• Widespread and long-term decrease in abundance of flora or impact on community structure.	• Widespread and long-term decrease in abundance of flora or impact on community structure.

Table 6-2 (Continued)
Consequence Factor

Relevant Consequence Criteria	Negligible 1	Minor 2	Moderate 3	Significant 4	Serious 5
Fauna	• Widespread, temporary behavioural impact; or • localised long-term behavioural impact or • Local, long-term decrease in abundance; or • Widespread, temporary decrease in abundance.	• Widespread and long-term behavioural impact or • Local, long-term decrease in abundance; or • Widespread but short-term decrease in abundance.	• Local, long-term impact on population; or • widespread, short-term impact on population.	• Widespread, long-term impact on population.	• Extinction in the immediate region.
Surface and Groundwater quality and quantity	• Local, temporary reduction in quality and quantity; or • Minor reduction in quality and quantity.	• Minor reduction in water quality which is widespread but short-term; or • Localised, long-term reduction in water quality; or • Large reduction in water quality which is local, short-term.	• Widespread, long-term reduction in water quality.	• Regional, short-term reduction in water quality.	• Regional, long-term reduction in water quality.

Table 6-3
Likelihood Factor/Ranking

Likelihood Category	Likelihood Factor	Description
Almost Certain	5	Very likely to occur on an annual basis or during construction
Likely	4	Likely to occur more than once during the life of the proposed development
Possible/Occasional	3	May occur during the life of the proposed development
Unlikely	2	Not likely to occur within the life of the proposed development
Rare/Improbable	1	Highly unlikely, but theoretically possible

Table 6-4
Risk Rating Classification

		Consequence Category				
		Negligible	Minor	Moderate	Significant	Serious
Likelihood Factor	Almost Certain	Low	Medium	High	High	High
	Likely	Low	Medium	High	High	High
	Possible/Occasionally	Low	Medium	Medium	High	High
	Unlikely	Low	Low	Medium	Medium	Medium
	Rare/Improbable	Low	Low	Low	Medium	Medium

The inherent level of risk posed by rehabilitation-related aspects to the relevant environmental factors was assessed assuming no controls in place.

The key environmental factors (those representing a medium or high inherent risk level) were subjected to further assessment in order to determine the extent and significance of environmental impacts.

To ensure the risks for each of the key factors was reduced to 'As Low as Reasonably Practicable' (ALARP), best practicable environmental management was applied to all key environmental factors to determine appropriate refinements of the MCCM design and controls to reduce the risks as far as practicable.

Appendix C presents the rehabilitation-related risk assessment conducted for this MSRP.

7 MONITORING AND REPORTING

7.1 OVERVIEW

The MCCM rehabilitation monitoring program will involve the gathering of information and data, systematic record keeping of all management inputs, regular review and analysis of the data, assessment of compliance with rehabilitation and mine closure criteria, and to drive continuous improvement. The monitoring program will:

- compare results against rehabilitation objectives and targets;
- identify possible trends and continuous improvement;
- link to records of rehabilitation activities and inputs to determine causes and explain results;
- assess effectiveness of environmental controls;
- where required, identify modifications required for the monitoring program, rehabilitation practices or areas requiring research;
- compare flora species present against original seed mix and/or analogue sites;
- assess vegetation health;
- assess landscape function (soil surface stability, nutrient cycling and water infiltration);
- assess vegetation structure (e.g. density and cover of upper, mid and lower storey); and
- where applicable, assess native fauna species diversity and the effectiveness of habitat creation for target fauna species.

The MCCM rehabilitation monitoring program involves regular record keeping and analysis of the following key rehabilitation inputs:

- mining operations;
- rehabilitation methods; and
- revegetation practices.

A summary of each aspect and the monitoring methods that are, or will be, applied is provided in Sections 7.2 to 7.4. Sections 7.5 and 7.6 describe the rehabilitation reporting mechanisms and adaptive management approach that will be adopted at the MCCM.

7.2 MONITORING OF MINING OPERATIONS

MCC will maintain detailed records of the mining operations at the MCCM in order to provide a record of the various activities and processes that occur at the site over the life of the mine. These records will allow MCC to identify areas and/or activities that may impact/influence the success of future rehabilitation, decommissioning and mine closure activities.

The records will include, but are not necessarily limited to:

- as-built plans for mine-related infrastructure and detailed plans for the open cut and overburden emplacement area as they are developed over the mine life (e.g. location, type, timing and volume of overburden materials placed in the out-of-pit and in-pit emplacement areas [including any identified PAF materials]);
- a register of the type, location, amount and characteristics of hazardous materials used at the mine site (e.g. details of the areas where explosives and hydrocarbons are stored);
- a register of all areas where land or water contamination occurs during the mine life and details of the source of contamination, its extent and how and when it was remediated;
- records of production wastes and other waste streams, including details of where they are located and/or have been stored on site (e.g. details of where, when and how coal rejects generated by the CHPP are disposed within the overburden emplacement areas);
- general environmental monitoring records, including meteorology, surface water, groundwater, noise and air quality as required by the State and Commonwealth approvals;
- environmental incident records; and
- soil survey, stripping and stockpiling records (i.e. mapped pre-disturbance soil types and depths, stripping areas and depths, and volumes, types and locations of stockpiled soil materials [as per the Soil Management Protocol – refer to Section 4.1]).

7.3 MONITORING OF REHABILITATION METHODS

MCC will maintain records of each rehabilitation campaign in order to track the progressive rehabilitation of the MCCM. The records will include, but are not necessarily limited to:

- plans showing the location and type of rehabilitation activities conducted as part of each campaign (e.g. landform and drainage design details);
- substrate characterisation details where relevant;
- details of the site preparation techniques used during the campaign (e.g. ripping depths and locations, replacement depths and types of soil materials applied, soil amelioration methods and rates);
- revegetation methodologies (e.g. rate and type of fertiliser, cover crop rate and seeding rate per native species, seed viability, seed purity, seed pre-sowing treatment, source of seed, time of sowing/planting);
- weather conditions;
- photographic records; and
- initial follow-up care and maintenance records.

7.4 MONITORING OF REVEGETATION PRACTICES

Visual monitoring of revegetation will be conducted on a regular basis to assess whether vegetation is establishing and to determine the need for any maintenance and/or contingency measures (such as the requirement for supplementary plantings, erosion control and weed control).

As described in Section 3.7, the quality of rehabilitation will be monitored annually using EFA or a similar systems-based approach. An overview of the EFA method is provided below.

EFA is a CSIRO developed method used to provide indicators of rehabilitation success and allows the assessment of ecosystem sustainability through the plotting of development trajectories. EFA aims to measure the progression of rehabilitation towards a self-sustaining ecosystem through the assessment of landscape function, vegetation dynamics and habitat complexity (http://www.csiro.au/Organisation-Structure/Divisions/Ecosystem-Sciences/EcosystemFunctionAnalysis.aspx). EFA is divided into the following three modules/components: the LFA component; the vegetation composition and dynamics component; and the habitat complexity component.

The LFA Soil Surface Analysis component of EFA provides an effective quantitative tool for assessing ecosystem function. Data recorded as part of LFA monitoring is based on landscape processes and focuses on the dynamics of resource mobilisation, transport, deposition, use and loss of soil condition. Parameters assessed as part of LFA monitoring typically include:

- soil cover;
- perennial grass basal cover and canopy cover;
- litter cover, origin and incorporation;
- cryptogam cover;
- crust condition;
- erosion type and severity;
- amount of deposited material;
- micro-topography (surface roughness);
- surface resistance to disturbance; and
- soil type (slake and texture tests).

The vegetation composition and dynamics component of EFA monitoring provides a quantitative assessment of species composition, density and cover. The habitat complexity component of EFA provides an index of the development of available habitats for fauna and includes measurements of vegetation cover, ground habitat (litter, logs and rocks) and the availability of water. The monitoring of habitat complexity is based on the assumption that more environmental niches for fauna develop as the diversity of vegetation and ground cover (e.g. litter) increases.

A number of permanent transects will be established within rehabilitated areas. Corresponding transects will also be established in adjacent undisturbed (analogue) communities. The information obtained will be used to track the rehabilitation progress, predict self-sustainable values and compare the rehabilitation and analogue sites. Remedial management strategies will be implemented where necessary.

Visual assessments will also be incorporated into the revegetation monitoring programme to allow for the rapid application of remedial actions where necessary.

The revegetation monitoring program will include specific data collection and analysis of the establishment of the Box-Gum Woodland CEEC in rehabilitation areas. The program will consider aspects such as the actual versus target vegetation density and the need for ecological thinning (e.g. through selective clearance or fire) or supplementary planting.

As the amount of rehabilitation at the MCCM increases, the requirement for monitoring will also increase. As described in Section 5.1, in the first several years as the mine site is developed, only small areas of the mine landforms will be available for rehabilitation. Accordingly, there are minimal requirements for monitoring of rehabilitation at this stage. Further details of the rehabilitation monitoring program will be provided in subsequent revisions of this MSRP and MOP as the mine develops.

7.5 REHABILITATION REPORTING

An Annual Review will be submitted by the end of March each year as per Condition 4 of Schedule 5 of State approval PA 10_0138. It will describe the environmental performance of the MCCM over the preceding 12 month period. The Annual Review will discuss rehabilitation performance and any non-compliance issues. This will include monitoring results, statutory requirements, and a description of rehabilitation activities and measures that will be implemented over the following year. An analysis of rehabilitation performance against the key objectives and completion criteria will be included in the Annual Review. All stakeholders will have access to this document via Whitehaven's website.

7.6 REHABILITATION RESEARCH AND ADAPTIVE MANAGEMENT AT THE MCCM

Rehabilitation research activities will be conducted as necessary during the mine life. These will be developed and implemented as required in order to investigate relevant components of the rehabilitation process (e.g. the rehabilitation and revegetation of Box-Gum Woodland CEEC). Where practicable and appropriate they will be conducted in collaboration with other nearby mining operations, landholders, Government agencies, interest groups or research/academic organisations. Research activities may cover a broad range of rehabilitation-related activities. The scope of the research activities will be summarised in the MOP and a summary of the findings will be provided in the Annual Review.

In the event that the monitoring and rehabilitation research programs identify that rehabilitation results are sub-optimal and/or improvements can be made, further investigation to establish a cause and appropriate remediation strategy(s) will be undertaken. Aspects that may be considered as part of the investigation may include, but are not necessarily limited to the following:

- nutrient availability;
- pH, salinity and metal toxicity;
- shallow root depth;
- other soil limitations;
- plant diseases;
- insect attack;
- lack of nitrogen fixing legumes;
- insufficient density and diversity of long lived plants (e.g. overstorey trees);
- lack of organisms involved in litter breakdown (e.g. fungal fruiting bodies) and nutrient cycling (e.g. puff balls);
- predation;
- evidence of drought effects or storm damage;
- in appropriate plant species density and diversity;
- poor soil and/or landscape preparation; and
- weed competition and/or competition with other species in the seed / tube stock mix.

The composition and structure of revegetated areas will also be compared with the target vegetation community characteristics at the analogue monitoring sites (Section 7.4). In cases where the performance is sub-optimal, additional management measures will be implemented (e.g. replanting, causing disturbance through grazing and/or fire).

A TARP for rehabilitation at the MCCM has been developed (Table 7-1) and will be implemented where required. The TARP provides triggers (mitigation triggers), actions and responses.

Table 7-1
Trigger Action Response Plan for Rehabilitation at the MCCM

Trigger*	Action	Response
Excessive erosion and/or sedimentation (e.g. gullying and sedimentation) resulting in land stability and vegetation growth issues	Undertake an investigation to identify the extent, source and cause of the trigger including an inspection of the area, detailed recording of the condition of the area, evaluation/identification of the cause of the issue(s).	Based on the investigation, a remediation program will be developed and implemented. Erosion and sediment control measures detailed in the MCCM Water Management Plan may be implemented, including: • repairing erosion channels or bare areas; • removing excessive sedimentation where required; • re-designing and constructing appropriate water management features (e.g. channels, bunds, dams) to prevent reoccurrence of erosion/sedimentation; • installation of sediment traps and fences; • use of available materials such as rock, mulch or stockpiled topsoil to stabilise areas identified; and • supplementary revegetation of any bare areas.
Monitoring indicates a increasing trend in feral animals	Where a feral animal species is observed, undertake an investigation to determine its extent and possible source/cause.	Management techniques specific to each species will be implemented as per the BMP. These may include: • vertebrate pests will be managed to be absent or kept under control and monitored on an annual basis; and • use of tree guards to protect seedlings and/or young tube stock plantings from browsing or grazing native animals.
Monitoring indicates high density of weed species (greater than 20% of the analogue sites) as evidenced through monitoring	Where a weed species is observed, undertake an investigation to determine its extent and possible source/cause.	Management techniques specific to each species will be implemented as per the BMP. These may include: • significant weed infestations or noxious weeds will be removed in accordance with relevant guidelines and Narrabri Shire Council Category 4 Weed Management plans for noxious weeds; • re-plant or re-seed areas if necessary; • identify any potential source of exotic weed introduction and implement appropriate treatments/controls; and • additional wash down and inspection procedures will be developed and implemented if required.
Rehabilitation monitoring indicates die-back and/or poor growth and development of revegetation as evidenced through monitoring	Conduct site investigation and review active mining and rehabilitation methodology records for the area to determine possible contributing factors.	Management techniques relevant to identified contributing factors/cause will be implemented. These may include: • conduct field inspections and implement remediation works which may include additional or ameliorated growth medium, additional plantings or further actions following planting such as application of fertilizer or watering of rehabilitation areas; and • development of an appropriate replanting contingency plan.
Performance of revegetated areas is sub-optimal as evidenced through monitoring	Collect and analyse revegetation (and other) monitoring data to enable the cause and extent of the affected area to be identified.	The response will be developed based on the cause, extent and significance of the affected revegetation area. Responses may include: • further testing of soil for contaminants, pH or other deficiencies; • supplementary seeding; • implementation of hygiene protocols to restrict and/or minimise plant diseases; • application of fertiliser, mulch or topsoil; and • irrigation of the affected area.

Table 7-1 (Continued)
Trigger Action Response Plan for Rehabilitation at the MCCM

Trigger*	Action	Response
Unstable landform.	Undertake a comprehensive investigation to identify the extent, source and cause of the trigger including an on ground inspection, completion of detailed records and implementing and ongoing monitoring program to assess the suitability of the response program.	Based on the investigation, management measures such as the following may be implemented: • use available materials such as rock, organic mulch or stockpiled topsoil to stabilise the affected areas; • revegetate areas where bare ground occurs; • assess and repair/re-design water management and drainage structures; and • commission a specialist engineer to assess the structural integrity and design appropriate remedial measures where necessary.

* Triggers should be viewed in the context of conditions 26, 29 and 30 of Commonwealth approval EPBC 2010/5566.

8 REVISION, AUDITING AND REPORTING OF IMPLEMENTATION OF THE MSRP

The MSRP will be subject to reporting procedures and regularly audited in order to demonstrate compliancy with approval conditions, review the implementation progress of management actions, and to review the adequacy of the document. Recommendations made available through the auditing and reporting procedure will be used to update rehabilitation, decommissioning and mine closure practices at the MCCM. This section summarises the reporting that will be completed for the MSRP and the revisions and audits that will or may be prepared.

8.1 REVISION OF THE MSRP

The MSRP may be reviewed and revised from time to time. In accordance with Condition 36 of the Commonwealth approval EPBC 2010/5566, if MCC wishes to carry out any activity otherwise than in accordance with the MSRP (as it pertains to Commonwealth approval EPBC 2010/5566), MCC will submit a revised MSRP to DotE for the Minister's written approval.

8.1.1 Revision of the MSRP to be consistent with the MOP/Rehabilitation Management Plan

In accordance with Condition 73 of Schedule 3 of State approval PA 10_0138, a RMP will be prepared and implemented. As discussed in Section 1.4, the initial RMP (i.e. Edition 1, Revision 1) was prepared by MCC and provided to the DRE in April 2013. Subsequently, and at the request of DRE, the content of the initial draft RMP was transferred across into the MOP. This MSRP has been prepared to be consistent with the rehabilitation component of the MOP.

MCC will review and revise this MSRP as necessary during the life of the MCCM to ensure that it is consistent with the MOP/Rehabilitation Plan. Each revision of the MSRP will be submitted to the DotE for the Minister's written approval.

8.1.2 Other Triggers for Revisions to the MSRP

In accordance with Condition 37 of Commonwealth approval EPBC 2010/5566, if the Minister believes that it is necessary or convenient for the better protection of listed threatened species and communities or listed migratory species to do so, the Minister may request MCC to make specified revisions to the MSRP and submit the revised plan for the Minister's written approval.

8.2 REPORTING AND AUDITING

In accordance with Condition 40 of Commonwealth approval EPBC 2010/5566, the MSRP will be published on Whitehaven's website. Any revisions to the MSRP will be published on the website within one month of being approved.

In accordance with Condition 28 of Commonwealth approval EPBC 2010/5566, the findings of the independent review of this MSRP (Section 1.5) will be published on the website.

8.2.1 Maules Creek Project Annual Review

An Annual Review will be submitted each year under Condition 4 of Schedule 5 of State approval PA 10_0138, which outlines the environmental performance of the MCCM over the preceding year.

The Annual Review will discuss environmental performance, environmental management, and any non-compliance issues. This will include identifying trends in monitoring results, comparisons to Project EA (Hansen Bailey, 2011) predictions and statutory requirements, and a description of measures that will be implemented over the following year. One section of the Annual Review will summarise the outcomes of management actions undertaken as part of the MCCM rehabilitation program and will collate documentation to demonstrate compliancy with the MOP/Rehabilitation Plan and this MSRP. A copy of the Annual Review will be provided to the DotE each year.

8.2.2 Commonwealth Approval Compliance Reports

A report pertaining to the annual compliance with Commonwealth approval EPBC 2010/5566 will be published on Whitehaven's website by the end of March each year after the commencement of the MCCM in accordance with Condition 34 of the Commonwealth approval EPBC 2010/5566. Non-compliance with any of the conditions will be reported to DotE at the same time as the compliance report is published.

8.2.3 Recording Survey Data and Other Information

In accordance with Condition 31 of the Commonwealth approval EPBC 2010/5566, survey data will be recorded so as to conform to data standards notified from time to time by DotE. When requested by the DotE, MCC will provide all species and ecological survey data and related survey information from ecological surveys undertaken for Matters of National Environmental Significance. This survey data will be provided within 30 business days of request, or in a timeframe agreed to by DotE in writing.

In accordance with Condition 39 of the Commonwealth approval EPBC 2010/5566, MCC will maintain accurate records substantiating all activities and outcomes associated with or relevant to Commonwealth approval EPBC 2010/5566, including measures taken to implement this MSRP, and make them available upon request to the DotE.

8.3 INDEPENDENT AUDITS

In accordance with Condition 35 of the Commonwealth approval EPBC 2010/5566, upon the direction of the Minister, MCC will ensure that an independent audit of compliance with the conditions of the Commonwealth approval is conducted and a report submitted to the Minister. The independent auditor will be approved by the Minister prior to the commencement of the audit. Audit criteria will be agreed to by the Minister and the audit report will address the criteria to the satisfaction of the Minister.

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APPENDIX A

INDEPENDENT ECOLOGIST REVIEW REPORT

Independent Peer Review

MAULES CREEK COAL MINE - MINE SITE REHABILITATION PLAN

Conducted by Dr David Freudenberger for ANU Enterprise Pty Limited

Canberra, ACT

July 2016

Review Scope

Whitehaven Coal Ltd has developed the *Mine Site Rehabilitation Plan for the Maules Creek Coal Mine* as specified in Conditions 25 to 27 in the Maules Creek Coal Mine (MCCM) Commonwealth approval (i.e. EPBC 2010/5566) issued under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). In particular, this plan is required to rehabilitate mine landforms to effectively restore potential habitat for the Regent Honeyeater (*Anthochaera phrygia*), the Swift Parrot (*Lathamus discolor*), the South-eastern Long-eared Bat (*Nyctophilus corbeni*) and the *White Box – Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grassland Critically Endangered Ecological Community* (referred to herein as the Box-Gum Woodland CEEC).

The Commonwealth Approval includes the requirement that "*The mine site rehabilitation plan must be subject to an independent review by a qualified ecologist prior to being submitted to the Minister for Approval. The findings of the independent review must be published on the proponent's website* (Condition 28). ANU Enterprise was engaged by Whitehaven Coal to undertake this review that was performed by Dr David Freudenberger, a senior ecologist and Board Member of the Society of Ecological Restoration Australasia.

