# RESPONSE TO ITEM 6 OF THE FURTHER REQUIREMENT NOTICE

*New Acland Coal Mine Stage 3 Project*

## Contents

# 1. Item 6(a) Cattle grazing trials outcomes

## *NAC – APC coexistence.*

New Acland Coal Pty Ltd (**NAC**) previously provided the Assessment Against Darling Downs Regional Plan as Appendix J to the Priority Agricultural Land Use Assessment Report for New Acland Mine Stage 3 Project dated November 2019 (**SLR Report**). NAC reiterates that the Project supports the co-existence of agricultural and resource sectors and that the resource activities the subject of the RIDA application are not proposed to be carried out on PALU Land[1]. The activity will not result in a material impact on the use of land in the region for PALU. The footprint of the resource activities has been minimised as far as possible, whilst still allowing for mining of the resource areas. Refer Appendix J of the SLR Report for a description of actions taken to minimise the footprint.[2]

The dominant land uses surrounding the Project are grazing and dryland cropping. The Project Site falls on the boundary of the cropping and grazing lands in the Central Darling Downs region. To the west and south, both dryland cropping and irrigated cropping are very extensive. To the east, grazing is the dominant land use. This land use distribution results from more unreliable surface water and groundwater resources in the basalt and Walloon uplands that dominate the locality of the mine than, for example, the lands associated with the Condamine Oakey and Gowrie creek systems and flood plains to the west. [3] Dryland cropping is dependent on soil moisture provided by rainfall and not on groundwater. While the application triggers a single "property"[4], NAC has also demonstrated that the application meets required outcome 2 for the Priority Agricultural Area as it is not located on PALU and will not have a widespread or irreversible impact on the future use of land in the area for a PALU [5].

## *Grazing Trials*

Acland Pastoral Company Pty Ltd (**APC**) commissioned independent scientific grazing trials over five years which assessed livestock production performance on rehabilitated land. Results of the trials showed that the rehabilitated land was a stable, safe environment for grazing with productivity at least as good as equivalent pastures on unmined land in the local area.

In summary, the grazing trials project has been ongoing since October 2011. Work to date includes a pilot trial (Stage 1) run from October 2011 to May 2012. Preliminary work to facilitate the Stage 2 trial commenced during January 2013 with the tender process to identify and engage the expertise of the project team. Stage 2 of the grazing trials project began during January 2014. A series of progressive reports were produced for this staged work:

- Acland Grazing Trial: Swiftsynd pasture results (**NAC Attachment 1**);
- Acland Grazing Trial: GRASP simulation analyses (**NAC Attachment 2**);
- Acland Grazing Trial: pasture & cattle performance (**NAC Attachment 3**);
- Acland Pastures Report 1 (**NAC Attachment 4**); and
- Acland Pastures Report 2 (**NAC Attachment 5**).

The final reports regarding the cattle grazing trials have been completed and managed by OUTCROSS, a third party agri-services business, in conjunction with the University of Southern Queensland and EcoRich Grazing:

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1 Refer to the SLR response to this Requirement Notice and the application material.

2 Page 8 of Appendix J, Assessment Against Darling Downs Regional Plan.

3 Bill Thompson's Statement of Evidence referred in New Acland Coal Pty Ltd v Ashman and Ors (No.4) [2017]QLC 24 at [1290].

4 APC is the landowner of all the surface lots in this application which are managed as part of the APC single agricultural enterprise.

5 See also sections 5 and 6 of this response to item 6 of the Further Requirement Notice.

- OUTCROSS - New Hope Cattle Grazing Trial (**NAC Attachment 6**);
- USQ - Assessing soil properties of rehabilitated coal mine soils for sustainable and economically viable beef cattle operations, Progress Report (**NAC Attachment 7**); and
- OUTCROSS - Optimising Rehabilitated Grazing Pastures For Sustainable and Economically Viable Beef Production (**NAC Attachment 8**).

The reports find that rehabilitated land proved as productive as surrounding unmined land for pasture growth and beef production. The reports also find that economic returns from the rehabilitated land were equal to or greater than unmined land nearby. Contaminant testing showed that there are no concerns with respect to food safety or toxification from cattle grazed on rehabilitated land. Pasture analysis and faecal testing indicate that rehabilitated pasture provides a diet that is comparable in quality and higher in quantity to unmined land. When the trial cattle have been slaughtered for human consumption, the cattle that have grazed rehabilitated land have received the same price as those grazing unmined land and have been independently assessed as having comparable eating quality as those grazing unmined land. Gross margin analysis indicates that cattle grazing rehabilitated land are economically viable and comparable to unmined land.

It has been concluded from the results of the trials that livestock grazing on the rehabilitated mined land is economically sustainable, environmentally sustainable and ultimately produces safe meat of an acceptable eating quality standard for the consumer.

NAC is still waiting to receive the final report on soil, which compared the nutrient and physical parameters of a series of soil plots within the trial and control sites. Findings will inform future trial and investigative work in this space. Currently, no new grazing trials are planned.

In terms of current grazing performance during the ongoing drought, areas rehabilitated by NAC have sustained 500 head of cattle that would otherwise have had to be sold on. Stock on these areas have performed well and have all produced calves which continue to maintain good condition. The Mine also allows the use of recycled Wetella water to rehabilitation areas, which eliminates the need for dams in these areas and is a demonstrated beneficial use of a waste product. NAC also supplies Wetella water to APC for agricultural purposes, such as cropping and stock watering.

## 2. Item 6(b) Details on management practices used

APC utilises some key management practices to achieve sustainable grazing, including the following actions.

- Using satellite imagery and remote sensing across all APC stocking areas to verify vegetation (feed) cover and density, which assists in determining sustainable stocking rates.
- During the prolonged drought period, using supplementary feed for cattle from APC crops, grown using Wetella recycled water. A veterinarian and nutritionist provide guidance on feed ratios and monitor cattle health.
- Where possible, recycled water from the Wetella system is used for cropping and grazing practices.

## 3. Item 6(c) Arrangements between NAC and APC for rehabilitated land to return to agricultural use.

APC is the landowner, whilst NAC holds the mining leases. The broader APC land holding is shown in Appendix H of the SLR Report. The existing mining leases and the primary mining areas on mining leases for MLA50232 (for mining) and MLA700002 (infrastructure mining lease for rail spur) for the Project is shown on **NAC Attachment 9**.

This application relates to the first 5 years of mining on MLA50232. Once rehabilitation areas post mining are confirmed by NAC, a formal process is followed for the handover of the land to APC for agricultural purposes. In addition, measures are taken to ensure the areas are fenced and made available to APC to introduce stock. APC is provided with a set of management rules for grazing of the rehabilitated mined land, which is monitored by NAC and periodically by one of the external consultants participating in the grazing trials. As required, ongoing consultation between NAC and APC is undertaken regarding access, maintenance work and status of the rehabilitated mined land.

This process of handover of the rehabilitated land back to APC for agricultural use by NAC will continue progressively up until surrender of the Project's mining leases and Environmental Authority (**EA**) (**NAC Attachment 10**). At that time, APC will assume complete control of all former mined land for agricultural purposes as the landowner.

## 4. Item 6(d) DES's comments on NAC's certified rehabilitation outcomes.

The Department of Environment and Science (**DES**) certified 349 hectares of progressive rehabilitation during November 2018 (**NAC Attachment 11**). At the time, the area certified was the largest single area of certified rehabilitation on an open cut mine in Queensland. The certification also demonstrates the rehabilitated land's ability to meet the current Stage 1/2 Mine's agreed post-mining agricultural land use.

The certification was in consideration of the EA conditions (**NAC Attachment 10**), rehabilitation completion criteria, rehabilitation report and standard criteria completed for the rehabilitation project. DES comments about the certified rehabilitation stated that:

- the rehabilitation was safe, stable and non-polluting; and
- the approved progressive rehabilitation area met the EA conditions and rehabilitation completion criteria.

## 5. Item 6(e) How the Stage 3 Project's rehabilitation will differ from the current Stage 1/2 Mine's rehabilitation.

The Project area has been more strictly conditioned than the current Stage 1/2 Mine to ensure that the mined land achieves a higher standard of rehabilitation from an agricultural land capability perspective. The relevant Coordinator-General and EA conditions are discussed in the Assessment Against Darling Downs Regional Plan in Appendix J to the SLR Report. The conditions are extracted at Appendix B & C to the Assessment (within Appendix J). The Queensland Coordinator-General has conditioned the Project to achieve the following rehabilitation outcome (Imposed Condition 7(b) of the Coordinator-General's Report 2014[6]).

*The rehabilitation of disturbed land is to result in the affected land units being able to support the best*

[6] http://statedevelopment.qld.gov.au/resources/project/new-acland-coal-mine/nacp-stage-3-eis-report.pdf

*post-disturbance land use possible. The post-disturbance land suitability of each land unit is to:*

*(i) represent that achievable on an ongoing basis;*

*(ii) be obtainable without the use of irrigation; and*

*(iii) be such that collectively at least 50 per cent of the total area of disturbed land originally meeting or exceeding the criteria for either Class 3 grazing land or Class 4 cropping land still meet or exceed those classifications.*

To achieve the Project's agricultural based rehabilitation outcome, the Queensland Coordinator-General has also conditioned the Project to undertake selective handling and return of topsoils and sub-soils within the proposed mining areas, which is a significant step change for the mining industry (Imposed Condition 7(a) of the Coordinator-General's Report 2014).

*Rehabilitation is to be undertaken so as to establish discrete land units (that is, no unjustified mixing of soil material from different land units) in the disturbed areas to be rehabilitated ('rehabilitation area'), each capable of ultimately being assigned a specific post-disturbance land use suitability.*

In addition, prior to the commencement of the Project, an extensive land resource (soil) survey has been completed to establish the soil types and soil profiles for future soil management purposes and to refine land suitability classifications within the proposed mining areas. Reference sites have also been established for each of the identified soil types to assist with future monitoring of rehabilitation performance. All these actions have been completed and the supporting reports have been approved by the Queensland Coordinator-General in accordance with the Coordinator-General's Imposed Conditions of approval.

The Project also differs from the current Stage 1/2 Mine in that a significant amount of investigative work and post mine closure planning has occurred at the front end of the project, with specific post mine land uses defined and significant effort focused on achieving land and soil management objectives throughout the life of the project to enhance rehabilitation outcomes.

A Soil Management Plan has been developed for the Project and approved by the Queensland Coordinator-General (**NAC Attachment 12**). The Soil Management Plan is designed to define the selective soil recovery and return parameters for each soil type, the management of selective subsoil and topsoil stockpiling, the management of stockpiles in general to improve soil longevity and prevent loss, and other soil management requirements.