Review Framework

The review was conducted using the over-arching framework of Noss (1991) which recognises that ecosystems have *functional, structural and compositional* attributes (characteristics) at multiple scales. The Tongway and Ludwig (2011) framework of how landscapes function and their "Principles for Restoring Landscape Functionality" were also used to guide this review. The review was also informed by the *National Standards for the Practice of Ecological Restoration in Australia* (McDonald et al. 2016). The practical restoration guides by Munro and Lindenmayer (2011) and Rawlings et al. (2010) were used to help assess the adequacy of specific rehabilitation methodologies described in the Rehabilitation Plan.

Review Findings

The *Mine Site Rehabilitation Plan for the Maules Creek Coal Mine* (25 July 2016) provides a broad and ecologically sound framework for informing and guiding more detailed annual Mine Operational Plans. This Rehabilitation Plan also provides a sound framework for regular assessments of progress in rehabilitating the final landforms of the mine site.

The "Rehabilitation Completion Criteria" (Plan Section 3.7, Table 3-3) provides explicit completion criteria based on restoring landscape function, vegetation structure and flora and fauna species composition to appropriate analogue (reference) conditions.

Plan Sections 3 to 5 provide ecologically sound guidance for rehabilitation management strategies and specific methodologies. Report Appendix B (summarised in Section 4) provides rigorous and detailed guidance for handling the diversity of topsoils that will be displaced by mining operations. This Rehabilitation Plan recognises that careful soil management is fundamental to ecologically effective rehabilitation.

Plan Sections 7 and 8 provide comprehensive guidance for monitoring rehabilitation inputs and outcomes to inform adaptive improvement in rehabilitation activities. It is also noted that the Plan indicates that a Rehabilitation Research Program will also inform the adaptive rehabilitation of the mined surfaces. There are a great many operational and environmental uncertainties when rehabilitating mined surfaces and these are identified in the comprehensive Risk Assessment (Plan Appendix D).

Review Recommendations

This review recommends to the relevant authority that the *Mine Site Rehabilitation Plan for the Maules Creek Coal Mine* (25 June 2016) is ecologically sound and provides clear guidance for the short, medium and long-term rehabilitation of this mining lease.

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APPENDIX B

SOIL SURVEY AND GROWTH MEDIA INVENTORY FOR REHABILITATION AREA 1

MAULES CREEK COAL PROJECT - SOIL SURVEY AND GROWTH MEDIA INVENTORY FOR REHABILITATION- AREA 1

29 July 2014

Whitehaven Coal

REPORT TITLE: Maules Creek Coal Project - Soil Survey and Growth Media Inventory for Rehabilitation- Area 1

CLIENT: Whitehaven Coal

Revision Number	Report Date	Report Author	Reviewer
Draft A	15 July 2014	Simon Buchanan CPSS Stage 2, CPESC	Helen Squires CPSS Stage 2, CPESC
Draft B	23 July 2014	Simon Buchanan CPSS Stage 2, CPESC	Dr Rob Loch CPSS Stage 3
Draft C	28 July 2014	Simon Buchanan CPSS Stage 2, CPESC	Dr Rob Loch CPSS Stage 3
Rev 0	29 July 2014	Simon Buchanan CPSS Stage 2, CPESC	

EXECECTIVE SUMMARY

Landloch Pty Ltd was engaged by Whitehaven Coal to conduct a soil survey and develop a growth media inventory for a portion of the Maules Creek Mine. The purpose of the assessment was to address the State and Commonwealth Conditions of Approval covering soil and land issues pertaining to the development of the open cut coal mine and associated infrastructure.

The scope of works provided was to undertake a soil survey with an observation density of 1 per 20 ha (1:25 000 scale) for the proposed disturbance area for operations for 2014–15, which is an area of 392 ha (inclusive of changes in topography) within the current Environmental Approval (EA) Area of 3,550 ha. The information within this soil survey report provides technical soil and landscape details to contribute to the management plans regarding soils and rehabilitation, as well as to the design of waste landforms and landform covers.

The study area contains the Maules Creek Formation and Boggabri Volcanic geological units. From these parent materials, 5 different soil profile classes have been formed. A total of 5 soil landscapes have been mapped that delineate where these soil profile classes occur. The soil landscapes are generally simple, containing one dominant soil profile class; but there is 1 complex soil landscape (Blue Vale Footslopes) with 2 soil profile classes that could not be delineated at the scale of this survey.

Each soil profile class has been described and characterised for the purpose of evaluating soil layers as plant growth media for rehabilitation. The suitability of materials as topsoil, subsoil, marginal topsoil or subsoil (amelioration required) has been assessed, and an inventory has been developed of these materials' volumes. A summary of the inventory is given below.

Soil Landscapes	**Available Growth Media Volumes (x 1000 m^3)**				
	Topsoil or Subsoil	Subsoil or Marginal Topsoil	Marginal Subsoil or Marginal Topsoil	Marginal Subsoil	Totals
Leard	101	235	-	-	**335**
Blue Vale Slopes	118	353	376	-	**846**
Blue Vale Footslopes	187	927	157	-	**1271**
Blue Vale Flats	83	193	-	275	**550**
Hartfell	45	113	-	248	**405**
Totals	**532**	**1818**	**533**	**523**	

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Maules Creek Coal Project - Soil Survey and Growth Media Inventory for Rehabilitation- Area 1

CLIENT: WHITEHAVEN COAL

1 INTRODUCTION

Landloch Pty Ltd was engaged by Whitehaven Coal to conduct a soil survey and develop a growth media inventory for a portion of the Maules Creek Coal Mine (MCCM). The purpose of the assessment was to address a number of the New South Wales (NSW) Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) Conditions of Approval, as well as comments provided by the North West Local Land Services (formerly Namoi Catchment Management Authority (CMA)), with respect to the soil and land issues pertaining to development of the open cut coal mine and associated infrastructure.

1.1 Scope and Relevant Approval Conditions

The scope of work provided was to undertake a soil survey with an observation density of 1 per 20 ha (1:25 000 scale) for the proposed disturbance area for operations for 2014–15, which is an area of 392 ha within the current EA area of 3,550ha.

Information within this soil survey and growth media inventory report provides technical soil and landscape details to contribute to the management plans regarding soils and rehabilitation, as well as to the design of landforms and landform covers. In particular, this report addresses the requirements of *Maules Creek Coal Mine Project Approval EPBC 2010/5556 Condition 27(c)* and Project Approval 10_138 (Schedule3, Condition39) as stipulated in the Maules Creek Soil Management Protocol (SMP). The SMP details a "Topsoil and Subsoil Testing Procedure", which specifies:

> *Prior to stripping, topsoil and subsoil will be sampled to:*
>
> - *identify the soil resource prior to stripping;*
> - *produce a soil map for all disturbed areas;*
> - *assist with the preparation of a soil balance or inventory to assist with rehabilitation planning; and*
> - *determine if the soil requires amelioration to ensure the soils' physical and characteristics are within recommended ranges.*

The SMP also specifies that:

> *Soil sampling will be undertaken at a minimum sampling frequency of approximately one sample per 20 hectares of each soil type and will include an assessment of the soil profile (topsoil and subsoil). This will include key soil survey assessment criteria, as per McDonald (1998), which include but are not limited to, type, depth, structure and chemical characteristics. Sampling will be performed from pits using a backhoe (or similar) to create suitable pits where needed, or a suitable soil sampling coring device. Pits will typically be 1.5m in depth.*

1.2 Project Description

The MCCM is located on the northwest slopes and plains of NSW, approximately 18 km north-east of Boggabri within an existing mining precinct centred within, and around, the Leard State Forest. The Leard State Forest has historically been predominantly utilised for forestry, recreation and more recently, mining-related activities.

The MCCM is operated by Maules Creek Coal, a joint venture between Aston Coal 2 Pty Limited (Whitehaven Coal Limited (Whitehaven)), ITOCHU Corporation and J-Power Corporation Pty Limited.

In 2010, Aston Coal 2 Pty Limited (a wholly owned subsidiary of Whitehaven) submitted a Project Application to the Department of Planning and Infrastructure (DP&I) for a new project approval under Part 3A of the EP&A Act to enable the construction and operation of an open cut coal mine, with a current mine life of at least 21 years.

2 METHODOLOGY

The methodology for the soil survey was developed to enable the aforementioned approval conditions to be addressed and provide suitable technical information to guide site rehabilitation. The methodology adopted is outlined below.

2.1 References and Guidelines

The soil survey has been developed in reference to the following guidelines:

- *Australian Soil and Land Survey: Guidelines for Survey Soil and Land Resources* (McKenzie, et al., 2008);
- *Australian Soil Classification* (Isbell, 2002);
- *Australian Soil Survey and Land Survey Field Handbook* (The National Committee on Soil and Terrain, 2009);
- *Soil and Landscape Issues in Environmental Impact Assessment* (NSW Department of Land and Water Conservation, 2000);
- *Protocols for soil condition and land capability monitoring.* Sydney South: Department of Environment, Climate Change and Water NSW (NSW DECCW, 2009).

2.2 Desktop assessment

A desktop assessment was undertaken prior to commencing field works to construct a baseline conceptual site model of the soil and landscape characteristics of the study area. This identified the preliminary mapping units that would require ground observations during the fieldwork and included:

- review of the regulatory requirements relevant to the project;
- review of available topographic, geological, vegetation, and soil mapping and associated reports for the survey area and surrounding region;
- review of the aerial imagery of the study area; and
- drafting of preliminary mapping units for validation during fieldwork.

Listed below are the background information sources referred to in the desktop component of this study.

- *Soil and Land Resources of the Liverpool Plains Catchment* interactive DVD (Office of Environment and Heritage, 2012).
- *Gunnedah Coalfield (North) Regional Geology 1:100 000*. Geological Series Sheet (Geological Survey of NSW, 1998).
- *Continuation of Boggabri Coal Mine Environmental Assessment* (Hansen Bailey, 2010).
- *The Bioregions of New South Wales: Their biodiversity, conservation and history* (NSW Parks and Wildlife Service, 2003).
- Digital Elevation Model and satellite imagery of the site at, supplied by the Client.
- Field and laboratory data collected for the project area by Landloch previously in 2013.
- *Maules Creek Coal Project Soil and Land Capability Impact Statement* (GSS Environmental, 2010).

2.2.1 Preliminary mapping units

The drafting of preliminary mapping units for the study area was based upon spatial analysis and a review of existing information. Existing mapping of soils, geology, topography, and vegetation communities was analysed through the use of a geographic information system (GIS). The preliminary mapping units identified tracts of land that were expected to share similar 'Soil Landscape' attributes (for example, similar soil type, geology, vegetation type and landform), which can be separated from neighboring tracts of land with a different pattern of similar attribute values.

2.3 Field work

The field work targeted preliminary mapping units for ground observations, with the aim that every soil landscape produced in the resultant mapping contains at least one detailed site description. Existing published soil landscape information from *Soil and Land Resources of the Liverpool Plains Catchment* interactive DVD, (Office of Environment and Heritage, 2012) was also used in this survey as a source of reliable information, even though this mine lies just outside the area of the study. There were also field and laboratory data relevant to this study from work that Landloch had previously undertaken (March 2013). Data from six of these sites were utilised.

2.3.1 Ground observation densities for the soil survey

The approval conditions for Maules Creek require *mapping of soils across the disturbance sites and soil sampling at no less than one sample point per 20 ha of each soil type identified*. This corresponds with a field scale of 1:25 000.

Ground observation densities and types required for soil surveys at 1:25 000 scale are included in the *Guidelines for Survey Soil and Land Resources* (McKenzie, et al., 2008). In general, complex landscapes and portions of the study area covered at the beginning of the field program were surveyed at a higher field density. As familiarity with the area improved, simple landscapes and portions of the study area assessed later in the field program were surveyed at lower field densities. The recommended and adopted intensity for ground observation sites is shown in Table 1.

Table 1 Ground Observation Site Intensities 1:25 000 (McKenzie, et al., 2008, p. 32)

Section	Area	Number of sites	
		Recommended	Adopted
Stage 1 Area	392 ha	19	28

2.3.2 Ground observation types and proportions

The fieldwork aimed to ensure that every preliminary mapping unit received a ground observation; and that every soil profile class produced in the resultant report and mapping contains at least one full morphological description with full laboratory analysis. Details of the recommended ground observation types (McKenzie, et al., 2008, p. 211) and that adopted are included in Table 2. The locations of ground observation sites are included in Appendix A (Map 1: Site Locations).

Table 2 Ground observation site types (McKenzie, et al., 2008, p. 211)

Site Types	Details	Recommended	Adopted
Detailed	Detailed morphological and site descriptions to characterise the main soils and landscapes in a survey area.	10–30 %	32 % (9)
Check	Brief mapping observations to confirm mapping boundaries, soil type distributions or other characteristics being mapped in the survey. These were brief with only the minimal amount of information recorded to correlate the site with a soil where a 'detailed' ground observation had occurred.	60–88 %	68 % (19)
Sampling	Profiles with samples analysed. Analysis was conducted to characterise reference soil profiles in regard to soil attributes such as fertility, sodicity or salinity. At select sites, partial profile analysis was undertaken mainly for soil grouping and classification purposes.	1-5 %	Full profile 32 % (9) Partial profile 39 % (10)

2.3.3 Surface descriptions

Data were collected from all ground observation sites in reference to the *Australian Soil and Land Survey Field Handbook* (The National Committee on Soil and Terrain, 2009). At all sites, these data included, but were not limited to:

- geospatial location;
- land use management;
- landscape attributes (landform, vegetation, erosion, micro-relief, rock outcrops etc.); and
- soil surface condition.

2.3.4 Full morphological descriptions

Full morphological descriptions included the collection and recording of the following details:

- horizon depths and designation;
- horizon boundary type & distinctness;
- field texture;
- colour (Munsell chart) and mottles;
- pedality & structure;
- coarse fragments and segregations; and
- slaking, 5 minute score; and dispersion, 10 minute score [based on (NSW Agriculture, 1999)].

Site descriptions were made in order of preference from test pits, undisturbed push-tube cores, or hand augered holes. Where available, existing exposures such as road cuttings or gullies were observed and recorded as check sites. Detailed soil profile descriptions were to depths of 1.2 to 1.5 m or until refusal, whichever was shallower. Copies of field sheets of site observations are included in Appendix D.

2.3.5 Sampling protocol

Soil samples were collected in reference with national and state protocols (Ryan & Wilson, 2008); (NSW OEH & OASFS, 2013); and (NSW DECCW, 2009). Generalised sampling depths were 0–0.5 m, 0.1–0.2 m, 0.2–0.3 m, 0.3–0.6 m, 0.6–0.9 m, 0.9–1.2 m, and 1.2–1.5 m, with no sample interval exceeding 0.3 m in thickness. Allowances were made for horizon boundaries, with samples collected from within major soil horizons (i.e. sampling did not cross A and B horizons).

Surface soil samples were bulked by combining at least 12 sub-samples taken at random within a 10 m radius of the soil profile and on the same landform element. All samples were identified using the project name, unique profile number and depth range from which the sample was taken. Samples for chemical analysis were placed into bags with approximately 250 to 500 grams (g) required to adequately analyse samples.

Undisturbed samples were collected at representative sites of different soil types for soil water measurement of the *drained upper limit*. Cores consisting of brass or steel rings 50 mm diameter x 50 mm long were inserted into the soil using a tanner sampler, then excavated with hand tools. Excess soil was trimmed from

the cores before the ends were enclosed with plastic caps and sealed in plastic bags. Samples were collected in duplicate from the surface (0.0–0.05 m) and at the upper subsoil (e.g. 0.25–0.3 m).

Corresponding disturbed samples were used in the measurement of the *crop lower limit* as soil structure is largely irrelevant at such low water potentials.

2.3.6 Laboratory analysis

Laboratory analysis was undertaken by a National Association of Testing Authorities (NATA) or Australian Soil and Plant Analysis Council (ASPAC) accredited laboratory. Different analytical suites were adopted, based on site description. The typical analytical suite for reference soils is itemised below (NSW DECCW, 2009). Sites that had partial analysis had one or more of these analytes measured mainly for classification purposes.

Topsoil suite

- Chemical tests included pH ($CaCl_2$), electrical conductivity (EC) (1:5 water), cation exchange capacity (CEC) and exchangeable cations, organic carbon, total nitrogen, available phosphorus (Bray 1, Bray 2 or lactate, depending on pH), phosphorus sorption capacity, and (for suspected ferrosols) citrate-dithionite extractable iron.
- Physical tests were conducted on selected samples and included particle size analysis, Emerson aggregate test, drained upper limit and crop lower limit.

Subsoil suite

- Chemical tests included pH ($CaCl_2$), electrical conductivity (EC) (1:5 water), cation exchange capacity (CEC) and exchangeable cations,
- Physical tests were conducted on selected samples and included particle size analysis, Emerson aggregate test, drained upper limit and crop lower limit.

Results of soil analyses are presented in Appendix B (Tables) of this report. Criteria for interpretation of soil analyses are presented in Appendix C. Interpretation of selected results is presented in the descriptions of soil profile classes (Section 4.1 to 4.5) and in the tables of laboratory results (Appendix B).

2.3.7 Water holding capacity and effective rooting depth

The *water holding capacity* (WHC) is an estimate of the plant available water (expressed as mm) between the *drained upper limit* (-10 kPa) and the *crop lower limit* (-15 000 kPa) within the *effective rooting depth* (ERD) of the profiles. The ERD refers to the depth that contains most (~90 %) of the root activity for the absorption of water. The adopted criteria for ERD is a soil depth 1 m, or to a physical barrier (e.g. bed rock), or to a limiting physio-chemical layer (e.g. very high salinity rating, extreme pH, or in rigid soils an exchangeable sodium > 15 %). It is recognized that these criteria are generally accepted cropping limitations, and that native tree and understory species are likely to be able to extract water from soil water potentials below -15 000 kPa, and may not be as severely limited in strongly sodic soils. It is also expected that the tap roots of tree species typically found in the study and surrounding area (e.g. *E. crebra, E. albens*,

and *Callitris glaucophylla*) may extend several metres deep, where possible, and that the principal restrictions will primarily be impenetrable bed rock or saline layers (NSW Department of Land and Water Conservation, NSW State Forests, NSW National Parks and Wildlife Service and Bureau of Rural Sciences, 1999).

However, for the purpose of this assessment, the adopted criteria for rating and comparing WHC of soils are considered sufficient. Baseline physio-chemical and water characteristic data are provided for use should more detailed soil-water studies with native tree species be conducted at a later date.

The water holding capacities of the soil profile classes were determined on up to 3 soil profiles per class on the basis of texture. These estimates were then compared against laboratory water characteristic data obtained from field samples. Each soil profile class type was then allocated a WHC class within the range of 200–175, 175–150 mm, 125–150 mm, 100–125 mm, 75–100 mm, 60–75 mm, 40–60 mm, and < 40 mm.

The texture method involves summing the amount of water that can be stored within each layer of the ERD. Published values for estimated plant available water capacity (EPAWC) based on texture, structure, and organic matter content have been used (NSW Department of Land and Water Conservation, NSW State Forests, NSW National Parks and Wildlife Service and Bureau of Rural Sciences, 1999) and adjusted for gravel content.

The laboratory method involved measuring the water content of soil samples at water potentials corresponding to the *drained upper limit* and the *crop lower limit* using a pressure plate apparatus. Once equilibrated, samples were weighed and oven dried to determine their gravimetric water content. Bulk density of undisturbed cores was also measured, thereby enabling volumetric water content to be determined.

2.4 Reporting

The technical soil report prepared describes the soil landscape units, mapping of soil distributions, laboratory results, soil classifications, landscape details, limitations and constraints, and recommendations. Guidance on the suitability of materials as topsoil, subsoil, marginal topsoil or subsoil (amelioration required) has been provided, and an inventory has been developed of these material volumes. Interpretation criteria for soil analytical results are presented in Appendix C.

2.4.1 Soil classification

The soil at each site was classified using the Australian Soil Classification system (Isbell, 2002), generally to a suborder level (NSW OEH & OASFS, 2013). Soil types were grouped into Soil Profile Classes (SPC) of comparable profiles related by similarity of morphological and physiochemical properties as well as by parent material, representative landforms and geomorphological position in the landscape (McKenzie, et al., 2008).

2.4.2 Mapping

Mapping was completed following the field work and laboratory analysis to refine and modify the preliminary mapping units and to develop 'soil landscape' mapping units. The soil landscapes delineate land units comprised of one or more dominant soil profile classes.