A Final Land Use and Rehabilitation Plan (FLURP) for the Project and the existing Mine has been approved by the Coordinator-General (**NAC Attachment 13**). This plan guides NAC rehabilitation effort by defining the progressive rehabilitation strategy for the mined areas, outlining the rehabilitation acceptance criteria required to achieve the post mine land use, summarising the monitoring methodology to confirm rehabilitation success, establishing a reporting framework, and providing a remediation program should substandard rehabilitation be identified.

## *How the Stage 3 Project's voids requirements will differ from the current Stage 1/2 Mine's void requirements.*

The current Stage 1/2 Mine is conditioned to allow voids to remain at the end of mine life. If the Project progresses all void space within the current Stage 1/2 Mine is intended to be backfilled by spoil and/or tailings, which will allow the former void area to be returned to an agricultural land use (e.g. grazing). The use of the Project's spoil for backfilling operations within the current Stage 1/2 Mine will remove the requirement for two out-of-pit dumps within the Project's Willeroo and Manning Vale Pit mining areas, which will reduce the Project's overall disturbance footprint requiring rehabilitation.

NAC proposes that at the end of the Project the remaining voids for the three proposed pits will be reformed into ‘depressed landforms’. Within these areas, the voids will be profiled with slope angles of 0-15%, which will allow the slopes of these areas following rehabilitation to be available for agricultural purposes (e.g. grazing). The rehabilitation outcomes for the Project’s ‘depressed landforms’ are provided in the FLURP.

As described above, the Coordinator-General's Imposed Conditions 7 and 8 require NAC to return the Project’s disturbed areas to a higher standard of rehabilitation than the current Stage 1/2 Mine. In addition, Imposed Condition 9 of the Coordinator-General's Report requires NAC to secure an equivalent amount of land to offset land which will be permanently lost to agricultural use (i.e. in relation to the proposed void areas). The equivalent land is to be like for like and legally secured by registration of a covenant on the land title. The equivalent land is to be improved to enhance the productivity of that land (e.g. erosion, pest and weeds, management and use). These conditions are set out in full in Appendix B to the Assessment Against Darling Downs Regional Plan[7]. NAC has engaged a consultant to develop a report to demonstrate how Imposed Condition 9 will be satisfied. This report will be provided to the Coordinator-General in the future for approval. NAC in consultation with the APC Manager has identified potential offset areas for Imposed Condition 9 within APC’s extensive agricultural land holdings.

NAC is required to develop and implement a FLURP under its EA and the Coordinator-General’s Imposed Conditions. The FLURP describes how all areas disturbed by mining activities are to be suitably rehabilitated (see above FLURP information). The FLURP must be approved by the Coordinator-General under Imposed Condition 8 of the Coordinator-General's Report and must comply with the EA requirements in Schedule H of the EA (**NAC Attachment 10)**. The FLURP has been approved by the Coordinator-General. There are specific rehabilitation criteria that must be met within Tables H1- H6 of the EA.

NAC is satisfied that the resource activity will not otherwise constrain, restrict or prevent the ongoing use of the mining lease or surrounding area for PALU or infrastructure necessary for the operation of a PALU. The resource activity will not result in widespread or irreversible impacts on the future use of land in the area for a PALU.[8]

# 6. Item 6(f) Information on the direction of clean water run-off from areas of and adjacent to the proposed pits and spoil dumps.

## *Water Management*

The Project’s EA (**NAC Attachment 10**) regulates NAC’s water management strategy for its mining operations. It defines three operational water categories and stipulates different management obligations for each water category.

The three operational water categories are:

- ‘Mine Affected Water’ (pit water, tailings water, process water);
- ‘Stormwater from disturbed areas’ (rainfall runoff that has been in contact with disturbed areas and newly rehabilitated areas); and
- ‘Clean Water’ (stormwater from undisturbed areas or substantially rehabilitated areas).

Based on the three operational water categories and the EA obligations, NAC has adopted the

[7] Appendix J to the SLR Report
[8] See also section 6 below.

following water management principles:

- the capture, storage, and eventual reuse (e.g. dust suppression and coal washing purposes) or controlled release of Mine Affected Water to the receiving environment;
- the effective capture of Stormwater from disturbed and newly rehabilitated areas, and treatment and release of this water through appropriately sized sediment dams to the receiving environment; and
- the effective separation of Clean Water and immediate release to the receiving environment.

The release of Mine Affected Water must only occur from environmental dams, at an acceptable water quality, at prescribed flow rates, and only during times of natural flow in Lagoon Creek. Therefore, environmental dams, pumps and pipes will be established on-site to manage Mine Affected Water and will be sized to avoid releases and be set-up to allow regulated releases offsite under the EA conditions of approval for release events.

The proposed Project's design has four main environmental dams purposed to receive water from the mine pit areas. The indicative locations of the environmental dams are shown in Figure 2 of the SLR Report. The environmental dams will be interconnected via a pumping network to allow effective water management across the site.

Stormwater is permitted to be released to the receiving environment from erosion and sediment control structures that are outlined in NAC's Erosion and Sediment Control Plan (**ESCP**). As a result, sediment dams and drains will be appropriately designed to manage Stormwater from disturbed and newly rehabilitated areas. The sediment dams and drains will be constructed according to the sediment control objectives prescribed in the ESCP.

In general, permanent sediment dams will be strategically placed to accept stormwater from disturbed areas (including  the advancing spoil dumps and rehabilitation areas). These dams will be sized to spill at a moderate frequency. Permanent and progressive construction of a passive drainage network will be required to direct this water to these dams.

Smaller temporary sediment dams will be constructed at the leading edge of pit progression to accept stormwater from disturbed areas at the early stripping stage of the Project's mining areas. These dams will be sized to spill at a moderate to high frequency. Construction of temporary drainage network to direct this water to these dams will also be required.

Clean water from undisturbed areas will be separated from water from disturbed areas.  This action may occur naturally or may be facilitated using diversion bunds. In-pit storage will provide an estimated 100ML of additional storage per pit, should a significant rainfall event occur at the site and/or further capacity is required.

A 50 metre exclusion zone either side of Lagoon Creek, which passes through the Project area, has been designed to allow the restoration of the riparian zone, which will help maintain clean water run off/discharge.

Water management and design for the Project has been based on extensive GOLDSIM water modelling completed for the Project areas. Model update work will be on-going to ensure a robust and compliant water management outcome over the life of the Project. The Project's EA (**NAC Attachment 10**) also requires:

- a Water Management Plan to be developed and submitted to the Department of Environment and Science for review and comment within 3 months upon the grant of the MLs (conditions C20-C22 of the EA);
- an Erosion and Sediment Control Plan to be developed and implemented for all stages of mining (Condition C18 of the EA);

- an annual water monitoring report to be submitted to the Department of Environment and Science (Condition C17 of the EA);
- the implementation of a specified regime for the release of Mine Affected Waters (Condition C2 of the EA); and
- compliance with strict release limits for the release of Mine Affected and other waters (Condition C3 of the EA).

NAC's water management is designed to:

- ensure compliance with the conditions of the Project's EA;
- prevent impacts to the downstream receiving environment (including Lagoon Creek's flow regime and water quality); and
- prevent impacts to the surrounding and downstream agricultural activities within the Lagoon Creek and Oakey Creek catchments (i.e. in terms of agricultural potential and production).

### *Comprehensive conditioning of Stage 3 with respect to groundwater*

NAC has adopted a robust and comprehensive strategy to ensure there is no adverse impact on groundwater caused by the Project. In the context of groundwater, the Project will be subject to a range of approval conditions and statutory obligations within:

- the EA;
- the approval given under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (**EPBC Approval**) (**NAC Attachment 14**);
- the associated water licence (**AWL**) (yet to be issued but DNRME has proposed conditions);
- the Queensland Coordinator-General's Imposed Conditions[9] (**CG's Imposed Conditions**); and
- Chapter 3 of the *Water Act 2000* (Qld) (**the Water Act**), including those arising due to the recent declaration of a cumulative management area (**CMA**) with respect to the Project mining leases.[10]

The conditions relate to the modelling of groundwater impacts across a range of potentially impacted aquifers (including alluvial aquifers), baseline assessments and monitoring to accurately determine those impacts, as well as offset and make good obligations for any impacts that do arise.

NAC has been conditioned with strict groundwater monitoring requirements, including a requirement to prepare groundwater management and monitoring programs and strategies and provide them to and have them approved by relevant regulatory agencies (conditions 12 of the EPBC Approval, condition D8 of the EA, condition 10 of the CG's Imposed Conditions and conditions proposed by DNRME to be included in the AWL as well as Chapter 3 of the Water Act). NAC is then required to conduct regular underground water monitoring consistent with those plans and strategies (condition 9 of the EPBC Approval, condition D3 of the EA, Chapter 3 of the Water Act and conditions proposed by DNRME to be included in the AWL).

NAC will be subject to comprehensive conditions pertaining to bore assessments and baseline assessments to assist in measurement of impacts to groundwater aquifers, including the Oakey Creek Alluvium and incorporation of that into the groundwater management and monitoring programs and strategies (Chapter 3 of the Water Act, condition 13 of the EPBC Approval, condition D9 of the EA, condition 10 of the CG's Imposed Conditions).

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[9] http://statedevelopment.qld.gov.au/resources/project/new-acland-coal-mine/nacp-stage-3-eis-report.pdf
[10] https://environment.des.qld.gov.au/management/activities/non-mining/coal-seam-gas/cumulative-management#toc-2

The Water Act also imposes make-good obligations for affected bore owners as a result of the recent amended declaration of the CMA over the Project area (Chapter 3 of the Water Act).[11] Furthermore, it is anticipated that DNRME will include conditions in the AWL requiring NAC to offset groundwater impacts in all affected aquifers and make good any impacts to affected bore owners. The EPBC Approval also requires NAC to submit a Groundwater Management and Monitoring Plan (**GMMP**) for written approval. Condition 13 of the EPBC approval requires NAC to offset groundwater impacts to the Oakey Creek Alluvium and Tertiary Basalt Aquifers:

*"13. The GMMP must include:*

*…*

*(x) mechanisms for addressing the impacts of the action to groundwater resources, including details of measures for impacts to water bores and offsets for the Oakey Creek Alluvium and Tertiary Basalt Aquifers;*

*(xi) a timeframe for when the measures and offsets for impacts to groundwater resources will be implemented;*

*…*

***Offsets for the Oakey Creek Alluvium and Tertiary Basalt Aquifers** may comprise a retirement of part or all of an existing entitlement, or purchase and retirement of a new entitlement*."

[11] https://www.publications.qld.gov.au/dataset/ada25992-9f9e-48a8-9511-6cf690dedaab/resource/ce375a63-7bbb-4068-8625-00673132fd09/fs_download/31.01.20-combined.pdf

**NAC Attachment 1 - Acland Grazing Trial: Swiftsynd pasture results**

**Target Journal: Animal Production Science**

## Title:

**Sustainability of beef production from brigalow lands after cultivation and mining: (1) sown pasture growth and carrying capacity**

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## Keywords

Pasture quality, GRASP, land type, nitrogen, pasture rundown, LTCC.

**Short Title** for running header: Acland Grazing Trial: Swiftsynd pasture results

## Paper summary for Table of contents

Little information existed on the long-term productivity of sown pastures for beef production on rehabilitated mining land compared with lands retired from cultivation in southern Queensland, Australia. This study measured the growth and quality of these pastures and employed the results in a pasture growth model using 60 years of historical weather to project their productivity and sustainability under grazing. Rehabilitated land proved as productive as surrounding unmined land with results now available to guide plans for better management of grazing lands.

## Abstract

The New Acland coal mine in south-east Queensland is seeking to rehabilitate mined land to pastures that are safe, stable and sustainable for beef production. Little was known of the productivity and sustainability of previously mined land for grazing in the Darling Downs study region, and information was required to specify management guidelines for sustainable grazing of regional land types retired from cultivation.

This paper identifies pasture growth characteristics, rainfall use efficiencies and long-term carrying capacities of subtropical sown pastures established on lands rehabilitated after open-cut coal mining in comparison to sown pastures established on un-mined but previously cultivated lands. Pasture growth and quality (% nitrogen) were observed using the Swiftsynd methodology in ungrazed exclosures with 3 sites on rehabilitated lands of the Acland Grazing Trial over a 5-year period (2014-2018), and 13 sites on unmined lands over periods of 2 to 5 years with most sites on lands surrounding the mine and 3 sites on commercial properties.

Peak pasture yield (autumn harvest) averaged across years and treatments, was greater ($P<0.05$) on rehabilitated sites than unmined sites (5,644 and 3,322 kg/ha, respectively). The least productive rehabilitated site (3,716 kg/ha) was possibly the most representative of rehabilitated lands. Pasture rundown was evident with pasture N uptake decreasing over time with the fall greater and of longer duration on sites with higher fertility. Total soil mineral N supply (potentially mineraliseable N and mineral N) in spring was a useful indicator of N uptake over the following growing season. Simulations using the GRASP pasture growth model for the grazing trial period gave rainfall use efficiencies of 12.0, 7.0, 9.1 and 4.8 kg/ha.mm rainfall for Rehab lands and unmined sites on Brigalow Uplands, Mountain Coolibah and Poplar Box land types, respectively. Long-term carrying capacities based on estimates of long-term median pasture growth and 30% utilisation were 4.01, 3.35 and 5.32 ha/AE respectively for these unmined land types, and 2.17 ha/AE for the rehab lands. This data will enable development of grazing management plans for sustainable management of mined and unmined lands and assist transition of rehabilitated lands to commercial agriculture.


## Introduction

A key principle for ensuring grazing lands are managed sustainably is to set stocking rates so they match long-term carrying capacity (LTCC) over periods of 20-30 years or more (Johnston *et al.* 1996; Hall *et al.* 1998; Hunt 2008; McKeon *et al*. 2009; O'Reagain et al. 2014; Walsh and Cowley 2016). Carrying capacity is defined as "the number of stock that can be sustainably carried in a paddock or on a property over a defined period of time" (Alexander et al. 2018) and thus LTCC is the average number of animals a paddock can be expected to safely support over a planning horizon of 20-30 years without any decline in land condition. Consequently, on novel grazing land (Hobbs et al 1998, Buisson et al.

2019) there is some uncertainty in calculating LTCC where pastures have only existed for a short period of time because there is a period of transience until stability is achieved. Determining LTCC requires knowledge of the average annual growth of pastures and their safe annual utilisation rates by herbivores (Chilcott *et al*. 2005; Hunt 2008; McKeon *et al*. 2009; Ash *et al*. 2002). These factors will vary by land type and local climatic conditions.

The combination of field data collection using the Swiftsynd process (Day and Philp 1997) with modelling and long-term simulation (McKeon *et al*. 2010) for determining LTCCs is a well-documented process. Seasonal pasture growth is measured in relation to soil type, fertility, depth, moisture holding characteristics and daily rainfall, for a minimum of one year. Data are used to calibrate the GRASP pasture growth model (McKeon *et al*. 2000, 2010, Clewett *et al*. this volume) for a land type and climate location, and the model is then run using long-term historical weather data to generate average annual pasture growth, rainfall use efficiencies (RUE) and safe utilisation rates necessary for calculating LTCC.

Land disturbed by mining activities in Australia is legally required to be suitably rehabilitated (Butler and Anderson, 2018; Queensland Government 2014). The New Acland coal mine in south-east Queensland is undertaking a program to rehabilitate its mined land to support pastures for grazing (SKM, 2013). Previously mined and rehabilitated land is usually different in structure and profile to the original pre-mined soil. These Anthroposols and some land types of the Darling Downs lacked supporting data to enable the calculation of LTCC, and thus, lacked a mechanism for setting stocking rates for sustainable grazing.

The open cut coal mining process at Acland continuously moves forward by sequentially removing soil and the sandstone/mudstone overburden (mine spoil) from new sections of the mine to a depth of some 60 m. The argillaceous mine spoil is used to progressively refill older sections of the mine which are then top dressed with freshly removed top soil to a depth of about 45 cm. Newly formed sections are rehabilitated by progressively sowing a mix of tropical pasture species to establish pastures, constructing fences, supplying water and subsequently grazing the land for beef production. Rehabilitation of the land in this way is known and referred to by industry and the community as either rehab land or rehab pasture.

The research reported here is integral to the Acland Grazing Trial (Bennett *et al*. in press, Melland *et al*. this volume, Clewett *et al*. this volume) established in 2013. The aim was to assess the sustainability and economic viability of beef cattle production from lands that were rehabilitated after open cut coal mining compared with surrounding unmined lands in preparation for relinquishment to commercial grazing (Newsome *et al*. 2014). The trial was established on undulating Brigalow lands that were mainly used for dairying, beef and crops before open cut coal mining began in 2002. These lands were first developed for agriculture and underground coal mining in the 1920s. Native pastures of the region originally consisted of the preferred species Kangaroo grass (*Themeda triandra*), Queensland bluegrass (*Dichanthium sericeum*), common wheatgrass (*Elymus scaber*)and wallaby grasses (*Austrodanthonia spp.*)(Silcock and Scatttini 2007), but with overgrazing became dominated by pitted bluegrass (*Bothriochloa decipiens*), green couch (*Cynodon dactylon*) and wiregrasses (*Aristida* spp.). The mainly clay soils have been derived from sandstones or overlying basalt flows. The mosaic of soils varied in depth and fertility and were well suited to grazing but marginal for cropping (McKenzie *et al*. 2017). Spatial differences in productivity should be expected when these soils are used for mine site rehabilitation.

While rehab pastures at Acland were accepted as meeting rehabilitation standards in 2018 by the Queensland Government (New Hope 2018), the productivity of pastures on Anthroposols for beef production had not been previously published. Productivity of sown rehab pastures is likely to decline with time due to decreasing levels of nitrogen availability after disturbance (Graham *et al*. 1985, Robbins *et al*. 1987; Myers and Robbins 1991; Peck *et al*. 2011). Furthermore, there is a dearth of information on the productivity of pastures for the grazing lands of the Darling Downs that have been established after a long period of cultivation for cropping (Bath 2016). This information is critical for determining long-term carrying capacities of properties and paddocks and developing grazing management plans.

The objective of this paper is to identify the pasture growth characteristics and long-term carrying capacity of sown pastures that have been established on rehabilitated mining lands in comparison to sown pastures established on un-mined but previously cultivated lands. Rainfall use efficiencies for calculating pasture growth, and effects of land type on estimates of long-term mean annual pasture productivity and livestock carrying capacity are addressed.

## Methods

### *New Acland mine trial sites*

The Acland Grazing Trial was located near the town of Acland in southern Queensland (-27.30 lat, 151.69 long) and adjacent to the Acland open cut coal mine (Figure 1). Pasture observations were made for five years using the Swiftsynd methodology (Day and Philp 1997) on rehab lands and on unmined lands that had been sown to pasture after a long period of cultivation for grain and forage cropping. The grazing trial had 3 paddocks on rehab land and a control paddock on previously cultivated unmined land. The trial also included observations of soil characteristics (Bennett *et al*. in press) including soil mineral N and potentially mineraliseable N (PMN), and cattle liveweight gains (Melland *et al*. this volume). Simulation of pasture productivity with the GRASP model (McKeon 2010; Clewett *et al.* this volume) with parameters calibrated to the observed soil, pasture and cattle measurements was used to address the influences of climate variability and to derive estimates of long-term (60-year) mean annual pasture growth and rainfall use efficiency.

After mining the Walloon coal measures the mine spoil in each rehab paddock was levelled, ripped, top soiled and sown without fertilizer using a mix of tropical grasses: Rhodes (*Chloris gayana*), Bisset creeping blue (*Bothriochloa insculpta* cv Bisset), green and Gatton panic (*Panicum maximum var. trichoglume*), silk sorghum (*Sorghum spp.* hybrid), and the native Queensland blue grass (*Dichanthium sericeum*); and legumes: Narrow-leaf vetch (*Vicia sativa var. angustifolia*), medics (*Medicago spp*.) and Lucerne (*Medicago sativa*). Hexham scent (*Melilotus indica*) was not sown but naturalised in pastures. Rehab pastures were sown in 2007 (Rehab 1), 2010 (Rehab 2) and 2012 (Rehab 3). They grew vigorously prior to first grazing in 2013 and the dry matter (DM) yields in Rehab paddocks 1 and 2 reached total standing dry matter yields (TSDM) of about 15,000 kg/ha following exceptionally high rainfall in 2010-11. The control paddock was also sown with the same pastures mix in 2012.

Pasture observations were also made for two years on adjacent unmined lands owned by the mining company, referred to as Benchmark (BMK) sites. The BMK sites are described in detail by Bennett *et al.* (in press).

### *Commercial grazing property trial sites*

To broaden comparisons of rehab lands with a range of unmined soil and land types, pasture observations were also made for three years on two commercial grazing properties on the Darling Downs. Swiftsynd exclosures were erected in grazed paddocks at three sites in October 2012. Two exclosures were on the Basaltic Uplands on relatively fertile but shallow clay soil at Colliery Park, Clifton (77 km to the south). Both paddocks containing the exclosures were successfully under-sown to oats using coated seed with several grasses at 10 kg/ha of coated seed (Rhodes, Gatton panic, Bissett creeping blue grass, Premier digit grass (*Digitaria eriantha*) and bambatsi (*Panicum coloratum*) and 1 kg/ha of Flaredale lucerne (*Medicago sativa*). Following more than 30 years of cropping one site was sown to pasture in 2007, and the other sown in 2012. The third site exclosure was on Brigalow Uplands at Roundview, Bell (52 km to the north-west), on a degraded couch grass pasture that had been cultivated for more than 40 years and originally sown to dairy pastures of unknown species in the 1970s. The soil at this site was a medium clay formed from sandstone.