A soil profile class is a group of profiles that all meet the definition of the class. The variation in soil features within the class is less than the variation between the classes. Soil profile classes are not considered to be unique, as the same soil profile classes may be encountered more than once in different soil landscape mapping units.

3 DESCRIPTION OF STUDY AREA

The predominant land use in the North West Region of NSW is agriculture, which includes sheep and cattle production and irrigated and dry land cropping of cotton and wheat along suitable floodplains. The construction of Keepit Dam in the 1960s, and then Split Rock Dam in 1987 ensures a constant water supply for irrigation is available along the Namoi River during periods of prolonged dry weather.

The Gunnedah coalfield supports a number of other small to medium sized coal mines including the Canyon Mine, Rocglen Mine, Werris Creek Mine, and Tarrawonga Coal Mine. Boggabri Coal Mine and the Tarrawonga Mine are located to the south of the MCCM, on the other site of Leard State Forest.

Situated amongst the large areas of agricultural land associated with the Namoi River is Mt Kaputar National Park and a number of state forests including Leard, Jacks Creek, Bibblewindi, Vickery, and Kelvin State Forests. In recent years, the forestry industry has substantially declined, as large tranches of previously forested land have been afforded environmental protection under the Brigalow Nandewar Community Conservation Act 2005 (Hansen Bailey, 2010).

3.1 Land use within the study area.

The predominant land uses in the region include coal mining (Boggabri Coal Mine and Tarrawonga Coal Mine), forestry of the Leard State Forest and agriculture. The proposed disturbance area (study area) of MCCM is 392 ha, within the existing Environmental Approval area of 3,550ha.

The Leard State Forest covers an area of approximately 8,134 ha and is utilised for forestry purposes and recreational activities. Its native vegetation communities are dominated by iron bark (*Eucalyptus crebra* and *E. melanophloia*), white box (*E. albens*) and white cyprus pine (*Callitris glaucophylla*).

To the east of the MCCM is the Namoi River alluvial floodplain that supports some of the most productive and fertile land within the district (Hansen Bailey, 2010). This floodplain is the most significant tributary in the region and supports both dry land and irrigated cropping with water either drawn from the Namoi River or underlying groundwater aquifers. The lighter soils on the surrounding slopes and foothills adjacent to the Namoi River floodplain are used primarily for grazing of sheep and cattle.

3.2 Climate

The project exists within a sub humid climate, with no dry season and a hot summer (NSW Parks and Wildlife Service, 2003). Temperatures in the summer months tend to be between minimum 17–19°C and maximum 30–34°C. In the winter months, temperatures tend to be between minimum 3–6°C and maximum 17–22°C. Annual rainfall is approximately 600 mm. In the summer, rainfall is approximately 70 mm per month, decreasing throughout the winter to approximately 40 mm per month.

3.3 Surface hydrology and flooding

The Namoi River rises in the Great Dividing Range and extends for over 350 km west where it discharges into the Barwon River near Walgett. It has a total catchment area of approximately 42,000 km^2. The study area is contained entirely within the catchment of Black Creek, which is a small ephemeral tributary of the Namoi River. There are a number of small unnamed drainage lines that commence within Leard State Forest and drain through the study area to Black Creek.

The Namoi Valley is subject to regular flooding. The largest recently recorded flood events in the Namoi Valley occurred in February 1955, January 1971, February 1984 and November 2000. The mining area, mine infrastructure area and administration area are not located within the floodplain.

3.4 Geology

The Project is situated in the north-east of the Gunnedah Basin Coalfield (Gunnedah Basin) within the early Permian Bellata Group and coal bearing sequence. The Bellata group is divided into two Sub-basins, the Maules Creek Sub-basin and the Mulalley Sub-basin. These sub-basins are separated by a volcanic intrusion commonly referred to as the Boggabri Ridge. Details of the geological units are provided in Table 3 and Figure 1.

Table 3 Geological units relevant to the study area (Pratt, 1998)

Geological unit	Map code	Description	Parent material category
Maules Creek Formation	Pmx	Basal carbonaceous claystone, pelletoidal clay sandstone, minor coal, passing upwards into upward-fining cycles of sandstone, thinly bedded siltone / sandstone and coal. Conglomerate dominant towards top.	Transitional siliceous/intermediate
Boggabri Volcanics	Pbr	Rhyolytic to dacitic lavas and ashflows tuffs with inter-bedded shale. Rare trachyte and andesite.	Highly siliceous and Transitional siliceous/intermediate

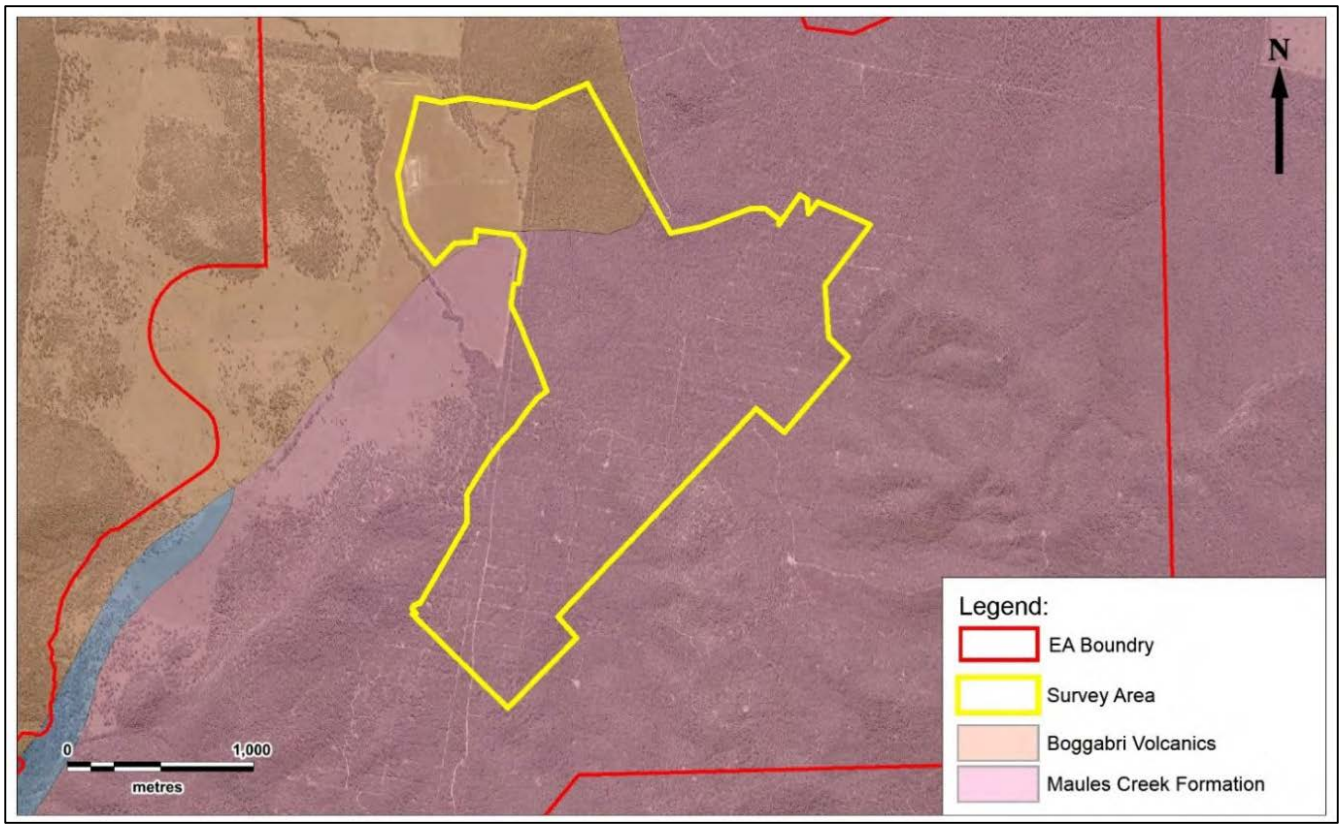

Figure 1 Geological units of the study area include Maules Creek Formation and Boggabri Volcanics.

4 SOILS

A total of 5 soil landscape mapping units have been developed, which encompass 5 soil profile classes, developed from 28 ground observations undertaken. The spatial distribution of these observation sites and soil landscapes is presented in Maps 1 and 2 (Appendix A).

Soil landscapes reflect variations in soil type, geology, landform, drainage and vegetation within the study area. All soil landscape units have some soil variation, and generally include more than one soil profile class. Where a soil mapping unit consists of predominantly one soil profile class, it is a *simple* unit. Where more than one class dominates, it is a *compound* unit. A soil *complex* is a compound unit with two or more soil profile classes that occur in an intricate pattern unable to be delineated at the published scale. A '*soil association*' is a compound unit where soil profile classes repeat in a predictable pattern. (McKenzie, et al., 2008).

Details of the soil mapping units and corresponding soil profile classes are given in Table 4. The soil landscape mapping units have been developed in reference to the soil landscapes presented in the *Soil and Land Resources of the Liverpool Plains Catchment Interactive DVD* (Office of Environment and Heritage, 2012).

Table 4 Summary descriptions of the Soil Mapping Units and Soil Profile Classes (Office of Environment and Heritage, 2012).

Soil Landscapes	Landform and Geology	Soil Profile Class(es)
Leard	Crests and upper slopes of low hills on the Maule's Creek Formation, sometimes extending to mid slopes. Moderately inclined slopes with to 8–30% gradient.	Maules Shallow Gravelly Sands
Blue Vale Slopes	Mid to lower slopes of low hills on the Maule's Creek Formation. Gently inclined slopes of 3–10 % gradient.	Maules Gravelly Duplex Soils
Blue Vale Footslopes	Drainage fans and plains derived from the Maule's Creek. Footslopes of 1–4% gradient.	Complex of Maules Deep Gravelly Sands and Loams (60–80%), and Maules Sodic Duplex Soils (20–40%)
Blue Vale Flats	Plains and flats derived from the Maule's Creek Formation. Terminal footslopes and flats with gradients < 3%.	Maules Sodic Duplex Soils
Hartfell	Crests and slopes of low hills on the Boggabri Volcanics. Gently and moderately inclined slopes with 4–20 % gradient.	Volcanic Cobbly Clays and Duplex Soils

Sections 4.1–4.5 provide descriptions of the soil profile classes together with references to the corresponding ground observation sites and laboratory data relevant to each class. For each soil profile class, key features and management issues that are expected to require consideration when salvaging soils for reuse as plant growth media are provided, together with a detailed morphological description of one or more sites.).

4.1 Maules Shallow Gravelly Sands

Brief Description	Gravelly, shallow or moderately deep, loamy sands, and clayey sands generally situated on hill crests and upper slopes of the Maules Creek Formation.		
Landform	Moderately inclined upper slopes and crests of rolling hills with gradients generally ranging from 8–30 %. Sometimes on gently inclined mid slopes.		
Geology/ Lithology	Maules Creek Formation. Basal carbonaceous claystone, siltstone, sandstone, and coal.		
ASC	Leptic Tenosols and Brown Orthic Tenosols		
Microrelief	Nil	**Runoff**	Moderately rapid
Permeability	Moderate–high	**ERD**	0.4 to 0.75 m
Drainage	Well	**WHC**	40–60 mm
Surface	Soft to firm condition. Gravel or cobbles covering up to 20–50 % of the surface on hill crests and upper slopes. On the mid and lowerslopes surface is less gravelly generally between 10–20 %.		
Vegetation	White cypress pine (*Callitris glaucophylla*), and narrow leaf iron bark (*Eucalyptus crebra*) open forest. Sometimes silver leaf ironbark (*E. melanophloia*). Selectively logged.		
Observations	**Analytical sites:** 014 & 016. **Detailed site:** 014; **Check sites:** 013, 016, 017 & MC3.		
Samples	MCC014:0.1–0.05, MCC014:0.15–0.3, MCC014:0.3–0.5, MCC16:0.0–0.05; MCC016:0.15–0.3, MCC016:0.3–0.5, MC3:0-10cm & MC3:30-60cm.		

Landscape and vegetation scene at Site 013.

Shallow rock at Site 017.

4.1.1 Key features

The features listed below are characteristic of the Maules Shallow Gravelly Sands:

- Erosional landscapes on transitional siliceous/intermediate parent materials.
- Uniform textured soil profiles that are commonly 40 % gravel. Typical depths are 0.4–75 m.
- Topsoil fertility rating is *moderate*: Total N: moderate; Available P: moderate; Available K: high; Organic Carbon: very high. The CEC indicates the topsoil has a moderate potential to supply nutrients, largely due to its very high organic matter content.
- Estimated soil erodibility (*K*-factor) – Topsoil: low–moderate; Subsoil: moderate.

Table 5 Summary of plant available water capacity and physio-chemical parameters

Typical Depth (mm)	Texture	EPAWC (mm)	pH	Salinity	Sodicity	Dispersive
0–150	Gravelly, loamy sand or clayey sand	15–20	Neutral	Low	Non	NA
150–500	Gravelly, loamy sand or clayey sand	25–35	Neutral	Very low	Non	NA

Table 6 Management considerations

Typical Depth (mm)	Growth Media Suitability	Comments
0–150	Topsoil	Moderate fertility, very high organic matter content. Negligible physio chemical limitations to root growth.
	Subsoil	Negligible physio chemical limitations to root growth.
150–500	Marginal Topsoil	Low fertility, low organic matter. Amelioration with fertiliser and organic matter required for use as topsoil.
	Subsoil	Negligible physio chemical limitations to root growth.

4.1.2 Representative profile description: Brown Orthic Tenosol (Site 014)

A1 0–150 mm	Very dark grey (moist 7.5YR 3/1) clayey sand. Structure weak with subangular blocky peds, < 15 mm. Coarse fragments 40–50 %, subrounded and rounded, < 20 mm. Field pH 6.5. Roots many. Gradual boundary to –
A21 150–300 mm	Brown (moist 7.5YR 4/3) clayey sand. Structure weak with subangular blocky peds <15 mm. Coarse fragments 40–50 %, subrounded and rounded, < 40 mm. Field pH 6. Roots common. Diffuse boundary to –
A22 300–>550 mm	Light brown (moist 7.5YR 6/4) loamy sand. Structure weak with subangular blocky peds <30 mm. Coarse fragments 40–50 %, subrounded and rounded, < 40 mm. Field pH 6. Roots few. Diffuse boundary to –
A/C	Weathered rock and loamy sand. Refusal at 600 mm

Shallow and gravelly soil profile at Site 014.

Surface cover at Site 014.

4.2 Maules Deep Gravelly Sands and Loams

Brief Description	Gravelly, moderately deep and deep, loamy sands to sandy clay loams generally situated on the footslopes of the Maules Creek Formation.		
Landform	Very gently to gently inclined footslopes, gradients ranging 1–6%.		
Geology/ Lithology	Maules Creek Formation. Basal carbonaceous claystone, siltstone, sandstone, and coal.		
ASC	Grey Predominantly Orthic Tenosols (Grey and Brown) and some Red Kandosols		
Microrelief	Nil	**Runoff**	Moderately rapid
Permeability	Moderate	**ERD**	0.8–1.0 m
Drainage	Well	**WHC**	75–150 mm
Surface	Firm condition with rounded and sub rounded gravel covering up to 10–20 % of the surface.		
Vegetation	White cypress pine (*C. glaucophylla*), white box (*E. albens*) and narrow leaf iron bark (*E. crebra*) open forest. Sometimes silver leaf ironbark (*E. melanophloia*). Selectively logged.		
Observations	Analytical sites: 005, 006, 020, MC4 & MC6; Detailed site: 005; 006; Check site: 020, MC4 & MC6.		
Samples	MCC005:0.0–0.05, MCC005:0.2–0.3, MCC005:0.3–0.5; MCC006:0.0–0.05, MCC006:0.1–0.25, MCC006:0.4–0.6, MCC020:0.0–0.05, MCC020:0.2–0.4; MCC020:0.4–0.6; MC4:0–10cm, MC4:30–60cm, MC6:0–10cm & MC6:30–60cm.		

Landscape and vegetation scene at Site 020.

Soil surface at Site 005.

4.2.1 Key features

The features listed below are characteristic of the Maules Deep Gravelly Sands and Loams:

- Transitional landscapes of transitional siliceous/intermediate parent materials.
- Uniform and gradationally textured soil profiles that are gravelly. Typical depths are 0.8–1.2 m.
- Topsoil fertility rating is *moderate to high*: Total N: moderate; Available P: high; Available K: high; Organic Carbon: very high. The CEC indicates the topsoil has a moderate potential to supply nutrients largely due to its very high organic matter content.
- Estimated soil erodibility (*K*-factor) – Topsoil: moderate; Subsoil: moderate.

Table 7 Summary of plant available water capacity and physio-chemical parameters

Typical Depth (mm)	Texture	EPAWC (mm)	pH	Salinity	Sodicity	Dispersive
0–150	Gravelly sandy clay loam	20–25	Neutral to moderately acidic	Very low	Non	Non
150–500	Gravelly clayey sand to sandy loam	35–55	Neutral to moderately acidic	Very low	Non or marginally	Slight to moderately
500–1000	Gravelly clayey sand to sandy loam	30–80	Neutral to moderately acidic	Very low	Non or marginally	Slight to moderately

Table 8 Management considerations

Typical Depth (mm)	Growth Media Suitability	Comments
0–150	Topsoil	Moderate to high fertility, very high organic matter content. Negligible physio chemical limitations to root growth.
	Subsoil	Negligible physio chemical limitations to root growth.
150–1000	Marginal Topsoil	Low fertility, low organic matter. Prone to hard setting. Ameliorate with fertiliser, gypsum, and organic matter.
	Subsoil	Negligible physio chemical limitations to root growth.

4.2.2 Representative profile description: Red Kandosol (Site 006)

A11 0–80 mm	Dark reddish grey (moist 5YR 4/2) sandy clay loam. Structure moderate with subangular blocky peds, < 20 mm. Coarse fragments 10–20 %, subrounded, rounded, and subangular, < 20 mm. Field pH 7. Roots many. Gradual boundary to –
A12 80–240 mm	Reddish brown (moist 5YR 4/4) sandy clay loam. Structure weak with subangular blocky peds, < 20 mm. Coarse fragments 10–20 %, subrounded, rounded, and subangular, < 20 mm. Field pH 6.5. Roots common. Gradual boundary to –
A31 240–600 mm	Yellowish red (moist 5YR 5/6) sandy clay loam. Apedal. Coarse fragments 10–20 %, subrounded, rounded, and subangular, < 20 mm. Field pH 6.5. Roots common. Gradual boundary to –
A32 600–1000 mm	Yellowish red (moist 5YR 5/6) sandy clay loam. Apedal. Coarse fragments 10–20 %, subrounded, rounded, and subangular, < 20 mm. Field pH 6.5. Roots few. Gradual boundary to –
D 1000–>1400 mm	Weathered rock and sandy clay loam.

Soil profile at Site 006.

4.3 Maules Gravelly Duplex Soils

Brief Description	Gravelly, moderately deep, texture contrast soils on slopes formed on the sedimentary Maules Creek Formation. Subsoils generally non-sodic, sometimes sodic.		
Landform	Dominant on the gently inclined lower and mid slopes of rolling hills, gradients 3–10 %		
Geology	Maules Creek Formation (Pmx). Basal carbonaceous claystone, siltstone, sandstone, and coal.		
ASC	Grey, Brown and Red Chromosols and Sodosols		
Microrelief	Nil	**Runoff**	Moderately rapid to rapid
Permeability	Moderate	**ERD**	0.75–1.0 m
Drainage	Moderately well to imperfect	**WHC**	125–175
Surface	Firm with subrounded and rounded gravel covering 10–50% of the surface. Sometimes cobbles.		
Vegetation	White cypress pine (*C. glaucophylla*), white box (*E. albens*) and narrow leaf iron bark (*E. crebra*) open forest. Selectively logged.		
Observations	Analytical sites: 007, 015, 019, 021, 022 & MC2; Detailed site: 007; Check sites: 018, 019, 021,022 & MC2.		
Samples	MCC007:0.0–0.05; MCC007:0.2–0.4; MCC007:0.45-0.65; MCC007:0.7–0.9; MCC015:0.35–0.55; MCC019:0.0-0.05; MCC019:0.1–0.2; MCC019:0.2–0.35; MCC019:0.4–0.7; MCC021:0.1–0.3; MCC022:0.2–0.4, MC02:0-10cm & MC02:30-60cm.		

Landscape post vegetation clearing at Site 019.

Soil Surface condition at Site 021.

4.3.1 Key features

The features listed below are characteristic of the Maules Gravelly Duplex.