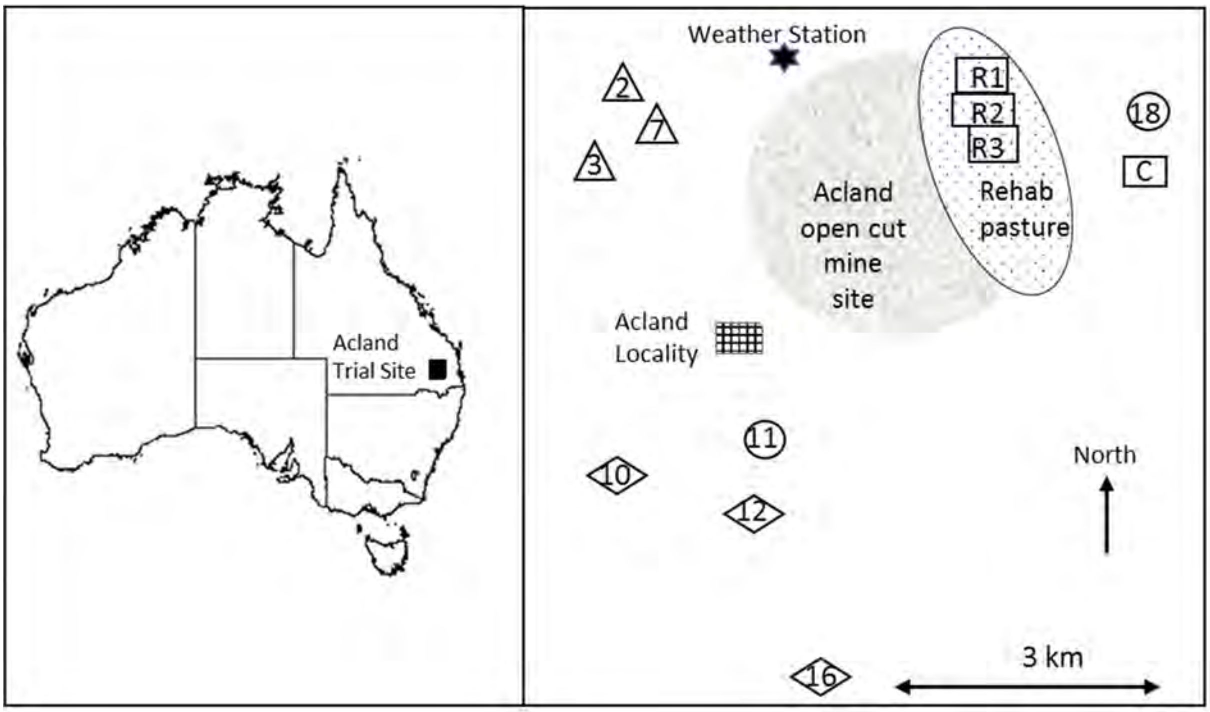



**Figure 1.** Location and layout of the Acland Grazing Trial with Swiftsynd exclosures located in rehab paddocks (R1, R2 and R3), the control paddock (C) on a Brigalow uplands land type, benchmark (BMK) sites on three land types: Mountain Coolibah on basalt (triangle sites 2, 3 and 7), brigalow uplands on Walloon sandstone (circle sites 11 and 18), and poplar box on alluvium (diamond sites 10, 12 and 16). Star shows location of automatic weather station.

**Table 1.** Land types (State of Qld, 2019) and Land Resource Areas (LRA) (Maher *et al.* 1996) surrounding the Acland Grazing Trial and found on the two commercial grazing sites at Bell and Clifton. ** Soil types and descriptions are from Harris et al. (1999).

| Land Type | LRA Name | Topography and geology | Vegetation before clearing | Soil description | Typical soils** & BMK profiles |
|---|---|---|---|---|---|
| Brigalow Uplands | 6a Brigalow Uplands | Gently undulating rises and plains on Walloon sandstones | Brigalow, belah, wilga open forest | Grey-brown cracking clays often sodic at depth | Acland, Moola and Edgefield (Control, BMK 11, 12 and 18) |
| Mountain Coolibah | 7a Basaltic Uplands | Undulating rises and rolling low hills on basalt overlying Walloon sandstone | Mountain coolibah open woodland | Black to dark brown clays brown clay loam | Mallard (BMK 2), Craigmore on slopes (BMK 3) or Burton (BMK 7) Clifton (CP 2007 & CP 2012) |
| Poplar Box Uplands | 8a Poplar Box Walloons | Undulating rises and plains on alluvium | Poplar box open woodland | Self-mulching, black cracking | Elphinstone (BMK 10, 12 and 16) |

| | | | | | |
|---|---|---|---|---|---|
| | | | | clays, sodic at depth | |
| Softwood Scrub | 6b Brigalow Uplands | Undulating to steep, low hills & rises on Walloon sandstone | Brigalow and dry vine scrub with bottle trees | Texture contrast sandy to clay loams overlaying sodic sub-soils | Walker (Rndview) |

### *Swiftsynd methodology*

The Swiftsynd methodology (Day and Philp 1997) aims to measure net primary production of pastures in ungrazed plots so that the opposing effects of pasture growth and losses (through grazing and detachment) can be separated. This methodology was used in an abbreviated "Minisynd" form as follows. Fencing was erected in in a representative area of grazed paddocks (usually 12 x 12 m areas) to exclude grazing. All paddocks had a history of grazing. These exclosures were mown to 5 cm height or less prior to the onset of the growing season and litter removed so that subsequent pasture growth was measured as total standing dry matter (TSDM) over the ensuing growing season. The exclosure was subdivided into four quarters and a single 0.5 x 0.5 m area (quadrat) was randomly selected from each quarter and pasture yield was measured by harvesting and bagging the TSDM. This gave four quadrats per plot at each harvest. Three harvests were made during the growing season: the first at the beginning of the growing season (in spring to mid-December), the second in summer (February) and third at the end of the growing season in autumn (April or May).

Pasture composition of exclosures was photographed and assessed before each harvest with major species recorded. Each quadrat was photographed and the following recorded: major species present, pasture height, estimated cover of green, dead, litter, bare ground and rocks and pasture yield fresh weight. TSDM was recorded after samples were dried in a forced draught dehydrator at 80$^{o}$ C for 48 hours with samples separated into grasses, forbs and legumes. Sub-samples were taken from each quadrat after drying and bulked by pasture type (grass, forbs, legumes) for each exclosure before chemical analysis for N, P, K and S. Harvests in December were to assess initial N uptake and yield (the product of pasture dry matter N concentration and yield). Harvests in mid-growing season, February, and at the end of the growing season were timed to observe peak dry matter and nitrogen uptake yields.

Swiftsynd exclosures were erected at 16 sites: one in each of the three Rehab paddocks of the Acland Grazing Trial (Rehab 1, Rehab 2 and Rehab 3) and 13 sites on previously cultivated unmined lands representing the three land types (Brigalow Uplands, Mountain Coolibah open woodlands and Poplar Box uplands) surrounding the Acland mine site. This included two sites in the control paddock (Control 1 and Control 2) of the Acland Grazing Trial, eight benchmark (BMK) sites within a 7 km radius of the Acland mine (Figure 1) and 3 sites on the commercial properties (two sites at Colliery Park and one at Roundview). Details of site locations and pasture species are shown in Table 2. Exclosures were erected at the following times: Oct 2012 (Colliery Park and Roundview), Nov 2013 (Rehabs 1, 2, 3 and Control 1), Oct 2014 (Control 2), and Oct 2016 (all BMK sites). Exclosures were reset in spring as described above and Swiftsynd observations were made at each site in the following seasons: Colliery Park and Roundview for three years (2012-13 to 2014-2015), Rehab and control paddocks for five years (2013-14 to 2017-18) and BMK sites for two years (2016-17 to 2017-18). Some sites were not harvested on some occasions as shown in the results (Table 4a).

Land condition was assessed at each site as the product of soil condition based on soil surface attributes, and pasture condition based on species composition (Quirk and McIvor 2007, Alexander *et al.* 2018) with ratings of “A” good condition to “D” very poor condition. Prior changes to land condition via soil erosion and nutrient depletion from previous land use for cultivation and annual cropping were considered as permanent changes to productivity and thus not included in field assessments.

**Table 2.** Swiftsynd site locations, year of pasture establishment and initially dominant pasture species.

| Land Type | Site | Latitude Longitude | Year established | Major pasture species in order of dominance |
|---|---|---|---|---|
| Rehab | Rehab 1 | -27.2705 151.7197 | 2007 | *Chloris gayana, Dichanthium sericeum* and *Medicago spp.* |
| | Rehab 2 | -27.2747 151.7150 | 2010 | *Chloris gayana*, *Panicum maximum* var. *trichoglume* and *Bothriochloa insculpta* cv. Bisset |
| | Rehab 3 | -27.2778 151.7237 | 2012 | *Chloris gayana* and *Bothriochloa insculpta* cv. Bisset |
| Brigalow Uplands | Control 1 | -27.2857 151.7459 | 2012 | *Chloris gayana* and *Bothriochloa insculpta* cv Bisset |
| | Control 2 | -27.2837 151.7429 | 2012 | *Chloris gayana* and *Bothriochloa insculpta* cv Bisset |
| | BMK 18 | -27.2766 151.7446 | 2009 | *Bothriochloa insculpta* cv Bisset |
| | BMK 11 | -27.3172 151.6945 | 2003 | Annual grasses and forbs |
| | Round-View | -26.8758 151.4510 | 1979 | *Cynodon dactylon* |
| Mountain Coolibah | BMK 2 | -27.2731 151.6671 | 2004 | *Bothriochloa insculpta* cv. Bisset |
| | BMK 3 | -27.2872 151.6515 | 2007 | *Dichanthium sericeum* and *Rhyncosia minima* |
| | BMK 7 | -27.2756 151.6801 | 2009 | *Bothriochloa insculpta* cv. Bisset |
| | Colliery Park 1 | -27.9747 151.9227 | 2008 | *Chloris gayana, Panicum maximum* var. *trichoglume, and Medicago sativa* |

| | | | | |
|---|---|---|---|---|
| | Colliery Park 2 | -27.9757 151.9325 | 2013 | *Panicum maximum* var. *trichoglume, Digitaria eriantha, Chloris gayana* and *Medicago sativa* |
| Poplar box Uplands | BMK 10 | -27.3623 151.7049 | 2003 | Annual grasses and forbs |
| | BMK 12 | -27.3290 151.6856 | 2007 | *Dichanthium sericeum* |
| | BMK 16 | -27.3623 151.7049 | 2006 | *Dichanthium sericeum* |

### *Soil and pasture N relationships*

Total soil mineral N supply, i.e. soil N that was potentially available for uptake by plants and/or subsequent immobilisation by soil microbes, was defined as PMN plus mineral N. By accounting for the soil bulk density, and by assuming that the total mineral N supply in the unmeasured depth of 20-40 cm was the average of values from the layers immediately above and below, total soil mineral N supply to 60 cm depth was expressed in kg/ha.

### *Modelling and Simulation*

The GRASP model (McKeon *et al*. 1990, 2000) modified for sown pastures (Clewett 2015, Clewett *et al*. this volume) was used to estimate daily changes in the soil water balance, pasture growth, nitrogen uptake and total standing dry matter (TSDM) of pasture. The model was calibrated to the field observations of TSDM in the Swiftsynd exclosures in the Rehab and Control paddocks, and at the BMK sites. The objective function of the calibration method was to minimise the root mean square of differences (RMSD) between model estimates and observed values. The calibrated model was used to estimate pasture growth rates and rainfall use efficiencies (RUE) (kg/ha pasture growth per mm of rainfall) between Swiftsynd harvests with rainfall calculated (to overcome errors in RUE caused by soil water storage) as the sum of evapotranspiration, runoff and deep drainage estimates. The calibrated model was also used in a long-term (60-year) simulation experiment to estimate the mean and frequency distribution of annual pasture growth (kg/ha DM) and RUE. This long-term simulation assumed a commercially relevant cattle-growing operation that adjusted stocking rates each year on 30$^{th}$ June to provide a long-term mean annual utilisation of 30% of pasture growth. This required a trial and error adjustment of stocking rates based on TSDM present at the end of the growing season (1$^{st}$ May) for each paddock/site in a series of simulation runs until the target of 30% utilisation was achieved. Gridded daily weather data (rainfall, temperature, pan-evaporation, radiation and vapour pressure) from the SILO database (Jeffrey *et al*. 2001, Stone *et al*. 2019) was used for input to the GRASP model for locations near the Acland township (lat. -27.30, long. 151.70) and the Colliery Park and Roundview trial sites. Data was sourced from the LongPaddock website (www.longpaddock.qld.gov.au/silo/) and was supplemented with daily weather data for the trial period from the New Hope automatic weather station (lat. -27.267, long. 151.698). Proximity of the weather station to Acland trial sites varied between 2 and 7 km as shown in Figure 1.

*Long-term carrying capacity*

LTCC is calculated from mean expected annual long-term pasture growth for a land type, its safe utilisation rate and expressed in adult equivalents (AE) where an AE is a 450 kg *Bos taurus* steer consuming 9 kg DM/day. A generic equation, also used in this paper, is:

LTCC (ha/AE) = Annual intake of an AE (eg. 3,285 kg DM) / (Average annual pasture growth for land type and climate location (kg DM/ha) x Safe utilisation rate (%) for the land type).

Modelled output is used in these calculations for land types in the trial and for comparisons with similar land types in other regions. The safe utilisation rate used for all trial calculations was estimated as 30% and thus in agreement with other studies (Clewett *et al*. this volume).

*Statistical analyses*

Statistical differences between grazing trial Swiftsynd sites and land types in mean annual values of TSDM for the 5 years of the trial and for the peak yield (mid-autumn) harvests were assessed using one-way analysis of variance and least significant difference (LSD) at $P<0.05$.

Comparisons of TSDM and pasture N yields between Rehab, Control and BMK sites were conducted by ANOVA (Genstat 19$^{th}$ edition, VSNi, UK) using the final five sampling times (i.e. the period when all sites were sampled) as replicates. Quadrats were included as an additional level of internal replication in the TSDM analyses. Variation in N composition within Swiftsynd plots was accounted for by bulking pasture samples from each of four quadrats rather than by measuring the N in each quadrat sample. Data were transformed using the natural logarithm to meet ANOVA assumptions of random residuals. Linear regression analysis was used to describe trends in N rundown of pasture.

*Nutrient analyses*

Conducted by SGS Australia Pty Ltd using NIRS techniques as per Melland *et al*. this volume.

## Results

*Swiftsynd Sites*

Mean annual rainfall (1898-2018) for the Acland site, downloaded from the SILO database (Jeffrey *et al*. 2001), was 642 mm. Mean annual rainfall for the trial period was 554 mm, 14% less than the historical mean with 2017-18 having 31% less than the historical mean (see Clewett *et al*, this volume for more detail).

*Pasture TSDM*

Peak pasture yields were observed at the end of the growing season in mid-autumn with TSDM in early and mid-summer at 34 and 65% of the mean peak yield of 3819 kg/ha. The mean peak yield of the three rehab sites (5644 kg/ha) was significantly greater ($P<0.05$) than the mean peak yield (3210 kg/ha) of the 13 unmined sites on Mountain Coolibah, Brigalow Uplands and Poplar Box land types which had means of 4006, 3393 and 2233 kg/ha respectively (Table 3b). The mean peak yield of the Poplar Box sites was significantly less ($P<0.05$) than the Mountain Coolibah sites but not significantly different ($P<0.05$) to the Brigalow Uplands sites. Variability within the rehab and unmined sites was high.

Pasture growth was greatest in Rehab 1 and 2 sites with mean peak yields of 5816 and 7400 kg/ha, respectively, growth rates of 25.5 and 34.1 kg/ha.day, respectively and rainfall use efficiencies of 11.9 and 16.0 kg/ha.mm, respectively. Peak yields, growth rates and RUE were least on sites in C and D condition and were equal to or less than 2537 kg/ha, 16.4 kg/ha.day and 5.2 kg/ha.mm, respectively (Table 3a). These pastures in C and D condition were the oldest pastures observed and had probably been subjected to over-grazing.

The peak pasture yield of the youngest rehab site (Rehab 3 sown in 2012) of 3716 kg/ha was significantly less ($P<0.05$) than the peak yields of Rehab sites 1 and 2 (sown in 2007 and 2010) but was not significantly different ($P<0.05$) from the unmined sites of Control 1 (3890 kg/ha) and Control 2 (2810 kg/ha) also sown in 2012. The mean TSDM of Rehab 3 over the last five Swiftsynd harvests was: (a) significantly less ($P<0.05$) than one of the unmined sites (BMK 18), (b) not significantly different from 5 unmined sites, and (c) significantly greater than 4 unmined sites (Table 3a). The mean growth rate and RUE of Rehab 3 (16.6 kg/ha.day and 8.1 kg/ha.mm, respectively) were more similar to the mean growth rate and RUE of unmined sites (18.4 kg/ha.day and 7.4 kg/ha.mm) than the growth rates and RUE for Rehab 1 and Rehab 2 described above.

Peak yields at Acland Swiftsynd sites averaged 3,117 kg /ha, 3,350 kg/ha and 5,644 kg/ha of TSDM for the BMK, Control and Rehab sites respectively over the duration of the trial from 2014 to 2018.

Pasture TSDM yields for autumn harvests averaged 2,537 kg/ha, 3,470 kg/ha and 5,548 kg/ha for Roundview, Colliery Park 2007 and Colliery Park 2012 sites, respectively.

Swiftsynd sites in the grazing trial were initially dominated by Rhodes grass with Bisset creeping bluegrass a sub-dominant in all but Rehab 1 where Queensland bluegrass was a sub-dominant (Table 2). At the trial’s completion in April 2018, Bisset creeping bluegrass dominated Swiftsynd sites in Rehab 2, Controls 1 and 2, was co-dominant with Rhodes grass in Rehab 3 and a minor component of Rehab 1 where Rhodes remained dominant.

**Table 3a.** Comparison of observed TSDM, growth rate and rainfall use efficiency (RUE) of pastures in the Rehab Swiftsynd sites to pastures on previously cultivated unmined land across three land types. Pasture age at the start of the trial, land condition and number of years of data (N) are shown. For mid-autumn harvest data from Rehab and Control treatments values with different letters are statistically different at $P<0.05$. Values without letters were not included in statistical analysis. Means were calculated giving equal weight to each observation. Mean TSDM given in last column is the mean of the last 5 harvests (2017-18) N=20 (5 harvests x 4 quadrats) with different letters indicating significant differences at the $P<0.05$ level.

| Land Type | Site | Pasture age at start (years) | N (years of data) | Land Cndtn Rating ** | Mean TSDM early summer (kg/ha) 9 Dec * | Mean TSDM mid-summer (kg/ha) 8 Feb * | Mean TSDM mid-autumn (kg/ha) 16 Apr * | Mean Growth Rate kg/ha.dy | RUE * kg/ha.mm | Mean TSDM (kg/ha) last 5 harvests |
|---|---|---|---|---|---|---|---|---|---|---|
| Rehab | Rehab 1 | 7 | 5 | A | 2190 | 3445 | 5816 [b] | 25.5 [b] | 11.9 [c] | 4840[g] |
| | Rehab 2 | 4 | 5 | A | 2503 | 6225 | 7400 [b] | 34.1 [b] | 16.0 [d] | 6244[h] |
| | Rehab 3 | 2 | 5 | A | 965 | 2135 | 3716 [a] | 16.6 [a] | 8.1 [b] | 2412[de] |
| Brigalow Uplands | Control 1 | 2 | 5 | A | 1150 | 2408 | 3890 [a] | 17.1 [a] | 8.1 [b] | 3472[efg] |
| | Control 2 | 2 | 4 | A | 765 | 1610 | 2810 [a] | 12.0 [a] | 5.6 [a] | 1606[abc] |
| | BMK 18 | 5 | 2 | A | 2860 | 2680 | 5605 | 27.4 | 12.2 | 3886[fg] |
| | BMK 11 | 11 | 2 | D | 880 | 1395 | 2390 | 12.7 | 5.1 | 1690[bc] |
| | R'nd View | 35 | 3 | C | | 2460 | 2537 | 16.4 | 5.2 | |
| Mountain coolibah | BMK 2 | 10 | 2 | B | 770 | 1825 | 3290 | 16.6 | 6.9 | 2200[bcd] |
| | BMK 3 | 7 | 2 | A | 1970 | 2995 | 3750 | 20.0 | 7.9 | 3092[ef] |
| | BMK 7 | 5 | 2 | A | 880 | 1910 | 3200 | 16.1 | 6.8 | 2220[cd] |
| | CPK 2007 | 6 | 3 | A | | 2380 | 3470 | 22.5 | 8.5 | |
| | CPK 2012 | 1 | 3 | A | | 4390 | 5548 | 36.0 | 13.3 | |
| Poplar box Walloons | BMK 10 | 11 | 2 | C | 680 | 1110 | 1605 | 8.4 | 3.3 | 1222[a] |
| | BMK 12 | 7 | 2 | A | 1230 | 1620 | 2965 | 15.5 | 6.4 | 2080[cd] |
| | BMK 16 | 8 | 2 | A | 990 | 1005 | 2130 | 10.6 | 4.6 | 1452[ab] |

* median date of harvest across the 5 years of the trial

** excludes consideration of soil erosion and nutrient depletion that may have occurred during a previous land use phase of cultivation and cropping.