- Residual landscapes on transitional siliceous/intermediate parent materials.
- Texture-contrast soil profiles that are gravelly. Depth to weathered rock is generally less than 1 m.
- Topsoil fertility rating is *moderate to high*. Total N: moderate to high; Available P: moderate to high; Available K: high; Organic Carbon: very high. The CEC indicates the topsoil has a moderate potential to supply nutrients.
- Estimated erosion potential (*K*-factor) – Topsoil: moderate; Subsoil: low.

Table 9 Summary of plant available water capacity and physio-chemical parameters

Typical Depth (mm)	Texture	EPAWC (mm)	pH	Salinity	Sodicity	Dispersive
0–125	Gravelly clayey sand, sandy loam, or clay loam sandy	15–25	Neutral	Very low	Non	Non or slightly
125–500	Gravelly medium clay to medium heavy clay	45–60	Neutral to low acidity	Very low	Non or sodic	Slightly
500–900	Gravelly medium clay to medium heavy clay	55–95	Low to high acidity	Very low	Non or sodic	Slightly

Table 10 Management considerations

Typical Depth (mm)	Growth Media Suitability	Comments
0–125	Topsoil	Moderate to high fertility, very high organic matter content. Negligible physio chemical limitations to root growth.
	Subsoil	Negligible physio chemical limitations to root growth.
125–500	Marginal Topsoil	Low fertility, low organic matter. Amelioration with fertiliser and organic matter required for topsoil use.
	Subsoil	Negligible physio chemical limitations to root growth.
500–900	Marginal Topsoil	Low fertility, low organic matter, acidic. Amelioration with fertiliser, lime and organic matter required for topsoil use.
	Marginal Subsoil	Acidic. Amelioration with lime and organic matter required for subsoil use.

4.3.2 Representative profile description: Grey Chromosol (Site 007)

A1 0–130 mm	Very dark grey (moist 7.5YR 3/1) sandy loam. Structure moderate with subangular blocky peds, <20 mm. Coarse fragments 10 %, subangular < 10 mm. Field pH 5.5. Roots many. Clear boundary to
B21 130–450 mm	Dark grey (moist 10YR 4/1) or very dark grey (moist 10YR 3/1) medium clay. Structure moderate with columnar blocky peds, > 50 mm. Coarse fragments 10 %, subangular < 10 mm Field pH 5.5. Roots common. Clear boundary to
B22 450–900 mm	Grey (moist 7.5YR 5/1) medium clay. Structure weak with columnar blocky peds, > 50 mm. Coarse fragments 10 %, subangular < 10 mm Field pH 5.5. Roots few. Diffuse boundary to –
C >900 mm	Weathered rock with inter-bands of clay.

Soil Profile at Site 007.

4.4 Maules Sodic Duplex Soils

Brief Description	Moderately deep, sodic texture contrast soils on footslopes and valley flats formed over colluvium		
Landform	Very gently to gently inclined footslopes, gradients ranging 1–6%.		
Geology	Boggabri Coal (Pmx). Basal carbonaceous claystone, siltstone, sandstone, and coal.		
ASC	Brown and Grey Sodosols		
Microrelief	Nil	**Drainage**	Moderately well to imperfect
Runoff	Slow or moderately rapid	**ERD**	0.8–1.0 m
Permeability	Moderate	**WHC**	125–175
Surface	Hardsetting condition, subrounded, rounded, and angular gravel covering 5–20% of the surface.		
Vegetation	Cleared		
Observations	Analytical sites: 003, 004, 008, MC7 & MC8; Detailed site: 003, 004 & 008; Check sites: MC7 & MC8.		
Samples	MCC003:0.0–0.05, MCC003:0.2–0.4, MCC003:0.5–0.8, MCC003:1.1–1.4; MCC004:0.1–0.3, MCC008:0.0–0.05, MCC008:0.2–0.3; MCC008:0.3–0.5; MCC008:0.6–0.9, MC7:0–10cm, MC7:30–60cm, MC8:0–10cm & MC8:30–60cm.		

Landscape and vegetation at Site 022.

Soil surface at Site 008.

Columnar structured subsoil exposure at Site 022.

4.4.1 Key features

The features listed below are characteristic of the Maules Sodic Duplex.

- Transferral landscapes from transitional siliceous/intermediate parent materials.
- Texture-contrast soils with sodic subsoils. Soil depth is typically 0.8–1.3 m and is underlain by colluvium.
- Topsoil fertility rating is *moderate to high*. Total N: high; Available P: moderate to high; Available K: high; Organic Carbon: very high. The CEC indicates the topsoil has a moderate to very high potential to supply nutrients.
- Estimated erosion potential (*K*-factor) – Topsoil: moderate; Subsoil: moderate.

Table 11 Summary of plant available water capacity and physio-chemical parameters

Typical Depth (mm)	Texture	EPAWC (mm)	pH	Salinity	Sodicity	Dispersive
0–150	Sandy clay loam to clay loam sandy	20–30	Low acidity to low alkalinity	Very low	Non	Non
150–500	Medium clay	55–60	Neutral or low alkalinity	Low	Non or sodic	Slight to very highly
500–1000	Medium clay to medium heavy clay	45–85	Low to high alkalinity	Low or moderate	Sodic	Slightly

Table 12 Management considerations

Typical Depth (mm)	Growth Media Suitability	Comments
0–150	Topsoil	Moderate to high fertility, very high organic matter content. Negligible physio-chemical limitations to root growth.
	Subsoil	Negligible physio chemical limitations to root growth.
150–500	Marginal Topsoil	Low fertility and sodic. Amelioration with fertiliser, gypsum, and organic matter required for use as topsoil.
	Subsoil	Minor physio-chemical limitations when used as a subsoil. Amelioration with gypsum will improve quality of the growth media.
500–1000	Unsuitable as topsoil	Salinity will likely cause limitations to germination and emergence.
	Marginal Subsoil	Moderate sodicity and salinity limitations when used as a subsoil. Ameliorate with gypsum, however the salinity limitation will remain a moderate limitation unless leached.

4.4.2 Representative profile description: Brown Sodosol (Site 003)

A1 0–130 mm	Very dark grey (moist 7.5YR 3/1) clay loam sandy. Structure moderate with subangular blocky peds, < 15 mm. Coarse fragments 10 %, subangular < 10 mm. Field pH 7. Roots many. Clear boundary to
B21 130–400 mm	Yellowish brown (moist 10YR 5/4) medium clay. Structure strong with columnar peds, > 50 mm. Coarse fragments 10 %, subangular < 10 mm Field pH 5.5. Roots common. Diffuse boundary to
B22 400–900 mm	Yellowish brown (moist 10YR 5/4) medium heavy clay. Coarse fragments 10 %, subangular < 10 mm Field pH 8. Roots few. Gradual boundary to –
D >900 mm	Weathered rock with inter-bands of clay, gravel, and sand.

Soil Profile at Site 003.

4.5 Volcanic Cobbly Clay and Duplex Soils

Brief Description	Cobbly clay and texture contrast soils on moderate inclined side slopes of low hills formed from Boggabri Volcanics. Upper slopes and crests typically have > 40 % surface cover of cobbles and stones.		
Landform	Undulating and rolling low hills between elevations and on slopes with gradients > 6 %.		
Geology	Boggabri Volcanics (Pbr). Permian/Carboniferous rhyolite, rhyolite tuff, dacite, and andesite.		
ASC	Brown Chromosols and Brown Dermosols		
Microrelief	Nil	**Runoff**	Moderately rapid
Permeability	Moderate	**ERD**	0.7–1.0 m
Drainage	Imperfect to moderately well	**WHC**	75–125
Surface	Firm condition with rhyolite & dacite cobbles (60-200 mm) and gravel covering 10–30 % or more of the surface. Hill crests typically have > 40 % cobbly rock cover.		
Vegetation	White cypress pine (*C. glaucophylla*), white box (*E. albens*) and narrow leaf iron bark (*E. crebra*) open forest. Selectively logged.		
Observations	Analytical sites: 001 & 012; Detailed sites: 001 & 012; Check sites: MCC002 & MCC011		
Samples	MCC001:0.0–0.05, MCC001:0.1–0.3, MCC001:0.4–0.6, MCC001:0.7–0.9; MCC001:1.1–1.4, MCC0.0–0.05, MCC012:0.15–0.3, MCC012:0.4–0.7. Undisturbed samples for WHC: MCC001:0.0–0.05, MCC001:0.3–0.35, MCC012:0.0–0.05 & MCC012:0.35–0.4.		

Landscape and vegasttion at Site 001.

Cobbly and gravelly surface condition at Site 011.

Very cobbly surface condition of upper slopes near Site 002

4.5.1 Key features

The features listed below are characteristic of the Volcanic Cobbly Clay and Duplex soils

- Erosional landscapes on highly siliceous and transitional siliceous/intermediate.
- Texture-contrast and gradational clay soils that are gravelly and cobbly to depth and generally less than 1 m deep.
- Topsoil fertility rating is *moderate*. Total N: moderate to high; Available P: low to high; Available K: high; Organic Carbon: very high. The CEC indicates the topsoil has a moderate to high potential to supply nutrients.
- Estimated erosion potential (*K*-factor) – Topsoil: moderate; Subsoil: low to moderate.

Table 13 Summary of plant available water capacity and physio-chemical parameters

Typical Depth (mm)	Texture	EPAWC (mm)	pH	Salinity	Sodicity	Dispersive
0–100	Sandy clay loam to light clay	15–20	Low acidity to neutral	Very low	Non	Non or highly
100–350	Sandy clay loam to medium clay	25–35	Low acidity to neutral	Very low to moderate	Non to marginal	Slightly
350–900	Medium clay	35–70	Low to high alkalinity	Low to moderate	Non or sodic	Slightly

Table 14 Management considerations

Typical Depth (mm)	Growth Media Suitability	Comments
0–100	Topsoil	Moderate fertility, very high organic matter content. Negligible physio-chemical limitations to root growth.
	Subsoil	Negligible physio chemical limitations to root growth.
100–350	Marginal Topsoil	Low fertility and marginally sodic. Amelioration with fertiliser, gypsum, and organic matter required for use as topsoil.
	Subsoil	Minor physio-chemical limitations when used as a subsoil. Amelioration with gypsum will improve quality of the growth media.
350–900	Unsuitable as topsoil	Salinity and alkalinity will likely cause limitations to germination and emergence.
	Marginal Subsoil	Moderate sodicity and salinity limitations when used as a subsoil. Ameliorate with gypsum, however the salinity limitation will remain a limitation until leached.

4.5.2 Representative profile description: Brown Dermosol (Site 001)

A1 0–75 mm	Very dark greyish brown (moist 7.5YR 3/2) light clay. Structure moderate with subangular blocky peds, < 20 mm. Coarse fragments 30 %. Field pH 6.5. Roots many. Clear boundary to
B21 75–370 mm	Dark yellowish brown (moist 10YR 4/4) medium clay. Structure moderate with polyhedral peds, < 20 mm. Coarse fragments 30 %. Field pH 7.0. Roots common. Diffuse boundary to –
B22 370–500 mm	Yellowish brown (moist 10YR 5/6) medium clay. Structure moderate with polyhedral peds, < 20 mm. Coarse fragments 30 %. Soft carbonate bands, < 10 mm thick, 5–10%. Field pH 8.0. Roots few. Diffuse boundary to –
B23 500–950 mm	Yellowish brown (moist 10YR 5/6) medium clay. Structure moderate with polyhedral peds, < 20 mm. Coarse fragments 30 %. Field pH 8.0. Roots few. Diffuse boundary to –
C 950–>1400 mm	Weathered rock with inter-bedded clay

4.5.3 Representative profile description: Brown Chromosol (Site 012)

A11 0–140 mm	Dark brown (moist 7.5YR 3/2) sandy clay loam. Structure moderate with subangular blocky peds, < 20 mm. Coarse fragments 20–30 %. Field pH 7. Roots many. Clear boundary to
A3 140–350 mm	Brown (moist 7.5YR 5/4) sandy clay loam. Structure apedal, single grained. Coarse fragments 20–30 %. Field pH 6.5. Roots common. Clear boundary to
B2 350–900 mm	Brown (moist 10YR 4/3) with red (moist 10R 3/4) and yellowish brown (moist 10YR 5/6) mottled medium clay. Structure moderate with subangular blocky peds, < 30 mm. Coarse fragments 40–50 %. Roots few. Diffuse boundary to –
C >900 mm	Weathered rock with inter-bedded clay

Soil profile at Site 012

5 GROWTH MEDIA INVENTORY

Effective planning for rehabilitation of disturbed areas requires details on the quality and distribution of soil materials able or unable to support plant growth. This information will guide the material handling processes such as stripping, stockpiling, storing, amelioration. Detail on the suitability of different soil layers (to a depth of ≤1.5 m) has been provided for each soil profile class in Section 4.

Successful rehabilitation to achieve post mining land use objectives requires adequate quantities of suitable growth media to support the desired vegetative community, and for the relevant landform and climate zone in which the site exists. Soil is biologically active and often fragile. If mismanaged, then this leads to degradation of chemical and physical quality, which greatly reduces the likelihood of achieving rehabilitation success.

The quality of topsoil media requires special mention. The fertility of the topsoil materials has generally been assessed as moderate or high. However inappropriate handling and stockpiling could easily degrade the fertility of these soils. The topsoils are mostly sands and loams that are high in organic matter, and it is the organic matter, and the associated micro-flora and micro-fauna that is largely responsible for the chemical and physical fertility. Soil management protocols and unsuitable stockpiling practices that lead to the degradation of organic matter and spoil biota will also result in degradation of topsoil quality, negatively impacting the potential for rehabilitation success.

A summary of the volumes available per soil landscape is provided in Table 15. Growth media volumes were estimated by assessing the extent of the soil landscape surface and multiplying this area by the average depth of available soil. Actual soil depth may vary due to changes in the landscape of each soil type. An error factor of ± 20 % is recommended to be applied to these volumes.

It is important to note that these are estimates of the potential available growth media across the survey area, and quantities should be considered with caution. Bulk earthworks and handling of materials has the potential to mix different soil layers and materials and either improve, or degrade, the quality of materials as growth media.

In particular, caution should be used with volume estimates in complex soil landscapes such as the Blue Vale Footslopes. Because of this landscape's complexity, soil variability is high and cannot be delineated at this survey scale. Should growth media be salvaged from these areas, it may be useful and cost-effective to undertake more detailed survey work to delineate soils and allow the segregation of undesirable materials during stripping.

Table 15 Growth Media Inventory

Soil Landscape	Area (ha)	Available Growth Media Volumes +/- 20% (x 1000 m^3)				
		Topsoil or Subsoil	Subsoil or Marginal Topsoil	Marginal Subsoil or Marginal Topsoil	Marginal Subsoil	Totals
Leard	67	101	235	-	-	335
Blue Vale Slopes	94	118	353	376	-	846
Blue Vale Footslopes	131	187	927	157	-	1271
Blue Vale Flats	55	83	193	-	275	550
Hartfell	45	45	113	-	248	405
Totals	**392**	**532**	**1818**	**533**	**523**	

6 CONCLUSIONS AND RECOMENDATIONS

The information within this soil survey report provides technical soil and landscape details to contribute to the management of soil as detailed in a number of management plans and protocols. The key features described for each soil profile class provide a detailed description and understanding which have not been available previously.

The management actions contained in the Soil Management Protocol and the rehabilitation activities outlined in the Mine Operations Plan pertaining to soil management activities can now be specified with some confidence. Information within this soil survey report should be used to inform and refine the following:

- Soil balance calculations;
- Topsoil and subsoil stripping;
- Amelioration;
- Characterization of subsoil and spoil; and
- Soil related completion criteria.

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8 GLOSSARY OF TERMS

The glossary of terms has largely been sourced from the Victorian Resources Online (VIC Department of Environment and Primary Resources, 2014).

A horizon	The surface mineral horizons where some have organic matter accumulation. They are usually darker in colour than the lower horizons and may be broken down into three distinct layers: • A1 horizon – Top layer of mineral soil with organic matter content and significant biological activity. Usually darker in colour than horizons below. • A2 horizon - It is usually paler in colour from the A1 horizon. It can have less organic matter, sesquioxides, silicate clay: • A3 horizon - Transitional horizon between the A and B horizons but has predominantly A horizon properties.
Acidic	Soils with a pH less than 7.0 in water. While some plants thrive in acid soils, others don't and require lime to make the soil more alkaline. This term is also used as a Subgroup distinction for a number of Soil Orders in the Australian Soil Classification (Isbell, 2002). It refers to soils with a B2 horizon that on the whole is strongly acid
Alkaline	A soil property expressed by a pH that exceeds 7.0 in soil/water suspension.
Alluvium	Alluvium is the sediment deposited from transportation by channelled stream flow or over-bank stream flow.
Ameliorant	A substance used to improve the chemical or physical properties of a soil. For example, gypsum to improve aggregate stability and soil structure, lime to increase pH levels.
Angular blocky structure	A cube-shaped ped where soil particles are arranged around a point, bounded by six relatively flat, roughly equal faces.
Anthroposols	These soils result from human activity e.g. mine spoil where origin soils may be buried and new parent material introduced. A Soil Order of the Australian Soil Classification (Isbell, 2002).
Apedal	These soils are either single grained (incoherent) or massive (coherent). Peds are not apparent when the soil is moderately moist.

B horizon	Subsoil horizons consisting of one or more mineral layers differing to the A Horizon by: clay, iron, aluminium or organic matter concentrations; structure and/or consistence; and/or colour. The B Horizons can have one or more of the following layers: • B1 Horizon - Transitional layer between the A and B horizons but dominated by B Horizon properties. • B2 Horizon - Has the dominant feature of greater clay, iron, aluminium, humus and/or maximum development of pedological organisation. May be divided into subhorizons B21, B22, B23 etc. • B3 Horizon - Transitional layer between the B and C horizons, dominated by B Horizon properties but integrating into the C material below.
Bleached horizon	Horizons that are paler than adjacent horizons. They are best viewed when the soil is dry. A bleach is generally associated with the A2 horizon although it is not restricted to this layer. It generally occurs on top of a much less permeable subsoil, pan or hard rock. A conspicuously bleached horizon is one in which 80% or more of the horizon is bleached. A sporadic bleach occurs irregularly throughout the horizon or as blotches at the interface of the A and B horizons. This horizon is the most leached part of a soil. Organic matter, clay, iron, aluminium and nutrient elements have all been removed, leaving an accumulation of silica giving the horizon its whitish colour. Field observations have established that bleached horizons are often saturated with water and their occurrence is usually an indication of periodic waterlogging. This can indicate sodic subsoils where there is a strong texture contrast between A and B horizons.
Blocky structure	A cube shaped ped.
Cation exchange capacity (CEC)	Is the measure of the capacity of a soil to hold the major cations: calcium, magnesium, sodium and potassium (including hydrogen, aluminium and manganese in acid soils). It is a measure of the potential nutrient reserve in the soil and is therefore an indicator of inherent soil fertility. An imbalance in the ratio of cations can result in soil structural problems. High levels of individual cations (e.g. aluminium and manganese) can also be toxic to plants.
Calcium / magnesium ratio	A ratio of exchangeable Calcium vs. exchangeable Magnesium in the soil. Soils with a low Ca:Mg will in most cases indicate low exchangeable calcium levels (possible calcium deficiency for some plants) and potential soil structural stability issues.
C horizon	Layers below the solum (AB profile) lacking pedological development. Includes consolidated rock and sediments that are generally weak in strength.
Colour	Soil colour is assessed in a moist condition using a Munsell Colour Chart (Munsell Colour Company, 1975) to assess the dominant colour. Secondary colours, bleaches and mottles are also recorded. Colour provides a useful indication of a number of profile attributes. Dark surface soils, for instance, indicate a high level of organic matter. In a subsurface A2 horizon, bleached colours indicate low levels of plant nutrients and that seasonal or periodic waterlogging occurs. In subsoils, the colour sequence from red to brown or yellow to grey colours, indicate a sequence from well aerated and well drained soils to poorly aerated and poorly drained soils.