**Table 3b.** Mean values of observed TSDM, growth rate and RUE of the Rehab pastures compared to mean values of pastures on previously cultivated unmined land on Brigalow, Mountain Coolibah and Poplar Box land types. Pasture age at the start of the trial, land condition and number of years of data are shown. Values with different letters are statistically different at P<0.05. Values without letters were not included in statistical analysis. Means were calculated giving equal weight to each observation.

| Land Type | Median Pasture age (years) | N (number of sites x years of data) | Land Cndtn Rating ** | Mean TSDM early summer (kg/ha) | Mean TSDM mid-summer (kg/ha) | Mean TSDM mid-autumn (kg/ha) | Mean Growth Rate (kg/ha.dy) | RUE (kg/ha.mm) |
|---|---|---|---|---|---|---|---|---|
| Rehab | 7 | 15 | A | 1886 | 3935 | 5644 [c] | 25.4 [b] | 12.0 [c] |
| Brigalow uplands | 7 | 16 | A, C & D | 1140 | 2118 | 3393 [ab] | 16.4 [a] | 7.0 [ab] |
| Mountain coolibah | 6 | 12 | A & B | 1207 | 2700 | 4006 [b] | 23.5 [ab] | 9.1 [bc] |
| Poplar box | 9 | 6 | A & C | 967 | 1245 | 2233 [a] | 11.5 [a] | 4.8 [a] |
| Mean | | | | 1300 | 2499 | 3819 | 19.2 | 8.2 |

** excludes consideration of soil erosion and nutrient depletion that may have occurred during a previous land use phase of cultivation and cropping.

*GRASP modelled predictions*

Estimates of annual growth from GRASP simulations gave reasonable agreement with observed values during the Acland trial period (Figure 2). Minimum RMSD values for the 13 Swiftsynd exclosures in the trial ranged from 113 kg/ha for the BMK 11 site (6% of the mean observed yield) to 897 kg/ha for the Rehab 2 exclosure (16% of observed mean yield). Several outliers occurred and were possibly caused by the spatial variability of rainfall. The regression of predicted versus observed pasture yield for all Swiftsynd sites at Acland gave a slope near unity (0.93) and an R squared value of 0.80. Similarly, predicted and observed pasture N uptake and yields were plotted. The fitted line slope was 0.91, close to 1:1, and $R^2$ was 0.53.

The mean annual pasture growth estimated by GRASP over the trial period for the rehab paddocks (5,951 kg/ha) was substantially greater than the mean annual production from pastures on unmined land (3,008 kg/ha). GRASP estimates of both the rehab and unmined exclosures showed a large variation between sites: 5,478 to 8,542 kg/ha TSDM for the rehab paddocks, and 1,369 to 4,690 kg/ha TSDM for the unmined land. Differences in soil fertility and pasture condition were probably the main causes of this variability. The mean of control exclosures (3,598 kg/ha) fits with the continuum of the unmined sites (Figure 3). Rainfall use efficiencies ranged from 3.3 to 16.0 kg/ha.mm rainfall (Table 3a) for the Swiftsynd sites and when averaged across land types were 12.0, 7.0, 9.1 and 4.8 kg/ha.mm rainfall for Rehab, Brigalow, Mountain Coolibah and Poplar Box land types respectively (Table 3b).

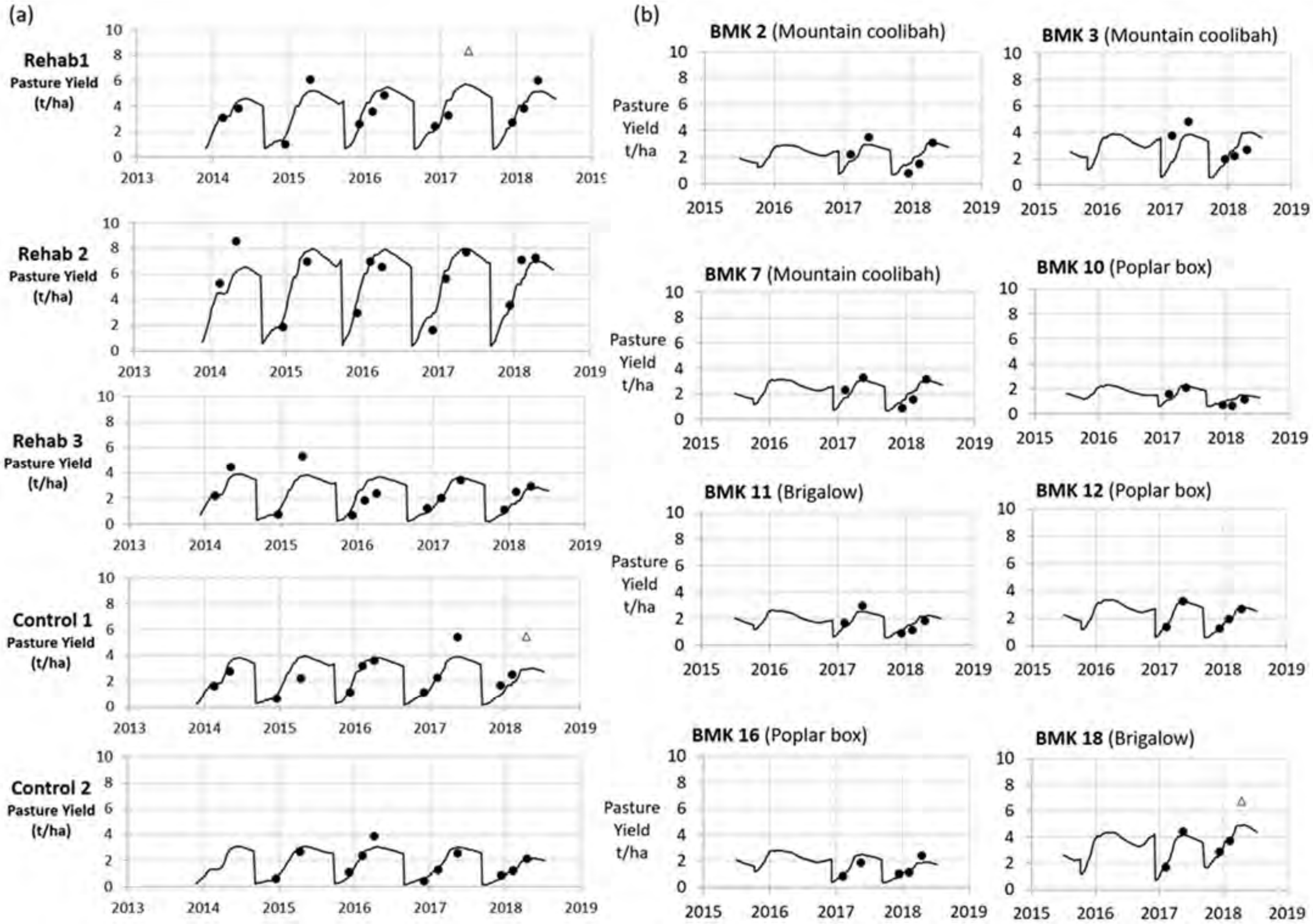
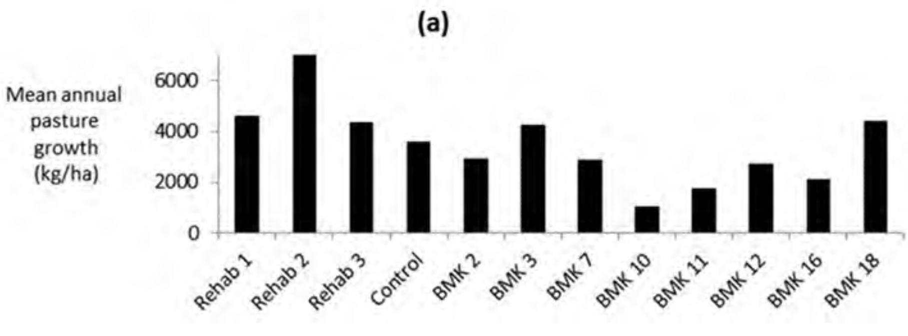



**Figure 2.** Estimates of pasture TSDM from GRASP simulations (solid line) versus observed pasture yields (solid points with outliers shown as open triangles) from Swiftsynd exclosures in (a) the three rehab paddocks and the control paddock over five years, and (b) the eight BMK sites over two years. All exclosures were mown each year in spring.



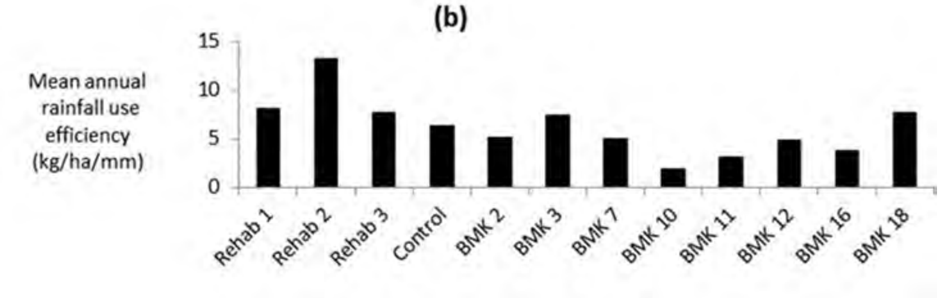



**Figure 3**. Estimates from GRASP simulations of mean annual pasture growth and rainfall use efficiency for the grazing trial rehab, control and BMK Swiftsynd enclosures for the period 2014 to 2018. A grazing pressure of 30% utilization of annual pasture growth was simulated for each exclosure.

*Pasture Nitrogen Concentrations and Yields*

Similar to TSDM, over the five sampling occasions in 2017 and 2018, mean N yields were lower ($P<0.05$) in Rehab 3 than in Rehabs 1 and 2 (Table 4a), were lower in Control 2 than in Control 1, and were equal or higher in Rehab 3 compared with the Controls. Also similar to TSDM, mean N yield in the Control 1 was equal to, or greater than, in the BMKs and Control 2 was equal to, or lower than, in the BMKs.