Columnar structure	Soil particles are arranged around a vertical axis with flat faced peds. The tops of the columns have clearly defined domes. Columnar structure is often associated with subsoil sodicity.
Crop lower limit	(Wilting point) The water content of the soil where the plant is no longer able to extract it and therefore the plant wilts.
Dermosols	Soil Order of the Australian Soil Classification (Isbell, 2002). Soils that have structured B2 Horizons more developed than weak throughout the major part of the horizon. They also lack strong texture contrast between the A and B horizons.
D horizon	Any soil material below the solum that is unlike the solum and C Horizon and is not a buried soil (McDonald *et al*, 1990).
Dispersion	Dispersion is an indicator of sodic soils as it occurs when excessive sodium is present. When water is added, the sodium attaches to the clay and forces the clay particles apart. This results in a cloud of clay forming around the aggregate. The fine clay particles that have dispersed, clog up the small pores in the soil and degrade soil structure as well as restricting root growth and water movement. Dispersive soils usually have a high exchangeable sodium percentage (ESP).
Drained upper limit	(Field capacity) The percentage of moisture remaining in a soil horizon 2-3 days after being saturated (by rainfall or irrigation) and after free drainage has ceased.
Duplex profile	It describes a soil where there is a sharp texture contrast between the A and B horizons. A duplex soil is often characterised by a sandy or loamy surface horizon with a sharp to clear boundary to a clay subsoil.
Electrical conductivity (EC)	A measure of the conduction of electricity through water, or a soil water extract. The value can reflect the amount of soluble salts in a soil extract - therefore providing an indication of soil salinity. Soil texture needs to be considered in interpretation.
Estimated plant available water capacity (EPAWC)	Largely a texture based estimate of the plant available water capacity of a soil, but also considers organic matter content and structure. Plant available water capacity and water holding capacity phrases are often used interchangeably.
Exchangeable sodium percentage (ESP)	Is calculated as the proportion of the cation exchange capacity occupied by the sodium ions and is expressed as a percentage. In Australia, sodic soils are categorised as soils with an ESP of 6-14% and strongly sodic soils have an ESP of >14%.
Ferrosols	Soil Order of the Australian Soil Classification (Isbell, 2002). These soils lack strong texture contrast between the A and B horizons. The B2 horizon has structure more developed than weak **and** a fine earth fraction which has a free iron oxide content greater than 5% (as opposed to a Dermosol).
Field capacity	See *Drained upper limit*
Golgai	Gilgai's are common where they are Vertosol soils. The land surface is irregular with alternating mounds (puffs) and depressions (hollows) and is commonly referred to as 'crab hole' country.
Gleying	Gleying is indicative of permanent or periodic intense reduction due to wetness and is characterised by greying, bluish or greenish color, generally of low chroma. Mottling may be prominent as well as rusty root channel mottling.

Gradational profile	A soil with a gradual increase in texture (i.e. becomes more clayey) as the profile deepens. Boundaries are usually gradual or diffuse.
Granular structure	Rounded peds that are porous, stable and less than 12 mm in diameter. Granular structure usually occurs in the surface horizons.
Gypsum	A naturally occurring soft crystalline material which is a hydrated form of calcium sulphate. Gypsum contains approximately 23% calcium and 18% sulphur and is used to improve soil structure and reduce crusting in hard setting clayey soils.
Hardsetting	The condition of a soil where the surface is dry, hard and compacted with no apparent pedal development. These soils are not disturbed or indented by pressure of the forefinger. These harder setting soils tend to result in high runoff
Hydrosol	Soil Order of the Australian Soil Classification. These are soils where a greater part of the profile is saturated for at least several months per year.
Kandosol	A Soil Order of the Australian Soil Classification. These soils lack strong texture contrast and have massive or only weakly structured B horizons. The B2 horizon is well developed and has a maximum clay content in some part of the B2 Horizon which exceeds 15%. They are also not calcareous throughout.
Kurosols	A Soil Order of the Australian Soil Classification. These soils have a clear or abrupt textural change at the A/B boundary. The upper B2 horizon is strongly acidic i.e. less than 5.5 in water
Massive	This term applies to soil horizons greater than 6 mm in thickness, that appear to be coherent or solid and devoid of peds. When displaced, the soil separates into fragments which may be crushed into individual particles.
Mottling	The presence of more than one soil colour in a horizon. The soil may differ in colour either within peds or aggregates, or between them. Mottling occurs as blotches or streaks of subdominant colour throughout the main (i.e. matrix) colour. It does not refer to stains or coloured deposits on ped faces. Mottling is often an indication of poor profile drainage but may be caused by the weathering of parent material. Diffusely mottled implies that neighboring colours are only slightly different.
Parent material	The rock from which a soil profile develops.
Particle size analysis	(Particle size distribution) The measurement of the relative amounts of coarse sand, fine sand, silt and clay size particles in a soil sample (as determined in the laboratory).
Pedal	A general soil science term indicating that soil structure is present.
Permeability	The characteristic of a soil which governs the rate at which water moves through it. It depends on soil texture, soil structure, the presence of compacted or dense soil horizons and the size and distribution of pores in the soil.
pH	Measure of soil acidity and alkalinity on a scale of 0 (extremely acidic) to 14 (extremely alkaline). A pH of 7 is neutral.
Platy structure	Peds are layered in plate-like sheets. This type of structure is usually associated with soils which have been subjected to compaction and is not normally associated with undisturbed soil profiles.
Polyhedral structure	A soil structural unit whereby soil particles are arranged around a point and bounded by more than six relatively flat but dissimilar faces.

Porosity	The degree of pore space in a soil i.e. the percentage of the total space between solid particles.
Prismatic structure	A soil structural unit whereby soil particles are arranged around a vertical axis and bounded by relatively flat faces. The top of the prisms are also relatively flat. Prismatic structure is often associated with subsoil sodicity.
Profile	The vertical section of the soil from the soil surface down through the horizons including the parent material. It consists of two parts: the solum and the parent material.
R horizons	These horizons contain continuous rock of a moderately strong to very strong nature such as bedrock.
Rudosols	These soils have limited pedological organisation as well as minimal development of the A1 horizon. A Soil Order of the Australian Soil Classification.
Salinity	A measure of the total soluble salts in a soil. A saline soil is one with an accumulation of free salts at the soil surface and/or within the profile affecting plant growth and/or land use. It is generally attributed to changes in land use or natural changes in drainage or climate, which affects the movement of water through the landscape. Salinity levels of soil or water can be tested using electrical conductivity (EC).
Segregations	Accumulations of minerals in the soil due to the concentration of constituents. They occur as a result of chemical or biological action. They can develop *in situ* by either current or relict pedogenic processes.
Self-mulching	A structural condition of soils where there is a high degree of pedality. The peds naturally fall apart as the soil dries to form a loose surface mulch. Some Vertosols have self-mulching surface soils.
Slaking	The breakdown of soil aggregates when immersed in water into smaller sized micro-aggregates. These aggregates may subsequently disperse.
Sodicity	Is a measure of exchangeable sodium in relation to other exchangeable cations. It is expressed as the exchangeable sodium percentage (ESP). A sodic soil contains sufficient exchangeable sodium to interfere with the growth of plants, including crops. A soil with an ESP greater than 6 is generally regarded as being a sodic soil.
Sodosol	A Soil Order of the Australian Soil Classification. These soils have a clear or abrupt textural change between the A Horizons and B Horizons. The top 20 cm of the B2 horizon is sodic and is not strongly acid.
Soil	Soil is a natural body consisting of layers (soil horizons) of mineral constituents of variable thicknesses, which differ from the parent materials in their morphological, physical, chemical, and mineralogical characteristics.
Soil profile class	A soil profile class is a group of similar profiles defined by any level of generalization. The variation in some features within the soil profile class in less than the variation between classes.
Structure	Describes the way the soil particles are arranged to form soil peds. Peds are units of soil structure that are separated from each other by natural planes of weakness. They differ from clods which are formed as a result of soil disturbance such as ploughing.
Sub-angular blocky structure	Similar to angular blocky except the peds are bound by six faces intersecting with round edges (i.e. like a rounded cube).

Subsoil	The subsurface soil below the topsoil. Typically B horizons and sometimes A2 or A3 horizons.
Texture (field)	Field texture is determined by measuring the behavior of a small handful of soil grains (<2 mm in size) when moistened and kneaded (1-2 minutes) until it does not stick to the hand. It provides an estimate of the relative amounts of coarse sand, fine sand, silt and clay size particles. Soil texture influences many soil physical properties such as water holding capacity and hydraulic conductivity. Numerous soil properties affect the determination of texture such as type of clay minerals, organic matter, carbonates, etc. Texture is determined by the behavior of the moist bolus and length of the ribbon when sheared between thumb and forefinger.
Topsoil	The surface layer of soil that usually has higher fertility and organic matter and better structure than the underlying layers. Typically it is the A1 horizon and contains the majority of the seed bank.
Uniform profile	These soil profiles have limited, if any texture change throughout the profile. There is generally no textural boundaries found within the uniform profile, except for possibly a surface crust.
Vertosols	A Soil Order of the Australian Soil Classification. These are clay soils with shrink/swell properties that display strong cracks when dry and have slickensides and/or lenticular structural aggregates at depth.
Water holding capacity	The amount of soil water that can be extracted by the plant. It is defined as the difference in soil moisture content between the *drained upper limit* and the *crop lower limit*. It is expressed as millimetres of plant-available water within the root zone.
Wilting point	See *crop lower limit*

9 LIMITATIONS

This report has been prepared by Landloch Pty Ltd in response to, and subject to, the following limitations:

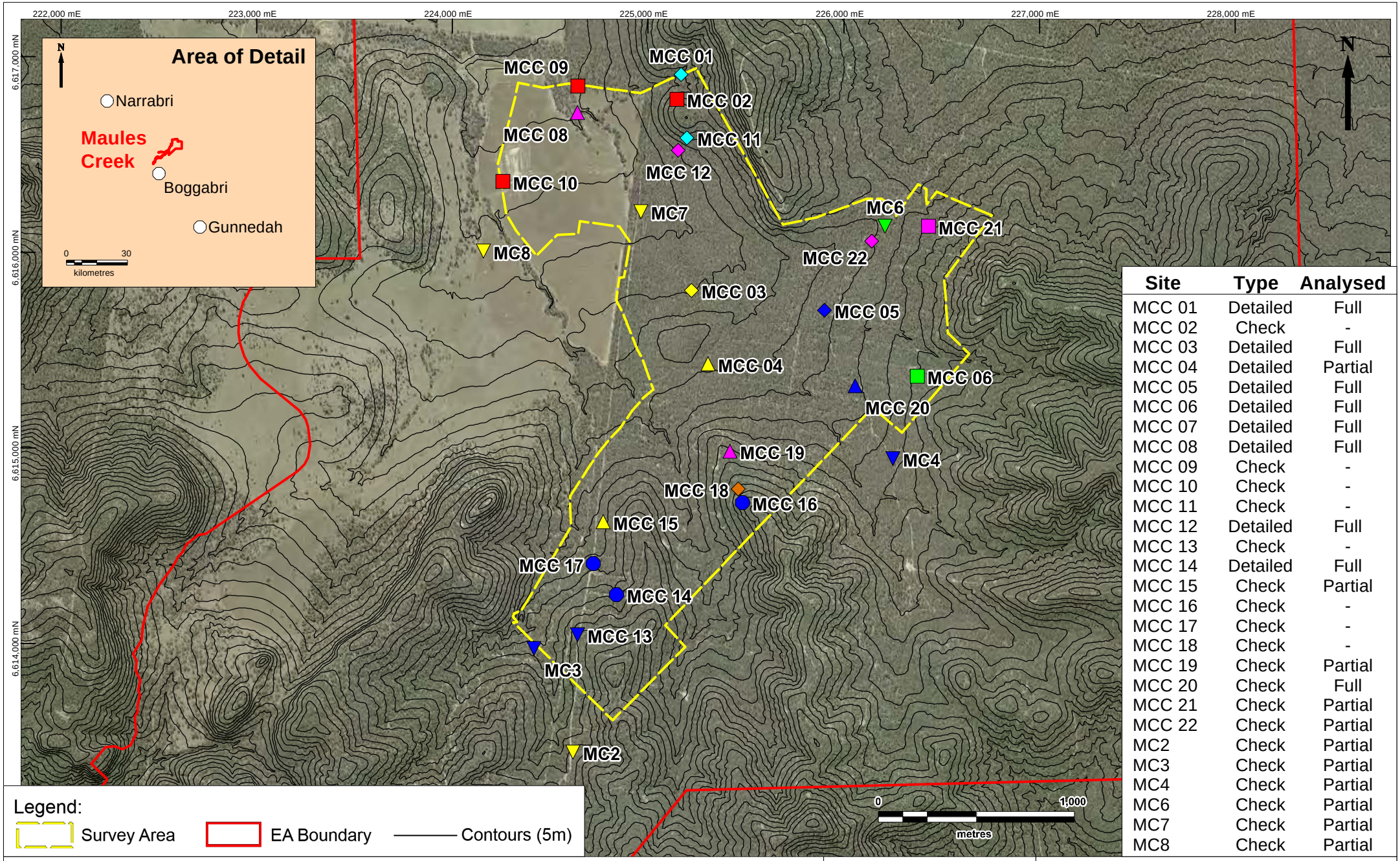
1. The specific instructions received from Parsons Brinkerhoff Pty Ltd (PB) on behalf of Idemitsu Pty Ltd;
2. The specific scope of works set out in correspondence to PB titled *Preparation of a Rehabilitation Management Plan for the Boggabri Coal Project Costing* (filename: LL _301211g_VAR_Boggabri Coal Rehabilitation PlanRev1_030214) dated 3 February 2014;
3. May not be relied upon by any third party not named in this report for any purpose except with the prior written consent of Landloch (which consent may or may not be given at the discretion of Landloch);
4. This report comprises the formal report, documentation sections, tables, figures and appendices as referred to in the index to this report and must not be released to any third party or copied in part without all the material included in this report for any reason;
5. Field notes of ground observation sites are provided. These are a reference to document variability within soil profile classes of features such as horizon thicknesses, texture, and gravel content. Comments, notes, sketches and other details included in field notes are considered draft in content, and represent the understanding of soils at that time in the field work phase. Hence notes may differ slightly in detail from that included in the report;

6. The report only relates to the study area referred to in the scope of works being located at the Maules Creek Coal Mine Project – Area 1 ("the site");
7. The report relates to the site as at the date of the report as conditions may change thereafter due to natural processes and/or site activities;
8. No warranty or guarantee is made in regard to any other use than as specified in the scope of works and only applies to the depth tested and reported in this report; and
9. Landloch's General Limitations.

APPENDIX A MAPS

Map 1: Site Locations

Map 2: Soil Landscapes



Site	Type	Analysed
MCC 01	Detailed	Full
MCC 02	Check	-
MCC 03	Detailed	Full
MCC 04	Detailed	Partial
MCC 05	Detailed	Full
MCC 06	Detailed	Full
MCC 07	Detailed	Full
MCC 08	Detailed	Full
MCC 09	Check	-
MCC 10	Check	-
MCC 11	Check	-
MCC 12	Detailed	Full
MCC 13	Check	-
MCC 14	Detailed	Full
MCC 15	Check	Partial
MCC 16	Check	-
MCC 17	Check	-
MCC 18	Check	-
MCC 19	Check	Partial
MCC 20	Check	Full
MCC 21	Check	Partial
MCC 22	Check	Partial
MC2	Check	Partial
MC3	Check	Partial
MC4	Check	Partial
MC6	Check	Partial
MC7	Check	Partial
MC8	Check	Partial

Legend:

Survey Area | EA Boundary | Contours (5m)

Australian Soil Classification (ASC):

- Boundary Check
- Brown Chromosol
- Red Chromosol
- Grey Chromosol
- Brown Chromosol/ Sodosol
- Brown Dermosol
- Kandosol
- Red Kandosol
- Brown Sodosol
- Grey Sodosol
- Sodosol
- Brown Orthic Tenosol
- Grey Orthic Tenosol
- Leptic Tenosol
- Tenosol

Map 1: Site Locations Soil Survey 2014

Project No. 1035.14a

Data Source: Whitehaven, Landloch

Whitehaven Coal - Maules Creek Mine

Date: 16/07/2014

GDA94 (MGA56) 1:25 000 (A4)

By: HS | QA: SB | Rev: 01

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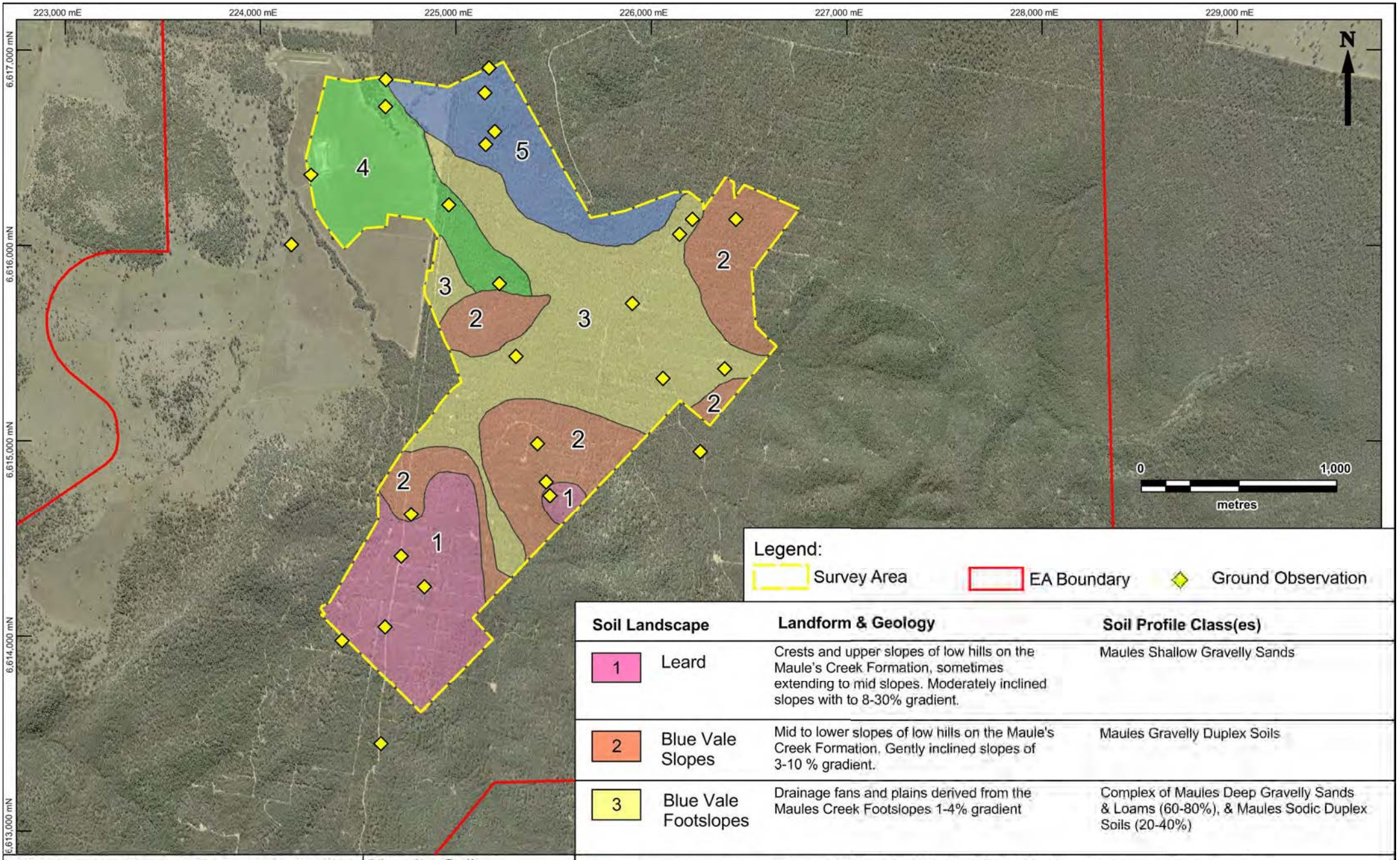

Legend:

Survey Area | EA Boundary | Ground Observation

Soil Landscape		Landform & Geology	Soil Profile Class(es)
1	Leard	Crests and upper slopes of low hills on the Maule's Creek Formation, sometimes extending to mid slopes. Moderately inclined slopes with to 8-30% gradient.	Maules Shallow Gravelly Sands
2	Blue Vale Slopes	Mid to lower slopes of low hills on the Maule's Creek Formation. Gently inclined slopes of 3-10 % gradient.	Maules Gravelly Duplex Soils
3	Blue Vale Footslopes	Drainage fans and plains derived from the Maules Creek Footslopes 1-4% gradient	Complex of Maules Deep Gravelly Sands & Loams (60-80%), & Maules Sodic Duplex Soils (20-40%)
4	Blue Vale Flats	Plains and flats derived from the Maules Creek Formation. Terminal footslopes & flats with gradients <3%	Maules Sodic Duplex Soils
5	Hartfell	Crests and slopes of low hills on the Boggabri Volcanics. Gently and moderately inclined slopes with 4-20 % gradient.	Volcanic Cobbly Clays & Duplex Soils

Whitehaven Coal - Maules Creek Mine

Map 2: Soil Landscapes

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Date: 16/07/2014

GDA94 (MGA56) 1:25 000 (A4)

Project No. 1035.14a

By: HS | QA: SB | Rev: 01

Data Source: Whitehaven, Landloch

APPENDIX B TABLES

Soil Physio-chemical Analytical Results

Soil Water Analytical Results

Table 16 Laboratory methods

Soil Analyses	Abbreviation	Units	Methodology	Reference
pH	pH	na	1:5 soil:water	Rayment & Lyons (2011)
Electrical Conductivity	E.C	dS/m	1:5 soil:water	Rayment & Lyons (2011)
Exchangeable Cations	Ex ($Ca^{2+,}$ Mg^{2+}, Na^{+}, K^{+}, Al^{3+})	meq/100g	15A1, 15A2, or 15C1)	Rayment & Lyons (2011)
Dispersion Potential	NA	Value 1-8	Emerson Index	Australian Standard (1980)
Total Nitrogen	Total N	mg/kg	Kjeldahl	Rayment & Lyons (2011)
Total Phosphorous	Total P	mg/kg	Nitric/Perchloric	Rayment & Lyons (2011)
Available Phosphorous	Av P	mg/kg	Colwell	Rayment & Lyons (2011)
Available Potassium	Av S	mg/kg	Colwell	Rayment & Lyons (2011)
Available Sulfur	Av S	mg/kg	KCl-40	Rayment & Lyons (2011)
Organic Carbon	OC	%	Walkley-Black	Rayment & Lyons (2011)
Micro Nutrients	Cu^{2+}, Mn^{2+}, Zn^{2+}	mg/kg	DTPA	Rayment & Lyons (2011)
Particle size distribution (% of clay, silt and sand)	PSA	%	Hydrometer	Rayment & Lyons (2011)
Phosphorous Buffer Index	PBI	na	PBI_{+ColP}	Rayment & Lyons (2011)
Effective Cation Exchange Capacity	*ECEC*	meq/100g	NH_4Cl	Rayment & Lyons (2011)
Exchangeable Sodium Percentage	*ESP*	%	NH_4Cl	Rayment & Lyons (2011)

ANALYSIS REPORT

East West Enviroag 82 Plain St Tamworth NSW 2340 ph:02 67621733	Lab No	140461-1		140461-2		140461-3		140461-4		140461-5		140461-6		140461-7		140461-8
	Sample ID	MCC 01		MCC 01		MCC 01		MCC 01		MCC 01		MCC 03		MCC 03		MCC 03
	Sample Depth	0.0-0.05		0.1-0.3		0.4-0.6		0.7-0.9		1.1-1.4		0.0-0.05		0.2-0.4		0.5-0.8
	ASC	DE		DE		DE		DE		DE		SO		SO		SO
	SCP	CGD		CGD		CGD		CGD		CGD		MSD		MSD		MSD
	Field Texture	LC		MC		MC		MC		MC+X		CLS		MC		MHC
Analyses	**Unit**	-		-		-		-		-		-		-		-
pH - Water	pH units	6.17	*L.Acid*	7.67	*L.Alk*	8.56	*H.Alk*	8.88	*H.Alk*	9.10	*E.Alk*	7.77	*L.Alk*	7.74	*L.Alk*	8.69
Electrical Conductivity	dS/m	0.05	*VL.Sal*	0.33	*M.Sal*	0.57	*H.Sal*	0.54	*M.Sal*	0.50	*M.Sal*	0.05	*VL.Sal*	0.13	*L.Sal*	0.29
Chloride	mg/kg	15.8	*VL.Sal*	184	*L.Sal*	533	*M.Sal*	537	*M.Sal*	437	*M.Sal*	6.0	*VL.Sal*	111	*L.Sal*	195
Total Nitrogen - Kjeldahl	mg/kg	2220	*M*	-		-		-		-		3142	*H*	-		-
Total Phosphorus - Nitric/Perchloric	mg/kg	683		-		-		-		-		767		-		-
Phosphorus - Colwell extr	mg/kg	12.0	*L*	-		-		-		-		22.5	*M*	-		-
Potassium - Colwell ext	mg/kg	759	*H*	-		-		-		-		620	*H*	-		-
Sulphur - KCl	mg/kg	3.6	*VL*	-		-		-		-		3.4	*VL*	-		-
Organic Carbon	%	3.91	*VH*	-		-		-		-		4.70	*VH*	-		-
Copper	mg/kg	1.46	*M*	-		-		-		-		1.28	*M*	-		-
Iron	mg/kg	96.7		-		-		-		-		59.2		-		-
Manganese	mg/kg	67.3	*H*	-		-		-		-		37.6	*M*	-		-
Zinc	mg/kg	0.97	*M*	-		-		-		-		2.10	*M*	-		-
Boron	mg/kg	0.89	*L*	-		-		-		-		1.19	*M*	-		-
Cation Extraction Method	Rayment& Lyons	15A1		15C1		15C1		15C1		15C1		15A1		15A1		15A1
Cation Exchange Capacity	meq/100g	30.9	*H*	20.8	*M*	21.0	*M*	18.2	*M*	17.1	*M*	23.1	*M*	23.1	*M*	29.9
Ex Calcium Percent	%	63.6		56.6		49.8		44.8		39.3		74.4		56.7		60.9
Ex Magnesium Percent	%	30.1		33.7		36.2		39.0		39.7		19.6		33.3		29.3
Ex Potassium Percent	%	4.66		2.17		2.49		2.74		2.73		4.90		1.99		1.42
Ex Sodium Percent	%	1.6	*N.Sodic*	7.5	*Sodic*	11.5	*Sodic*	13.5	*Sodic*	18.2	*H.Sodic*	1.1	*N.Sodic*	8.0	*Sodic*	8.3
Ex Aluminium Percent	%	0.02	*VL*	0.04	*VL*	0.03	*VL*	0.02	*VL*	0.03	*VL*	0.03	*VL*	0.04	*VL*	0.02
Exchangeable Calcium	mg/kg	3930		2353		2095		1635		1342		3437		2619		3641
Exchangeable Magnesium	mg/kg	1116		840		913		853		813		543		922		1052
Exchangeable Potassium	mg/kg	562		176		204		195		182		441		179		165
Exchangeable Sodium	mg/kg	116		361		555		565		715		57.0		424		568
Exchangeable Aluminium	mg/kg	0.5		0.7		0.6		0.3		0.4		0.6		0.8		0.6
Exchangeable Calcium	meq/100g	19.7	*H*	11.8	*H*	10.5	*H*	8.18	*M*	6.7	*M*	17.2	*H*	13.1	*H*	18.2
Exchangeable Magnesium	meq/100g	9.30	*VH*	7.00	*H*	7.61	*H*	7.11	*H*	6.78	*H*	4.53	*H*	7.68	*H*	8.77
Exchangeable Potassium	meq/100g	1.44	*H*	0.45	*M*	0.52	*M*	0.50	*M*	0.47	*M*	1.13	*H*	0.46	*M*	0.42
Exchangeable Sodium	meq/100g	0.50	*M*	1.57	*H*	2.41	*VH*	2.46	*VH*	3.11	*VH*	0.25	*L*	1.84	*H*	2.47
Exchangeable Aluminium	meq/100g	0.01		0.01		0.01		0.00		0.00		0.01		0.01		0.01
Calcium/Magnesium Ratio	-	2.1	*L*	1.7	*L*	1.4	*L*	1.2	*L*	1.0	*VL*	3.8	*L*	1.7	*L*	2.1
Gravel >2.0mm	%	11.8		5.5		-		25.9		-		7.9		5.5		5.9
Coarse Sand 0.2-2.0mm	%	15.9		13.2		-		16.2		-		25.0		12.6		20.4
Fine Sand 0.02-0.2mm	%	25.9		18.4		-		24.2		-		31.6		18.3		26.2
Silt 0.002-0.02mm	%	8.6		6.1		-		4.3		-		10.8		7.8		9.2
Clay <0.002mm	%	37.8		56.8		-		29.3		-		24.7		55.9		38.2
ADMC	%	15.5		21.4		-		10.0		-		11.2		17.0		12.8
Emerson Class	Class	2		5		4		4		-		8		1		3b

ANALYSIS REPORT

East West Enviroag 82 Plain St Tamworth NSW 2340 ph:02 67621733	Lab No		140461-9		140461-10		140461-11		140461-12		140461-13		140461-14		140461-15	
	Sample ID		MCC 03		MCC 04		MCC 05		MCC 05		MCC 05		MCC 06		MCC 06	
	Sample Depth		1.1-1.4		0.1-0.3		0.0-0.05		0.2-0.3		0.3-0.5		0.0-0.05		0.1-0.25	
	ASC		SO		SO		TE		TE		TE		KA		KA	
	SCP		MSD		MSD		MDGSL		MDGSL		MDGSL		MDGSL		MDGSL	
	Field Texture		MHC+X		MC								SCL		SCL	
Analyses	**Unit**		-		-		-		-		-		-		-	
pH - Water	pH units	*H.Alk*	8.97	*H.Alk*	7.81	*L.Alk*	7.02	*Neutral*	6.75	*Neutral*	6.77	*Neutral*	6.89	*Neutral*	7.04	*Neutral*
Electrical Conductivity	dS/m	*M.Sal*	0.24	*M.Sal*	0.07	*VL.Sal*	0.04		0.01		0.01		0.04	*VL.Sal*	0.02	*VL.Sal*
Chloride	mg/kg	*L.Sal*	177	*L.Sal*	35.3	*VL.Sal*	5.8	*VL.Sal*	2.7	*VL.Sal*	2.9	*VL.Sal*	5.5	*VL.Sal*	11.0	*VL.Sal*
Total Nitrogen - Kjeldahl	mg/kg		-		-		2187	*M*	-		-		1992	*M*	-	
Total Phosphorus - Nitric/Perchloric	mg/kg		-		-		699		-		-		813		-	
Phosphorus - Colwell extr	mg/kg		-		-		27.1		-		-		46.8	*H*	-	
Potassium - Colwell ext	mg/kg		-		-		383		-		-		541	*H*	-	
Sulphur - KCl	mg/kg		-		-		3.5	*VL*	-		-		2.9	*VL*	-	
Organic Carbon	%		-		-		3.49	*VH*	-		-		3.16	*VH*	-	
Copper	mg/kg		-		-		1.42	*M*	-		-		1.28	*M*	-	
Iron	mg/kg		-		-		290		-		-		83.1		-	
Manganese	mg/kg		-		-		232	*H*	-		-		54.4	*H*	-	
Zinc	mg/kg		-		-		2.33	*M*	-		-		1.64	*M*	-	
Boron	mg/kg		-		-		0.48	*VL*	-		-		0.66	*L*	-	
Cation Extraction Method	Rayment& Lyons		15A1		15A1		15A1		15A1		15A1		15A1		15A1	
Cation Exchange Capacity	meq/100g	*H*	25.2	*H*	14.1	*M*	12.4	*M*	4.9	*VL*	4.7	*VL*	16.3	*M*	11.0	*L*
Ex Calcium Percent	%		56.9		57.3		76.2		71.4		62.1		74.2		75.8	
Ex Magnesium Percent	%		30.6		31.6		16.7		19.5		26.6		18.9		17.1	
Ex Potassium Percent	%		1.87		3.14		4.88		4.22		5.65		5.39		4.30	
Ex Sodium Percent	%	*Sodic*	10.4	*Sodic*	7.9	*Sodic*	2.1	*N.Sodic*	4.7	*N.Sodic*	5.5	*N.Sodic*	1.4	*N.Sodic*	2.8	*N.Sodic*
Ex Aluminium Percent	%	*VL*	0.17	*VL*	0.05	*VL*	0.03	*VL*	0.24	*VL*	0.07	*VL*	0.09	*VL*	0.03	*VL*
Exchangeable Calcium	mg/kg		2874		1622		1883		696		587		2416		1661	
Exchangeable Magnesium	mg/kg		928		537		248		114		151		369		225	
Exchangeable Potassium	mg/kg		184		173		235		80.3		104		342		184	
Exchangeable Sodium	mg/kg		602		256		60.6		52.6		59.7		53.3		70.7	
Exchangeable Aluminium	mg/kg		3.8		0.6		0.3		1.1		0.3		1.4		0.3	
Exchangeable Calcium	meq/100g	*H*	14.4	*H*	8.11	*M*	9.42	*M*	3.48	*L*	2.94	*L*	12.1	*H*	8.31	*M*
Exchangeable Magnesium	meq/100g	*VH*	7.73	*H*	4.48	*H*	2.07	*M*	0.95	*L*	1.26	*M*	3.08	*H*	1.88	*M*
Exchangeable Potassium	meq/100g	*M*	0.47	*M*	0.44	*M*	0.60	*M*	0.21	*L*	0.27	*L*	0.88	*H*	0.47	*M*
Exchangeable Sodium	meq/100g	*VH*	2.62	*VH*	1.11	*H*	0.26	*L*	0.23	*L*	0.26	*L*	0.23	*L*	0.31	*M*
Exchangeable Aluminium	meq/100g		0.04		0.01		0.00		0.01		0.00		0.02		0.00	
Calcium/Magnesium Ratio	-	*L*	1.9	*L*	1.8	*L*	4.6	*M*	3.7	*L*	2.3	*L*	3.9	*L*	4.4	*M*
Gravel >2.0mm	%		-		-		-		-		-		21.8		10.1	
Coarse Sand 0.2-2.0mm	%		-		-		-		-		-		34.4		34.8	
Fine Sand 0.02-0.2mm	%		-		-		-		-		-		24.4		30.3	
Silt 0.002-0.02mm	%		-		-		-		-		-		8.3		10.1	
Clay <0.002mm	%		-		-		-		-		-		11.2		14.7	
ADMC	%		-		-		-		-		-		17.1		6.9	
Emerson Class	Class		-		-		-		-		-		8		3b	

ANALYSIS REPORT

East West Enviroag 82 Plain St Tamworth NSW 2340 ph:02 67621733	Lab No	140461-16		140461-17		140461-18		140461-19		140461-20		140461-21		140461-22		140461-23
	Sample ID	MCC 06		MCC 06		MCC 07		MCC 07		MCC 07		MCC 07		MCC 08		MCC 08
	Sample Depth	0.4-0.6		0.7-1.0		0.0-0.05		0.2-0.4		0.45-0.65		0.7-0.9		0.0-0.05		0.2-0.3
	ASC	KA		KA		CH		CH		CH		CH		CH		CH
	SCP	MDGSL		MDGSL		MGD		MGD		MGD		MGD		MSD		MSD
	Field Texture	SCL		SCL		SL		MC		MC		MC		CLS		CLS
Analyses	**Unit**	-		-		-		-		-		-		-		-
pH - Water	pH units	7.19	*Neutral*	7.08	*Neutral*	6.79	*Neutral*	6.75	*Neutral*	6.58	*L.Acid*	7.62	*L.Alk*	6.40	*L.Acid*	6.80
Electrical Conductivity	dS/m	0.02	*VL.Sal*	0.02	*VL.Sal*	0.05	*VL.Sal*	0.04	*VL.Sal*	0.06	*VL.Sal*	0.05	*VL.Sal*	0.12	*L.Sal*	0.03
Chloride	mg/kg	7.3	*VL.Sal*	7.3	*VL.Sal*	6.6	*VL.Sal*	14.0	*VL.Sal*	38.5	*VL.Sal*	39.7	*VL.Sal*	13.7	*VL.Sal*	16.7
Total Nitrogen - Kjeldahl	mg/kg	-		-		3005	*H*	-		-		-		3811	*H*	-
Total Phosphorus - Nitric/Perchloric	mg/kg	-		-		727		-		-		-		868		-
Phosphorus - Colwell extr	mg/kg	-		-		28.8	*H*	-		-		-		77.6	*H*	-
Potassium - Colwell ext	mg/kg	-		-		633	*H*	-		-		-		1107	*H*	-
Sulphur - KCl	mg/kg	-		-		3.6	*VL*	-		-		-		6.2	*L*	-
Organic Carbon	%	-		-		5.09	*VH*	-		-		-		5.92	*VH*	-
Copper	mg/kg	-		-		1.32	*M*	-		-		-		1.67	*M*	-
Iron	mg/kg	-		-		71.5		-		-		-		120		-
Manganese	mg/kg	-		-		32.8	*M*	-		-		-		89.2	*H*	-
Zinc	mg/kg	-		-		3.03	*M*	-		-		-		5.34	*H*	-
Boron	mg/kg	-		-		1.04	*M*	-		-		-		1.26	*M*	-
Cation Extraction Method	Rayment& Lyons	15A1		15A1		15A1		15A1		15A1		15A1		15A1		15A1
Cation Exchange Capacity	meq/100g	6.9	*L*	7.2	*L*	22.0	*M*	17.3	*M*	15.5	*M*	14.1	*M*	22.7	*M*	11.2
Ex Calcium Percent	%	72.7		70.7		70.6		48.3		47.6		49.1		73.9		74.1
Ex Magnesium Percent	%	17.5		18.2		22.6		40.8		41.3		40.5		17.6		17.8
Ex Potassium Percent	%	5.87		6.13		5.35		6.65		5.78		5.12		7.48		5.48
Ex Sodium Percent	%	3.9	*N.Sodic*	4.1	*N.Sodic*	1.4	*N.Sodic*	4.1	*N.Sodic*	4.8	*N.Sodic*	5.0	*N.Sodic*	1.0	*N.Sodic*	2.6
Ex Aluminium Percent	%	0.04	*VL*	0.83	*VL*	0.03	*VL*	0.05	*VL*	0.53	*VL*	0.25	*VL*	0.04	*VL*	0.03
Exchangeable Calcium	mg/kg	1003		1023		3110		1673		1478		1382		3358		1655
Exchangeable Magnesium	mg/kg	145		158		598		848		770		684		479		239
Exchangeable Potassium	mg/kg	158		173		460		449		350		281		663		239
Exchangeable Sodium	mg/kg	61.8		68.2		73.2		164		171		161		53.7		66.8
Exchangeable Aluminium	mg/kg	0.3		5.4		0.6		0.7		7.4		3.1		0.8		0.3
Exchangeable Calcium	meq/100g	5.02	*M*	5.12	*M*	15.6	*H*	8.37	*M*	7.39	*M*	6.91	*M*	16.8	*H*	8.28
Exchangeable Magnesium	meq/100g	1.21	*M*	1.32	*M*	4.98	*H*	7.07	*H*	6.42	*H*	5.70	*H*	3.99	*H*	1.99
Exchangeable Potassium	meq/100g	0.41	*M*	0.44	*M*	1.18	*H*	1.15	*H*	0.90	*H*	0.72	*H*	1.70	*H*	0.61
Exchangeable Sodium	meq/100g	0.27	*L*	0.30	*L*	0.32	*M*	0.71	*H*	0.74	*H*	0.70	*H*	0.23	*L*	0.29
Exchangeable Aluminium	meq/100g	0.00		0.06		0.01		0.01		0.08		0.03		0.01		0.00
Calcium/Magnesium Ratio	-	4.2	*M*	3.9	*L*	3.1	*L*	1.2	*L*	1.2	*L*	1.2	*L*	4.2	*M*	4.2
Gravel >2.0mm	%	-		-		5.3		14.5		16.9		-		-		-
Coarse Sand 0.2-2.0mm	%	-		-		47.7		33.3		39.2		-		-		-
Fine Sand 0.02-0.2mm	%	-		-		23.9		18.5		20.0		-		-		-
Silt 0.002-0.02mm	%	-		-		5.4		6.5		4.9		-		-		-
Clay <0.002mm	%	-		-		17.6		27.2		19.1		-		-		-
ADMC	%	-		-		8.0		8.5		8.4		-		-		-
Emerson Class	Class	3a		3a		8		3a		3a		3a		8		3b