Statistical comparisons of mean seasonal N yields for the duration of the trial (5 years) and from the commercial grazing properties (all data given in Table 4a) could not be made for 2 reasons: the BMKs were only harvested in the last 2 years of the grazing trial and; Clifton and Bell were harvested at different times to Rehab, Control and BMK sites. However, data are presented for a complete picture (Tables 4a and 4b).

Nitrogen yields peak in summer and autumn. Mean N yields for summer and autumn harvests only, averaged 11.1 kg/ha, 11.4 kg/ha and 27.2 kg/ha for the BMK, Control, and Rehab sites respectively over the five years of the trial (2017 and 2018 only for BMKs). Mean N yields in mid-autumn were 39.5 and 40.6 kg/ha for Rehabs 1 and 2, respectively, twice as much as Rehab 3 and almost three times the N yield in both Control sites (Table 4a). Mean N yield at mid-autumn harvests for Roundview was 32.8 kg/ha and Colliery Park 2012 was 33.7 kg/ha compared with Colliery Park 2007, the older pasture, was 16.1 kg/ha. Mean N yield in mid-autumn averaged across Rehab sites was 33.4 kg/ha, almost twice that of the Brigalow and Mountain Coolibah land types (Table 4b), and more than twice the yield of the Poplar Box land type.

**Table 4a).** Mean N concentrations and mean N yields for harvests in early summer, mid-summer and mid-autumn for Swiftsynd sites at Acland, Bell and Clifton. Mean N yield given in last column is the mean of the last 5 harvests (2017-18) N=5 (5 harvests) with different letters indicating significant differences at the $P<0.05$ level.

| Land Type | Site | Mean %N early summer * | Mean N yield early summer (kg/ha) # | Mean %N mid summer * | Mean N yield mid summer (kg/ha) # | Mean %N mid autumn * | Mean N yield mid autumn # | Mean N yield (last 5 harvests) (kg/ha) |
|---|---|---|---|---|---|---|---|---|
| | Median Date | 9-Dec | 9-Dec | 8-Feb | 8-Feb | 16-Apr | 16-Apr | |
| Rehab | R1 | 0.89% | 18.92 | 0.57% | 19.38 | 0.70% | 39.52 | 29.1[d] |
| | R2 | 0.69% | 17.53 | 0.53% | 32.72 | 0.54% | 40.62 | 24.5[d] |
| | R3 | 0.63% | 5.02 | 0.55% | 11.16 | 0.56% | 19.95 | 13.0[c] |
| Brigalow | Control 1 | 0.59% | 6.30 | 0.44% | 10.22 | 0.35% | 13.71 | 13.3[c] |
| Uplands | Control 2 | 0.80% | 6.29 | 0.58% | 7.84 | 0.49% | 13.95 | 7.1[a] |
| | BMK 18 | 0.53% | 15.10 | 0.44% | 10.06 | 0.29% | 16.52 | 13.7[c] |
| | BMK 11 | 0.99% | 8.81 | 1.02% | 14.14 | 0.33% | 7.51 | 10.8[abc] |
| | RndVw | | | 1.80% | 33.23 | 1.90% | 32.77 | |
| Mtn Coolibah | BMK 2 | 0.61% | 4.32 | 0.50% | 9.12 | 0.37% | 12.09 | 9.7[abc] |
| | BMK 3 | 0.32% | 6.18 | 0.37% | 11.15 | 0.35% | 12.72 | 12.9[bc] |
| | BMK 7 | 0.58% | 5.07 | 0.38% | 7.15 | 0.30% | 9.72 | 7.8[ab] |
| | CPK 2007 | | | 0.80% | 14.80 | 0.67% | 16.08 | |
| | CPK 2012 | | | 1.25% | 21.22 | 1.10% | 33.68 | |
| Poplar | BMK 10 | 1.14% | 4.54 | 1.21% | 12.89 | 0.76% | 13.83 | 12.5[bc] |
| Box | BMK 12 | 0.50% | 5.70 | 0.54% | 9.46 | 0.47% | 14.91 | 12.0[abc] |
| | BMK 16 | 0.53% | 5.17 | 0.59% | 6.04 | 0.49% | 10.23 | 7.7[abc] |
| Mean | | 0.68% | 8.38 | 0.72% | 14.41 | 0.60% | 19.24 | 13.4 |

Means calculated giving equal weight to observations

* % N for grasses only

# N yield for grasses + dicots but not legumes

**Table 4b)** Mean N concentrations (%) and N yields (kg/ha) in harvested pasture for Rehab, Brigalow uplands, Mountain Coolibah and Poplar Box land types.

| Land Type | N concentration early summer * (%) | N yield early summer (kg/ha) # | N concentration mid summer * (%) | N yield mid summer (kg/ha) # | N concentrations mid autumn * (%) | N yield mid autumn # (kg/ha) |
|---|---|---|---|---|---|---|
| Rehab | 0.74 | 13.8 | 0.55 | 21.1 | 0.60 | 33.4 |
| Brigalow | 0.73 | 9.1 | 0.85 | 15.1 | 0.67 | 16.9 |
| Mtn Cool | 0.50 | 5.2 | 0.66 | 12.7 | 0.56 | 16.9 |
| Pop Box | 0.72 | 5.1 | 0.78 | 9.5 | 0.57 | 13.0 |

Means calculated giving equal weight to observations

* % N for grasses only

# N yield for grasses + dicots but not legumes

Pasture N yields plotted against pasture age in months since sowing showed Rehabs 1 and 2 aligned closely (Group 1) and Rehab 3 aligned with both Control 1 and 2 sites (Group 2) (Figure 4). Linear regressions were fitted to both groups showing significant declines in N yield with time since sowing.

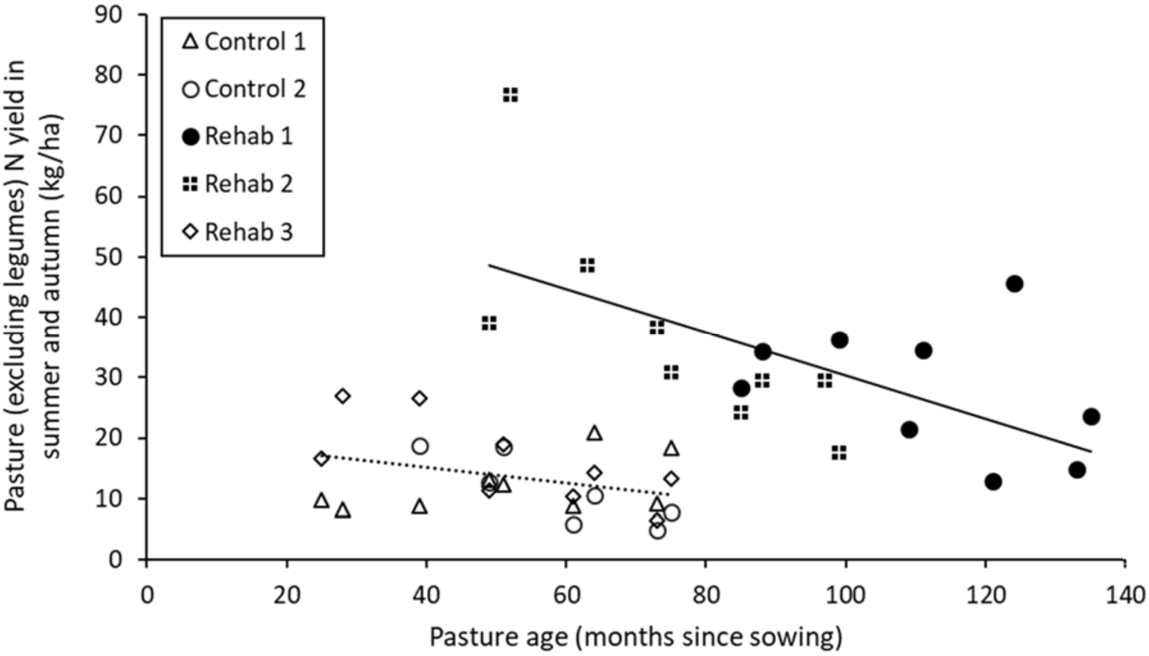



**Figure 4.** Relationships between pasture N yields (excluding legumes)(kg/ha) and age of pasture (months since sowing) in summer and autumn each year for Swiftsynd site harvests in the trial paddocks, showing fitted models for linear regressions of two clearly defined groups; Group 1 (solid symbols, Rehab 1 and Rehab 2 ) and Group 2 (open symbols, Rehab 3, Control 1 and Control 2). Regression statistics were; Group 1 Pasture N yield = -0.36*age_mo+66, $P<0.05$, $R^2$ 34.7 and Group 2 Pasture N yield = -0.13*age_mo+20, $P<0.1$, $R^2$ 9.2.

*Soil and pasture N relationships*

Over the 5 years of the trial, the total soil mineral N supply was highest in Rehab 2, followed by Rehab 1 and the BMK sites, and lowest in the Control and Rehab 3 (Bennett *et al*. in press and Figure 5). Trends over time in total soil mineral N supply, tested using regression analysis, indicated that there was a small and similar increase across the four trial sites (i.e. excluding the BMK sites) and the percentage variance accounted for by time of sampling was 42.3% (Bennett *et al*. in press). Pasture N yields in both summer and autumn were compared with total soil mineral N supply in spring and summer. The variance in pasture N yield was best explained by the relationship between pasture N uptake in mid-summer (February) and total soil mineral N supply measured in spring (November/December)(**Figure** 6). The linear slope estimate suggested that pasture N uptake was 42% of total soil mineral N supply.