ANALYSIS REPORT

East West Enviroag 82 Plain St Tamworth NSW 2340 ph:02 67621733	Lab No		140461-24		140461-25		140461-26		140461-27		140461-28		140461-42		140461-43	
	Sample ID		MCC 08		MCC 08		MCC 12		MCC 12		MCC 12		MCC 14		MCC 14	
	Sample Depth		0.3-0.5		0.6-0.9		0.0-0.05		0.15-0.3		0.4-0.8		0.0-0.05		0.15-0.3	
	ASC		CH		CH		CH		CH		CH		TE		TE	
	SCP		MSD		MSD		CGD		CGD		CGD		MSGS		MSGS	
	Field Texture		MC		MC		SCL		SCL		MC		CS		CS	
Analyses	**Unit**		-													
pH - Water	pH units	*Neutral*	6.93	*Neutral*	7.51	*L.Alk*	6.91	*Neutral*	7.46	*L.Alk*	7.40	*L.Alk*	6.87	*Neutral*	6.72	*Neutral*
Electrical Conductivity	dS/m	*VL.Sal*	0.03	*VL.Sal*	0.12	*L.Sal*	0.06	*VL.Sal*	0.05	*VL.Sal*	0.13	*L.Sal*	0.08	*L.Sal*	0.03	*VL.Sal*
Chloride	mg/kg	*VL.Sal*	10.9	*VL.Sal*	123	*L.Sal*	9.9	*VL.Sal*	6.2	*VL.Sal*	17.2	*VL.Sal*	16.1	*VL.Sal*	5.7	*VL.Sal*
Total Nitrogen - Kjeldahl	mg/kg		-		-		3356	*H*	-		-		2475	*M*	-	
Total Phosphorus - Nitric/Perchloric	mg/kg		-		-		805		-		-		263		-	
Phosphorus - Colwell extr	mg/kg		-		-		42.9	*H*	-		-		14.1	*M*	-	
Potassium - Colwell ext	mg/kg		-		-		794		-		-		513	*H*	-	
Sulphur - KCl	mg/kg		-		-		4.5	*L*	-		-		8.4	*M*	-	
Organic Carbon	%		-		-		5.56	*VH*	-		-		6.06	*VH*	-	
Copper	mg/kg		-		-		0.79	*M*	-		-		1.04	*M*	-	
Iron	mg/kg		-		-		81.8		-		-		115		-	
Manganese	mg/kg		-		-		46.4	*M*	-		-		101	*H*	-	
Zinc	mg/kg		-		-		2.82	*M*	-		-		1.81	*M*	-	
Boron	mg/kg		-		-		1.39	*M*	-		-		0.77	*L*	-	
Cation Extraction Method	Rayment& Lyons		15A1		15A1		15A1		15A1		15A1		15A1		15A1	
Cation Exchange Capacity	meq/100g	*L*	12.1	*M*	16.7	*M*	22.8	*M*	9.8	*L*	24.3	*M*	18.8	*M*	5.2	*VL*
Ex Calcium Percent	%		62.9		55.0		78.9		64.2		63.7		72.6		58.2	
Ex Magnesium Percent	%		28.8		32.5		15.0		24.1		24.9		21.6		30.2	
Ex Potassium Percent	%		3.31		3.04		4.87		8.99		9.29		4.53		7.90	
Ex Sodium Percent	%	*N.Sodic*	4.9	*N.Sodic*	9.4	*Sodic*	1.2	*N.Sodic*	2.7	*N.Sodic*	2.1	*N.Sodic*	1.22	*N.Sodic*	3.65	*N.Sodic*
Ex Aluminium Percent	%	*VL*	0.03	*VL*	0.08	*VL*	0.04	*VL*	0.03	*VL*	0.03	*VL*	0.05	*VL*	0.13	*VL*
Exchangeable Calcium	mg/kg		1521		1835		3591		1254		3093		2731		604	
Exchangeable Magnesium	mg/kg		418		651		409		282		727		487		188	
Exchangeable Potassium	mg/kg		156		198		432		342		880		332		160	
Exchangeable Sodium	mg/kg		137		359		62.4		59.7		116		52.8		43.6	
Exchangeable Aluminium	mg/kg		0.4		1.17		0.87		0.25		0.63		0.79		0.62	
Exchangeable Calcium	meq/100g	*M*	7.61	*M*	9.18	*M*	17.96	*H*	6.27	*M*	15.47	*H*	13.7	*H*	3.02	*L*
Exchangeable Magnesium	meq/100g	*M*	3.48	*H*	5.43	*H*	3.41	*H*	2.35	*M*	6.06	*H*	4.06	*H*	1.57	*M*
Exchangeable Potassium	meq/100g	*M*	0.40	*M*	0.51	*M*	1.11	*H*	0.88	*H*	2.26	*VH*	0.85	*H*	0.41	*M*
Exchangeable Sodium	meq/100g	*L*	0.60	*M*	1.56	*H*	0.27	*L*	0.26	*L*	0.50	*M*	0.23	*L*	0.19	*L*
Exchangeable Aluminium	meq/100g		0.00		0.01		0.01		0.00		0.01		0.01		0.01	
Calcium/Magnesium Ratio	-	*M*	2.2	*L*	1.7	*L*	5.3	*M*	2.7	*L*	2.6	*L*	3.4	*L*	1.9	*L*
Gravel >2.0mm	%		-		-		11.5		-		28.8		48.8		33.2	
Coarse Sand 0.2-2.0mm	%		-		-		25.2		-		14.2		31.5		29.5	
Fine Sand 0.02-0.2mm	%		-		-		39.5		-		28.8		15.3		30.2	
Silt 0.002-0.02mm	%		-		-		8.0		-		6.9		3.0		5.5	
Clay <0.002mm	%		-		-		15.7		-		21.3		1.4		1.5	
ADMC	%		-		-		7.9		-		10.4		24.0		5.9	
Emerson Class	Class		3a		3a		8		-		4		-		-	

ANALYSIS REPORT

East West Enviroag 82 Plain St Tamworth NSW 2340 ph:02 67621733	Lab No	140461-44		140461-32		140461-33		140461-34		140461-35		140461-36		140461-37		140461-38
	Sample ID	MCC 14		MCC 15		MCC 19		MCC 19		MCC 19		MCC 19		MCC 20		MCC 20
	Sample Depth	0.3-0.5		0.35-0.55		0.0-0.05		0.1-0.2		0.2-0.35		0.4-0.7		0.0-0.05		0.2-0.4
	ASC	TE		CH		CH		CH		CH		CH		TE		TE
	SCP	MSGS		MGD		MGD		MGD		MGD		MGD		MDGSL		MDGSL
	Field Texture	CS		MC		CS		CS		CLS		MHC		SL		CS
Analyses	**Unit**															
pH - Water	pH units	6.55	*L.Acid*	7.19	*Neutral*	6.66	*Neutral*	6.29	*L.Acid*	5.93	*M.acid*	5.42	*H.Acid*	5.78	*M.acid*	5.82
Electrical Conductivity	dS/m	0.02	*VL.Sal*	0.1	*VL.Sal*	0.06	*VL.Sal*	0.02	*VL.Sal*	0.03	*VL.Sal*	0.05	*VL.Sal*	0.05	*VL.Sal*	0.03
Chloride	mg/kg	6.4	*VL.Sal*	52	*VL.Sal*	9.0	*VL.Sal*	7.6	*VL.Sal*	9.2	*VL.Sal*	72.2	*VL.Sal*	4.6	*VL.Sal*	6.1
Total Nitrogen - Kjeldahl	mg/kg	-		-		2417	*M*	-		-		-		2328	*M*	-
Total Phosphorus - Nitric/Perchloric	mg/kg	-		-		603		-		-		-		706		-
Phosphorus - Colwell extr	mg/kg	-		-		16.3	*M*	-		-		-		47.9	*H*	-
Potassium - Colwell ext	mg/kg	-		-		597	*H*	-		-		-		574	*H*	-
Sulphur - KCl	mg/kg	-		-		2.9	*VL*	-		-		-		2.9	*VL*	-
Organic Carbon	%	-		-		3.79	*VH*	-		-		-		3.98	*VH*	-
Copper	mg/kg	-		-		0.56	*M*	-		-		-		0.94	*M*	-
Iron	mg/kg	-		-		53.5		-		-		-		55.5		-
Manganese	mg/kg	-		-		30.9	*M*	-		-		-		31.9	*M*	-
Zinc	mg/kg	-		-		2.24	*M*	-		-		-		2.13	*M*	-
Boron	mg/kg	-		-		0.84	*L*	-		-		-		0.61	*L*	-
Cation Extraction Method	Rayment& Lyons	15A1		15A1		15A1		15A1		15A1		15A1		15A1		15A1
Cation Exchange Capacity	meq/100g	4.4	*VL*	16.9	*M*	14.0	*M*	5.8	*VL*	6.7	*L*	12.0	*M*	13.3	*M*	3.6
Ex Calcium Percent	%	46.0		38.3		76.4		66.1		53.4		43.5		74.9		45.9
Ex Magnesium Percent	%	37.2		48.1		16.6		24.6		37.8		46.6		18.0		39.1
Ex Potassium Percent	%	11.8		8.25		5.02		4.60		4.00		3.61		5.15		7.87
Ex Sodium Percent	%	4.77	*N.Sodic*	5.2	*N.Sodic*	1.9	*N.Sodic*	4.2	*N.Sodic*	4.4	*N.Sodic*	4.2	*N.Sodic*	1.8	*N.Sodic*	6.8
Ex Aluminium Percent	%	0.32	*VL*	0.14	*VL*	0.05	*VL*	0.52	*VL*	0.43	*VL*	2.12	*VL*	0.11	*VL*	0.29
Exchangeable Calcium	mg/kg	404		1294		2133		766		719		1044		1992		329
Exchangeable Magnesium	mg/kg	196		974		278		171		305		671		287		168
Exchangeable Potassium	mg/kg	202		543		273		104		105		169		267		110
Exchangeable Sodium	mg/kg	48.2		201		61.1		55.7		67.7		117		55.3		56.2
Exchangeable Aluminium	mg/kg	1.25		2.1		0.58		2.69		2.62		22.9		1.27		0.95
Exchangeable Calcium	meq/100g	2.02	*L*	6.47	*M*	10.7	*H*	3.83	*L*	3.60	*L*	5.22	*M*	9.96	*M*	1.65
Exchangeable Magnesium	meq/100g	1.63	*M*	8.12	*VH*	2.32	*M*	1.43	*M*	2.54	*M*	5.59	*H*	2.39	*M*	1.40
Exchangeable Potassium	meq/100g	0.52	*M*	1.39	*H*	0.70	*H*	0.27	*L*	0.27	*L*	0.43	*M*	0.68	*M*	0.28
Exchangeable Sodium	meq/100g	0.21	*L*	0.87	*H*	0.27	*L*	0.24	*L*	0.29	*L*	0.51	*M*	0.24	*L*	0.24
Exchangeable Aluminium	meq/100g	0.01		0.02		0.01		0.03		0.03		0.25		0.01		0.01
Calcium/Magnesium Ratio	-	1.2	*L*	0.8	*VL*	4.6	*M*	2.7	*L*	1.4	*L*	0.9	*VL*	4.2	*M*	1.2
Gravel >2.0mm	%	29.9		-		-		-		-		-		-		-
Coarse Sand 0.2-2.0mm	%	32.8		-		-		-		-		-		-		-
Fine Sand 0.02-0.2mm	%	31.6		-		-		-		-		-		-		-
Silt 0.002-0.02mm	%	5.3		-		-		-		-		-		-		-
Clay <0.002mm	%	0.5		-		-		-		-		-		-		-
ADMC	%	5.5		-		-		-		-		-		-		-
Emerson Class	Class	-		-		5		3b		3a		3a		-		-

ANALYSIS REPORT

East West Enviroag 82 Plain St Tamworth NSW 2340 ph:02 67621733	Lab No		140461-39		140461-40		140461-41		130286-2		130286-3		130286-4		130286-5	
	Sample ID		MCC 20		MCC 21		MCC 22		MC2		MC2		MC3		MC3	
	Sample Depth		0.4-0.6		0.1-0.3		0.2-0.4		0-10 cm		30-60 cm		0-10 cm		30-60 cm	
	ASC		TE		CH		CH		SO		SO		TE		TE	
	SCP		MGD		MGD		MGD		MGD		MGD					
	Field Texture		CS		MHC		MC									
Analyses	**Unit**								-		-		-		-	
pH - Water	pH units	*M.acid*	5.68	*M.acid*	6.03	*M.acid*	6.59	*L.Acid*	6.12	*L.Acid*	4.94	*VH.Acid*	5.85	*M.acid*	5.92	*M.acid*
Electrical Conductivity	dS/m	*VL.Sal*	0.02	*VL.Sal*	0.13	*L.Sal*	0.08	*VL.Sal*	0.05	*VL.Sal*	0.29	*M.Sal*	0.04	*VL.Sal*	0.03	*VL.Sal*
Chloride	mg/kg	*VL.Sal*	5.6	*VL.Sal*	68.5	*VL.Sal*	16.7	*VL.Sal*		*VL.Sal*		*VL.Sal*		*VL.Sal*		*VL.Sal*
Total Nitrogen - Kjeldahl	mg/kg		-		-		602	*L*	1846	*M*	*		2236	*M*	*	
Total Phosphorus - Nitric/Perchloric	mg/kg		-		-		542		282		*		347		*	
Phosphorus - Colwell extr	mg/kg		-		-		12.0	*L*	5.8	*L*	*		12.9	*L*	*	
Potassium - Colwell ext	mg/kg		-		-		520	*H*	392	*H*	*		300	*H*	*	
Sulphur - KCl	mg/kg		-		-		1.4	*VL*	3.5	*VL*	*		2.9	*VL*	*	
Organic Carbon	%		-		-		0.68	*L*	2.96	*H*	*		2.70	*H*	*	
Copper	mg/kg		-		-		1.32	*M*	<1.0	*L*	*		<1.0	*L*	*	
Iron	mg/kg		-		-		113		181		*		255		*	
Manganese	mg/kg		-		-		42.9	*M*	34.4	*M*	*		64.0	*H*	*	
Zinc	mg/kg		-		-		0.60	*M*	<1.0	*L*	*		<1.0	*L*	*	
Boron	mg/kg		-		-		0.97	*L*		*VL*		*VL*		*VL*		*VL*
Cation Extraction Method	Rayment& Lyons		15A1		15A1		15A1									
Cation Exchange Capacity	meq/100g	*VL*	3.9	*VL*	25.1	*H*	26.4	*H*	13.5	*M*	20.1	*M*	10.3	*L*	5.4	*VL*
Ex Calcium Percent	%		34.7		44.6		44.5		53.1		9.1		68.2		47.0	
Ex Magnesium Percent	%		46.5		47.7		47.6		39.0		72.3		23.5		44.6	
Ex Potassium Percent	%		7.12		4.41		4.54		6.21		1.70		6.96		6.98	
Ex Sodium Percent	%	*Sodic*	7.3	*Sodic*	3.3	*N.Sodic*	3.3	*N.Sodic*	1.61	*N.Sodic*	13.80	*Sodic*	1.18	*N.Sodic*	1.22	*N.Sodic*
Ex Aluminium Percent	%	*VL*	4.36	*VL*	0.04	*VL*	0.03	*VL*	0.04	*VL*	3.06	*VL*	0.14	*VL*	0.14	*VL*
Exchangeable Calcium	mg/kg		272		2238		2351		1435		367		1406		511	
Exchangeable Magnesium	mg/kg		219		1436		1511		633		1741		291		291	
Exchangeable Potassium	mg/kg		109		432		468		327		133		280		148	
Exchangeable Sodium	mg/kg		66.2		191		201		50.0		637		28.0		15.2	
Exchangeable Aluminium	mg/kg		15.4		0.84		0.67		0.4		55.3		1.3		0.7	
Exchangeable Calcium	meq/100g	*VL*	1.36	*VL*	11.2	*H*	11.8	*H*	7.2	*M*	1.8	*VL*	7.0	*M*	2.6	*L*
Exchangeable Magnesium	meq/100g	*M*	1.83	*M*	12.0	*VH*	12.6	*VH*	5.3	*H*	14.5	*VH*	2.4	*M*	2.4	*M*
Exchangeable Potassium	meq/100g	*L*	0.28	*L*	1.11	*H*	1.20	*H*	0.84	*H*	0.34	*M*	0.72	*H*	0.38	*M*
Exchangeable Sodium	meq/100g	*L*	0.29	*L*	0.83	*H*	0.87	*H*	0.22	*L*	2.77	*VH*	0.12	*L*	0.07	*VL*
Exchangeable Aluminium	meq/100g		0.17		0.01		0.01		0.00		0.61		0.01		0.01	
Calcium/Magnesium Ratio	-	*L*	0.7	*VL*	0.9	*VL*	0.9	*VL*	1.4	*L*	0.1	*VL*	2.9	*L*	1.1	*L*
Gravel >2.0mm	%		-		-		-		15.7		2.2		36.5		35.0	
Coarse Sand 0.2-2.0mm	%		-		-		-		15.6		4.9		36.4		41.3	
Fine Sand 0.02-0.2mm	%		-		-		-		31.6		11.9		16.2		13.5	
Silt 0.002-0.02mm	%		-		-		-		15.8		17.7		4.5		4.8	
Clay <0.002mm	%		-		-		-		21.5		63.3		6.4		5.4	
ADMC	%		-		-		-		8.2		13.1		5.6		7.2	
Emerson Class	Class		-		-		-		8		3a		8		8	

ANALYSIS REPORT

East West Enviroag 82 Plain St Tamworth NSW 2340 ph:02 67621733	Lab No	130286-6		130286-7		130286-10		130286-11		130286-12		130286-13		130286-14		130286-15
	Sample ID	MC4		MC4		MC6		MC6		MC7		MC7		MC7		MC8
	Sample Depth	0-10 cm		30-60 cm		0-10 cm		30-60 cm		0-10 cm		30-45 cm		50-80 cm		0-10 cm
	ASC	TE		TE		KA		KA		SO		SO		SO		SO
	SCP	MDGSL		MDGSL		MDGSL		MDGSL		MSD		MSD		MSD		MSD
	Field Texture															
Analyses	**Unit**	-		-		-		-		-		-		-		-
pH - Water	pH units	6.31	*L.Acid*	7.30	*Neutral*	6.66	*Neutral*	6.20	*L.Acid*	5.55	*H.Acid*	5.40	*H.Acid*	6.58	*L.Acid*	6.56
Electrical Conductivity	dS/m	0.04	*VL.Sal*	0.02	*VL.Sal*	0.05	*VL.Sal*	0.04	*VL.Sal*	0.03	*VL.Sal*	0.01	*VL.Sal*	0.15	*L.Sal*	0.09
Chloride	mg/kg										*VL.Sal*		*VL.Sal*		*VL.Sal*	
Total Nitrogen - Kjeldahl	mg/kg	1938	*M*	*		2515	*H*	*		1369	*L*	*		*		1620
Total Phosphorus - Nitric/Perchloric	mg/kg	419		*		322		*		422		*		*		391
Phosphorus - Colwell extr	mg/kg	33.6	*H*	*		9.3	*L*	*		54.3	*H*	*		*		33.4
Potassium - Colwell ext	mg/kg	301	*H*	*		356	*H*	*		376	*H*	*		*		553
Sulphur - KCl	mg/kg	3.1		*		3.4		*		2.2	*VL*	*		*		1.4
Organic Carbon	%	2.12	*H*	*		2.58	*H*	*		1.60	*M*	*		*		1.37
Copper	mg/kg	<1.0	*L*	*		<1.0	*L*	*		<1.0	*L*	*		*		<1.0
Iron	mg/kg	441		*		73.3		*		193		*		*		250
Manganese	mg/kg	164		*		61.1		*		77.1	*H*	*		*		101
Zinc	mg/kg	4.4	*M*	*		1.6	*M*	*		<1.0	*L*	*		*		<1.0
Boron	mg/kg										*VL*		*VL*		*VL*	
Cation Extraction Method	Rayment& Lyons															
Cation Exchange Capacity	meq/100g	13.4		5.4		17.0		12.3		5.6	*VL*	4.3	*VL*	13.6	*M*	7.8
Ex Calcium Percent	%	76.3		52.9		71.8		43.0		61.8		37.4		45.3		68.1
Ex Magnesium Percent	%	18.3		36.3		23.2		45.0		26.8		24.7		36.2		16.9
Ex Potassium Percent	%	4.70		7.93		4.53		6.16		9.82		28.88		3.33		14.23
Ex Sodium Percent	%	0.69	*N.Sodic*	2.62	*N.Sodic*	0.46	*N.Sodic*	5.74	*N.Sodic*	0.96	*N.Sodic*	3.66	*N.Sodic*	15.04	*H.Sodic*	0.76
Ex Aluminium Percent	%	0.03	*VL*	0.19	*VL*	0.04	*VL*	0.10	*VL*	0.55	*VL*	5.33	*L*	0.14	*VL*	0.08
Exchangeable Calcium	mg/kg	2046		575		2440		1056		688		323		1228		1062
Exchangeable Magnesium	mg/kg	294		237		472		663		179		128		589		158
Exchangeable Potassium	mg/kg	246		168		300		295		213		486		176		433
Exchangeable Sodium	mg/kg	21.3		32.8		17.9		162		12.3		36.3		469		13.7
Exchangeable Aluminium	mg/kg	0.4		1.0		0.6		1.2		2.8		20.7		1.7		0.5
Exchangeable Calcium	meq/100g	10.2	*H*	2.9	*L*	12.2	*H*	5.3	*M*	3.4	*L*	1.6	*VL*	6.1	*M*	5.3
Exchangeable Magnesium	meq/100g	2.5	*M*	2.0	*M*	3.9	*H*	5.5	*H*	1.5	*M*	1.1	*M*	4.9	*H*	1.3
Exchangeable Potassium	meq/100g	0.63	*M*	0.43	*M*	0.77	*H*	0.76	*H*	0.55	*M*	1.25	*H*	0.45	*M*	1.11
Exchangeable Sodium	meq/100g	0.09	*VL*	0.14	*L*	0.08	*VL*	0.70	*H*	0.05	*VL*	0.16	*L*	2.04	*VH*	0.06
Exchangeable Aluminium	meq/100g	0.00		0.01		0.01		0.01		0.03		0.23		0.02		0.01
Calcium/Magnesium Ratio	-	4.2	*M*	1.5	*L*	3.1	*L*	1.0	*VL*	2.3	*L*	1.5	*L*	1.3	*L*	4.0
Gravel >2.0mm	%	25.0		15.7		8.2		4.3		19.7		37.0		1.4		11.6
Coarse Sand 0.2-2.0mm	%	37.4		37.0		25.1		27.5		41.7		32.3		23.0		42.0
Fine Sand 0.02-0.2mm	%	24.9		28.0		39.0		35.0		25.2		24.0		20.1		25.0
Silt 0.002-0.02mm	%	6.7		9.4		11.9		12.6		4.2		3.0		19.3		8.0
Clay <0.002mm	%	6.0		9.9		15.9		20.5		9.2		3.7		36.2		13.5
ADMC	%	4.3		5.9		5.8		7.4		4.5		4.4		10.8		5.3
Emerson Class	Class	8		3b		8		2		8		3b		3a		8

ANALYSIS REPORT

East West Enviroag 82 Plain St Tamworth NSW 2340 ph:02 67621733	Lab No		130286-16	
	Sample ID		MC8	
	Sample Depth		30-60 cm	
	ASC		SO	
	SCP		MSD	
	Field Texture			
Analyses	**Unit**		-	
pH - Water	pH units	*L.Acid*	6.96	*Neutral*
Electrical Conductivity	dS/m	*L.Sal*	0.02	*VL.Sal*
Chloride	mg/kg	*VL.Sal*		*VL.Sal*
Total Nitrogen - Kjeldahl	mg/kg	*M*	*	
Total Phosphorus - Nitric/Perchloric	mg/kg		*	
Phosphorus - Colwell extr	mg/kg	*H*	*	
Potassium - Colwell ext	mg/kg	*H*	*	
Sulphur - KCl	mg/kg	*VL*	*	
Organic Carbon	%	*M*	*	
Copper	mg/kg	*L*	*	
Iron	mg/kg		*	
Manganese	mg/kg	*H*	*	
Zinc	mg/kg	*L*	*	
Boron	mg/kg	*VL*		*VL*
Cation Extraction Method	Rayment& Lyons			
Cation Exchange Capacity	meq/100g	*L*	3.7	*VL*
Ex Calcium Percent	%		62.6	
Ex Magnesium Percent	%		26.1	
Ex Potassium Percent	%		9.60	
Ex Sodium Percent	%	*N.Sodic*	1.42	*N.Sodic*
Ex Aluminium Percent	%	*VL*	0.36	*VL*
Exchangeable Calcium	mg/kg		468	
Exchangeable Magnesium	mg/kg		117	
Exchangeable Potassium	mg/kg		140	
Exchangeable Sodium	mg/kg		12.2	
Exchangeable Aluminium	mg/kg		1.2	
Exchangeable Calcium	meq/100g	*M*	2.3	*L*
Exchangeable Magnesium	meq/100g	*M*	1.0	*L*
Exchangeable Potassium	meq/100g	*H*	0.36	*M*
Exchangeable Sodium	meq/100g	*VL*	0.05	*VL*
Exchangeable Aluminium	meq/100g		0.01	
Calcium/Magnesium Ratio	-	*M*	2.4	*L*
Gravel >2.0mm	%		26.9	
Coarse Sand 0.2-2.0mm	%		38.1	
Fine Sand 0.02-0.2mm	%		22.4	
Silt 0.002-0.02mm	%		3.9	
Clay <0.002mm	%		8.6	
ADMC	%		6.5	
Emerson Class	Class		3b	

APPENDIX C SOIL INTERPRETATION CRITERIA

Soil analysis results are presented in the Appendix A (Tables) of this report. Interpretation criteria referred to in the interpretation of the field findings and laboratory results are presented below.

Table 17 Soil pH ratings (Hazelton & Murphy, 2007) (Baker & Eldershaw, 1993)

Rating	pH (1:5)
Extremely acidic (E.Acid)	<4.5
Very highly acid (VH.Acid)	4.5–5
Highly acidic (H.Acid)	5.1–5.5
Moderately acid (M.acid)	5.6–6.0
Slightly acid (L.Acid)	6.1–6.5
Neutral	6.6–7.3
Slightly alkaline (L.Alk)	7.4–7.8
Moderately alkaline (M.Alk)	7.9–8.4
Highly alkaline (H.Alk)	8.59.0
Very highly alkaline (VH.Alk)	>9.0

Table 18 Soil salinity classification (Shaw, 1999)

Soil salinity rating	$EC_{1:5}$ (dS/m) for a range of soil clay contents				Plant salt response
	10–20% clay	20–40% clay	40–60% clay	60–80% clay	
Very low	<0.07	<0.09	<0.12	<0.15	
Low	0.07–0.15	0.09–0.19	0.12–0.24	0.15–0.3	Moderately sensitive crops
Moderate	0.15–0.34	0.19–0.45	0.24–0.56	0.3–0.7	Moderately tolerant crops
High	0.34–0.63	0.45–0.76	0.56–0.96	0.7–1.18	Tolerant crops
Very high	0.63–0.93	0.76–1.21	0.96–1.53	1.18–1.87	Very tolerant crops
Extreme	>0.93	>1.21	>1.53	>1.87	Too saline

Table 19 Soil chloride ratings (Bruce & Rayment, 1982)

Rating	Chloride (mg/kg)
Non-saline (VL.Sal)	< 100
Slightly saline (L.Sal)	100–300
Moderately saline (M.Sal)	300–600
Highly saline (H.Sal)	600–2000
Extremely saline (E.Sal)	> 2000

Table 20 Soil organic matter and organic carbon ratings (Hazelton & Murphy, 2007) (NSW Office of Environment and Heritage, 2010)

Organic Matter (%)	Organic Carbon (%)	Rating	Interpretation
< 0.7	< 0.4	Extremely low (EL)	Subsoils or severely eroded, degraded surface soils
0.7–1.0	0.4–0.6	Very low (VL)	Very poor structural condition, very low structural stability
1.0–1.7	0.6–1.0	Low (L)	Poor to moderate structural condition, low to moderate structural stability
1.7–3.0	1.0–1.8	Moderate (M)	Average structural condition, average structural stability
3.0–5.15	1.8–3.0	High (H)	Good structural condition, high structural stability
> 5.15	> 3.0	Very high (VH)	Good structural condition, high structural stability and soils probably water repellent.

Table 21 Sodicity rating (Hazelton & Murphy, 2007)

Rating	Exchangeable Sodium Percentage
Non-sodic (N.Sodic)	< 6 %
Marginally sodic to sodic (Sodic)	6–14 %
Strongly sodic (H.Sodic)	14–30 %
Extremely sodic (E.sodic)	> 30 %

Table 22 Emerson aggregate class interpretation (Hazelton & Murphy, 2007)

Emerson aggregate class	Dispersibility	Sodicity Estimate
Classes 1 and 2(3)	Very high	Almost certainly sodic
Class 2(2)	High	Highly likely to be sodic
Class 2(1)	High to moderate	May be sodic
Classes 3(4) and 3(3)	Moderate	May be sodic
Classes 3(2), 3(1) and 5	Slight	Unlikely to be sodic
Class 4	Negligible/ aggregated	May be sodic
Classes 6, 7 and 8	Negligible/ aggregated	Almost certainly non-sodic

Note: Dispersion subclasses for EAT classes 2 and 3 (shown in brackets): (1) Slight milkiness, (2) Obvious milkiness < 50% of the aggregate affected, (3) obvious milkiness > 50% of the aggregate affected; and (4) Total dispersion leaving only sand grains.

Table 23 Chemical Dispersion Indices (McKenzie, 1998)

Rating	Interpretation
Ca:Mg ratio < 0.5	Potentially dispersive
Electrochemical–Stability Index (ESI) < 0.05	Potentially dispersive

Table 24 Soil fertility ratings

Analyte	Unit	Very Low	Low	Moderate	High	Very High
Nitrogen (Total) [1]	mg/kg	<500	500–1500	1500–2500	2500–5000	>5000
Nitrogen (Total) [1]	%	0.05	0.05–0.15	0.15–0.25	0.25–0.5	>0.5
Phosphorus (Colwell) [1]						
Sandy Loams	mg/kg		<14	14–20	>20	
Loams	mg/kg		<16	16–30	>30	
Clay loam	mg/kg		<18	18–40	>40	
Heavy Clay	mg/kg		<30	30–80	>80	
Potassium (Colwell) [2]						
Sands	mg/kg	<50	50–140	141–170	>170	
Sandy loams	mg/kg	<80	80–150	151–200	>200	
Clay loams	mg/kg	<110	110–160	161–250	>250	
Clays	mg/kg	<120	120–180	181–300	>300	
Sulphur (KCl) [2]	mg/kg	<4	4–8	8–12	12–20	>20
Effective Cation Exchange Capacity (ECEC) [1,4]	meq/100g	<6	6-12	12-25	25-40	>40
Exchangeable Calcium [1,4]	meq/100g	<2.0	2.0–5.0	5.0–10	10–20	>20
Exchangeable Magnesium [1,4]	meq/100g	<0.3	0.3–1.0	1.0–3.0	3.0–8.0	>8.0
Exchangeable Potassium[1,4]	meq/100g	<0.2	0.2–0.3	0.3–0.7	0.7–2.0	>2.0
Exchangeable Sodium [1,4]	meq/100g	<0.1	0.1–0.3	0.3–0.7	0.7–2.0	>2.0
Exchangeable Aluminium [1,4]	%	<5	5–10	10–15	15–35	>35
Calcium/Magnesium ratio [1,4]		<1.0	1.0–4.0	4.0-6.0	6.0–10	>10
Boron [3]	mg/kg	<0.5	0.5–1	1–2	2–5	>5
Copper [3]	mg/kg	<0.1	0.1-0.3	0.3-5	5-15	>15
Manganese [3]	mg/kg	<1.0	1.0–2.0	2.0–50	50–500	>15
Zinc (pH >7) [3]	mg/kg	<0.3	0.3–0.8	0.8–5.0	5.0–15	>15
Zinc (pH <7) [3]	mg/kg	<0.2	0.2–0.5	0.5–5.0	5.0–15	>15

Very Low (VL), Low (L), Moderate (M), High (H), Very High (VH)

[1] (Hazelton & Murphy, 2007); [2] (VIC Department of Environment and Primary Industries, 2014); [3] (Baker & Eldershaw, 1993); [4] (NSW Office of Environment and Heritage, 2010)

Table 25 Estimated plant available water capacity. Values for soils with high organic matter or very fine and strong structure are multiplied by a factor of 1.2 (NSW Department of Land and Water Conservation, NSW State Forests, NSW National Parks and Wildlife Service and Bureau of Rural Sciences, 1999).

Texture	EPAWC (mm/m)
Sands	
Sand	150
Coarse sand	80
Fine sand	200
Loamy sand	160
Loamy coarse sand	108
Loamy fine sand	217
Clayey sand, light clayey sand	150
Heavy clayey fine sand	215
Loams	
Sandy loam (light-heavy)	180
Coarse sandy loam (light–heavy)	125
Fine sandy loam (light–heavy)	192
Loam	180
Loam, fine sandy	185
Silty loam	200
Sandy clay loam (fine–heavy)	150
Coarse sandy clay loam (fine–heavy)	140
Fine sandy clay loam (fine–heavy)	180
Clay loam (fine–heavy)	180
Clay loam (light–heavy), sandy	175
Clay loam, coarse sandy	170
Light clay loam, fine sandy	190
Heavy silty clay loam	190
Light silty clay loam, fine sandy	195
Clays	
Sandy clay (light–heavy)	140
Coarse sandy clay (light–heavy)	130
Fine sandy clay (light–heavy)	150
Silty clay (light–heavy)	183
Clay (light–heavy)	180
Clay, cracking	200

Table 26 Approximations of soil erodibility based on texture (Hazelton & Murphy, 2007)

Texture	K factor
Sand	0.015
Loamy sand	0.020
Clayey sand	0.025
Sandy loam	0.030
Fine sandy loam	0.035
Sandy clay loam	0.025
Loam	0.040
Loam, fine sandy	0.050
Silt loam	0.055
Clay loam	0.030
Silty clay loam	0.040
Fine sandy clay loam	0.025
Sandy clay	0.017
Silty clay	0.025
Light clay	0.025
Light medium clay	0.018
Medium clay	0.015
Heavy clay	0.012

Table 27 Soil erodibility classes (Roswell & Loch, 2002)

Rating	K factor
Very low	0.00–0.01
Low	0.01–0.02
Moderate	0.02-0.04
High	0.04–0.06
Very high	>0.06

APPENDIX D SITE OBSERVATION FIELD SHEETS

APPENDIX C

REHABILITATION RISK ASSESSMENT

Risk Assessment of Rehabilitation-Related Aspects

Environmental Factor	Hazard (Stressor)	Source of Hazard	Event	Potential Impacts	Likelihood	Consequence	Inherent Risk	Proposed Controls	Likelihood	Consequence	Residual Risk
Landforms and Closure	Clearing and earthworks Physical presence	• Open cut and OEA	• Landform instability • Landform incompatibility • Alteration of natural landform function	Design failure results in landform instability	5	4	High	• Controls outlined in the MSRP and the MOP, specifically: – progressive mine planning; – regular review and revision of mine plans and rehabilitation performance; and – progressive rehabilitation.	2	4	Medium
				Significantly impacts on visual amenity	2	4	Medium	• Controls outlined in the MSRP and the MOP, specifically: – progressive rehabilitation; and – low impact colour infrastructure.	2	1	Low
				Significant change in surface water flow	5	4	High	• Controls outlined in the MSRP, MOP and Water Management Plan, specifically: – Stockpiled materials will be selected and drainage designed to minimise erosion. • Appropriately engineered surface water diversions.	2	4	Medium

Environmental Factor	Hazard (Stressor)	Source of Hazard	Event	Potential Impacts	Likelihood	Consequence	Inherent Risk	Proposed Controls	Likelihood	Consequence	Residual Risk
Surface Water	Clearing and rehabilitation earthworks Liquid and solid waste disposal Hazardous substances	Overburden emplacement area Open cut Mine infrastructure area	• Misdirection of surface water flows • Erosion • Sedimentation • Contamination of surface water flows	Sedimentation of watercourses	4	2	Medium	• The open cut will be bunded to separate clean and dirty run-off. • Sediment control measures will be designed and implemented as required. • Containment bunds. • Controls outlined in the MOP. • Controls outlined in the Water Management Plan.	4	2	Medium
				Significant reduction in water quality	3	2	Medium	• Spill procedures/kits. • Water quality monitoring and maintenance of hydraulic control structures. • Controls outlined in the Water Management Plan, specifically: – Controlled wastes will be properly handled. – On-site solid waste disposal will be minimised and properly managed. – Hazardous substances will be stored in properly bunded facilities. – Manage drainage and water flows so as to protect water quality and direction of water flow including drainage diversions.	3	2	Medium

Environmental Factor	Hazard (Stressor)	Source of Hazard	Event	Potential Impacts	Likelihood	Consequence	Inherent Risk	Proposed Controls	Likelihood	Consequence	Residual Risk
Groundwater	Clearing and earthworks Liquid and solid waste disposal Hazardous substances	Open cut dewatering Overburden emplacement area	• Localised dewatering of aquifer • Contamination of aquifer during operations • Contamination of aquifer post-closure	Significant impact on existing supply bores	2	2	Low	• Monitoring to verify predicted groundwater model drawdown. • Monitor abstraction of groundwater volume and levels and quality of groundwater bores. • Identification of at-risk bores and implementation of mitigation measures (if required).	2	2	Low
				Significant impact on surface water (incl. Back Creek, Namoi River)	2	2	Low	• Monitoring to verify predicted low risk of impact.	2	2	Low
				Significant reduction in groundwater quality	3	2	Medium	• Promote awareness of management procedures for contaminants used on-site. • Store contaminants in appropriately bunded facilities, ensure spills are thoroughly cleaned up. • Appropriate disposal. • Spill procedures/kits. • Monitoring and maintenance strategy.	2	2	Low
				Long-term significant groundwater contamination (salinity) arising from pit lake	3	2	Medium	• Monitoring to verify predicted groundwater behaviour. • Implementation of mitigation measures (e.g. backfill if required).	2	2	Low

Environmental Factor	Hazard (Stressor)	Source of Hazard	Event	Potential Impacts	Likelihood	Consequence	Inherent Risk	Proposed Controls	Likelihood	Consequence	Residual Risk
Flora and Vegetation	Climatic conditions Fire Dust Weed Invasion Inappropriate soil substrate	Overburden storage area Backfilled sections of the open cut	• Failure of revegetation through poor climatic conditions, pests, inappropriate selection of plant species • Accumulation of dust in rehabilitation areas (from nearby operational areas) • Weed invasion/spread into rehabilitation areas • Failure of vegetation due to poor soil conditions	Vegetation communities that develop in rehabilitation areas are inconsistent with surrounding areas and the pre-mining vegetation.	4	4	High	• Soil Management Protocol. • Implement the MOP and MSRP. • Conduct progressive rehabilitation. • Implement the rehabilitation monitoring program. • Implement the BMP. • Educate employees about preventing bushfires and implement the MCCM Bushfire Management Plan. • Educate employees about dust control and implement the MCCM Air Quality Management Plan.	2	4	Medium
Fauna	Clearing and rehabilitation earthworks Lighting Noise Physical presence Physical interaction	Overburden storage area Backfilled sections of the open cut	• Failure of fauna habitat in rehabilitation areas due to climatic conditions, pests, inappropriate selection of plant species • Artificial lighting • Noise associated with mining activities adjacent to rehabilitation areas • Increase in feral animal habitat	Fauna habitat in rehabilitation areas is not suitable or insufficiently developed. Feral animals become established in rehabilitation areas.	4	2	Medium	• Implement the MOP and MSRP. • Conduct progressive rehabilitation. • Implement the rehabilitation monitoring program. • Implement the BMP. • Educate employees about the identification and management of feral animals.	2	2	Low

Environmental Factor	Hazard (Stressor)	Source of Hazard	Event	Potential Impacts	Likelihood	Consequence	Inherent Risk	Proposed Controls	Likelihood	Consequence	Residual Risk
Soil Resources	Clearing and earthworks Hazardous substances	Rehabilitation areas Project wide	• Inadequate salvage of topsoil • Compaction of soil • Inadequate management of PAF material • Lack of stockpile coordination • Soil mixed up with waste dumps or buried under waste dumps	Loss of soil resources that significantly impacts rehabilitation	3	2	Medium	• Implement the MOP and MSRP. • Soil Management Protocol and Land Disturbance Protocol. • Mine planning measures to identify PAF material and avoid or appropriately manage.	2	2	Low
				Significant contamination of soil resources	2	2	Low	• Bunded fuel/chemical storage. • Appropriate disposal. • Spill procedures/kits.	2	2	Low
				Reduction in viability of seeds, nutrients, organic matter and micro-organisms	2	2	Medium	• Stockpile management as per measures outlined in Soil Management Protocol.	2	2	Low
				Changes to the natural soil evolution/forming process caused by stripping and reusing soil from disturbed areas in rehabilitation	2	2	Low	• Stockpile management as per measures outlined in Soil Management Protocol.	2	2	Low