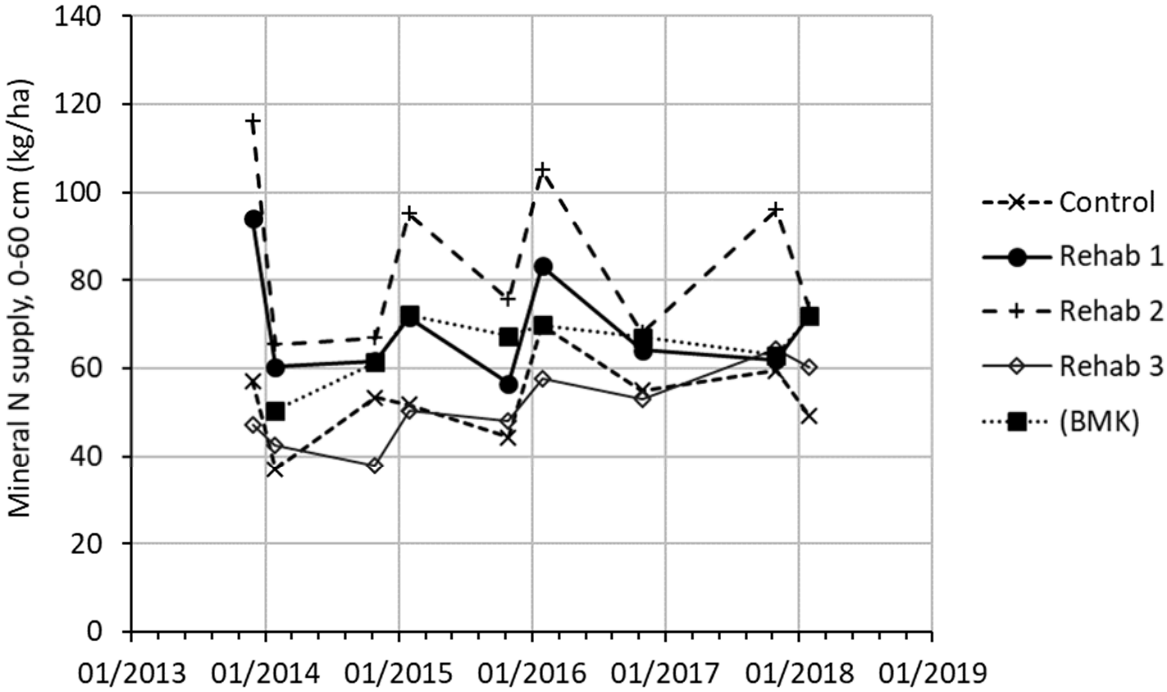



**Figure 5.** Total soil mineral N supply (PMN plus mineral N expressed as kg/ha using T3 bulk density data) for 0-60 cm soil depth across sites and sample times.

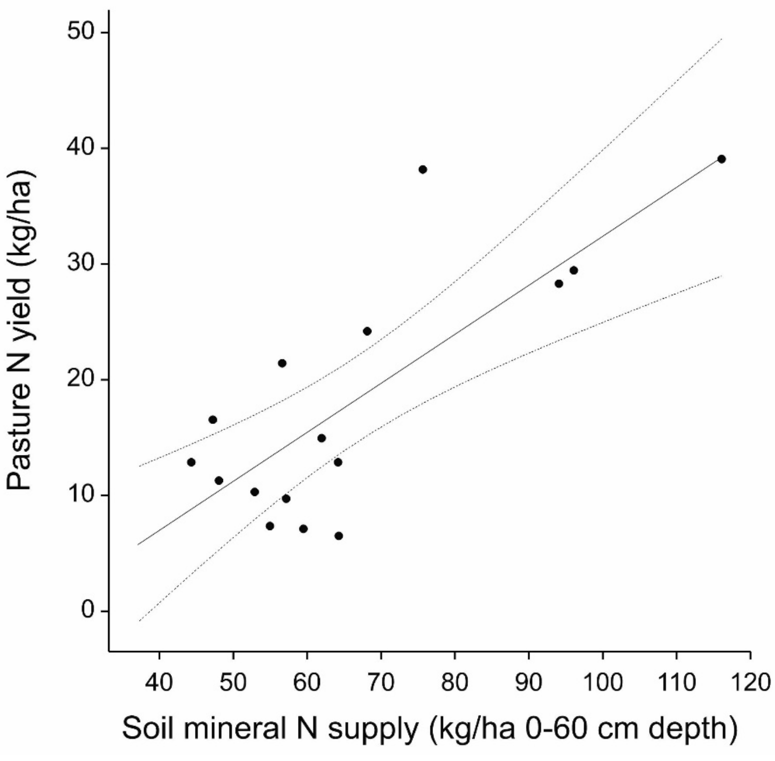


**Figure 6.** Pasture N yield (excluding legumes) in Swiftsynd sites (kg/ha of N) measured in mid-summer (February) vs total soil mineral N supply (mineral N plus PMN, 0-60 cm, kg/ha) measured in spring of 2013, 2015, 2016 and 2017 showing 95% confidence limits for the fitted regression ($P<0.001$, 58.8% variance accounted for, slope estimate 0.42, constant ns).

*GRASP estimates of long-term average pasture growth*

Long-term estimates for rainfall use efficiency and pasture productivity derived via 60-year simulations show a similar pattern to the trial period. Stratifying pasture production on the basis of land type showed the following order of productivity (high to low): Rehab sites (RUE 7.8 kg/ha.mm rainfall), unmined sites on Mountain Coolibah (RUE 5.2 kg/ha.mm rain), unmined sites on Brigalow Uplands (RUE 4.4 kg/ha.mm rain), and lastly unmined sites on the Poplar Box (RUE 3.2 kg/ha.mm rain) (Table 5).

**Table 5.** Estimates of long-term (60 year) mean annual productivity and variation around the mean (percentile) of rehab lands compared with the productivity of unmined land types in the district and calculated LTCCs at a safe utilisation rate of 30%. Estimates are from GRASP simulations of pasture growth and rainfall use efficiency (RUE) at a grazing pressure of 30 % utilisation of pasture growth.

| Land Type | Location & Land Condition** | | Site | Annual Pasture Growth (kg/ha) | | | Rainfall Use Efficiency (kg/ha.mm) | | | Mean LTCC (ha/AE) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 10th %ile | Mean | 90th %ile | 10th %ile | Mean | 90th %ile | |
| Rehab | Acland | A | Rehab 1 | 4250 | 4611 | 5026 | 5.9 | 7.2 | 8.4 | 2.64 |
| | | A | Rehab 2 | 6096 | 6528 | 7009 | 8.4 | 10.3 | 12.1 | 1.86 |
| | | A | Rehab 3 | 3424 | 3736 | 4099 | 4.8 | 5.9 | 6.8 | 3.26 |
| | | | **Mean** | 4590 | 4959 | 5378 | 6.4 | 7.8 | 9.1 | 2.45 |
| Mountain coolibah | Acland | B | BMK 2 | 2606 | 2977 | 3292 | 3.9 | 4.7 | 5.4 | 4.09 |
| | | A | BMK 3 | 3758 | 4091 | 4486 | 5.2 | 6.4 | 7.5 | 2.97 |
| | | A | BMK 7 | 2439 | 2659 | 2927 | 3.4 | 4.2 | 4.9 | 4.58 |
| | Clifton | A | Coll'Park | 3490 | 3856 | 4121 | 4.6 | 5.7 | 6.7 | 3.16 |
| | | | **Mean** | 3073 | 3396 | 3706 | 4.3 | 5.2 | 6.1 | 3.58 |
| Brigalow Uplands | Acland | A | Control | 2898 | 3169 | 3511 | 4.1 | 5.0 | 5.8 | 3.84 |
| | | D | BMK 11 | 1520 | 1831 | 2050 | 2.4 | 2.9 | 3.4 | 6.64 |
| | | A | BMK 18 | 3466 | 3775 | 4151 | 4.8 | 5.9 | 6.9 | 3.22 |
| | Bell | C | R'ndview | 2109 | 2309 | 2531 | 3.1 | 3.7 | 4.4 | 5.27 |
| | | | **Mean** | 2498 | 2771 | 3061 | 3.6 | 4.4 | 5.1 | 4.39 |
| Poplar Box Walloons | Acland | A | BMK 16 | 1869 | 2150 | 2394 | 2.8 | 3.4 | 3.9 | 5.66 |
| | | A | BMK 12 | 2460 | 2740 | 3065 | 3.5 | 4.3 | 4.9 | 4.44 |
| | | C | BMK 10 | 707 | 1272 | 1549 | 1.3 | 1.9 | 2.4 | 9.56 |
| | | | **Mean** | 1678 | 2054 | 2336 | 2.5 | 3.2 | 3.8 | 5.92 |
| **Mean** | | | | 2935 | 3265 | 3586 | 4.2 | 5.0 | 6.0 | 3.73 |

** excludes consideration of soil erosion and nutrient depletion that may have occurred during a previous land use phase of cultivation and cropping.

Seasonal growth patterns of pasture were strongly spring and summer dominant, irrespective of land type, with RUE being 59 and 56% higher respectively than the mean annual RUE (Figure 7). RUE in autumn and winter were 70 and 15% of mean annual RUE. These figures will be useful for calculating pasture growth from rainfall received at different times of the year when performing forage budgets in this region.

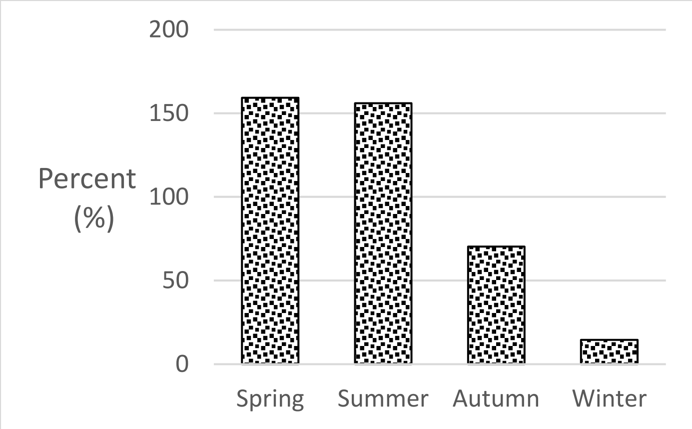



**Figure 7**. Seasonal RUE as % of mean annual RUE.

*Long-term carrying capacity*
The mean LTCC for the Rehab land type was the highest at 2.45 ha/AE, more than twice the mean LTCC of the Poplar Box land type (Table 5). Rehab 2 gave the highest potential LTCC of 1.86 ha/AE.

## Discussion

*Observed and predicted TSDM*
The observed data and estimates of mean annual pasture growth from GRASP show that previously mined and rehabilitated land can be as productive as unmined land. Peak pasture yield, determined by autumn harvests, averaged across years and treatments for rehabilitated land was 5,644 kg/ha. This was significantly greater (at $P<0.05$) than peak yields observed on the unmined Mountain Coolibah, Brigalow Uplands and Poplar Box sites which were 4,006, 3,393 and 2,233 kg/ha respectively. Similarly, GRASP estimates of the long-term mean annual pasture growth for the rehab and unmined lands were substantially different and were 4,959 and 2,989 kg/ha respectively.

Mean observed TSDM for the last 5 harvests of Acland sites, 2017 to 2018 showed that Control 1 was similar to or higher than the BMK sites ($P<0.05$) indicating Control 1 is representative of, or higher yielding than, unmined land. Control 2 was similar to BMKs 11, 2, 7, 10, 12 and 16 but significantly less than BMKs 18 and 3 ($P<0.05$) indicating it is also representative of unmined land. However, this has to be viewed in the context of land condition of these sites. Land in poor condition (C) is less than half as productive as land in good condition (A) (McIvor *et al* 1995; Alexander *et al*. 2018; Ash *et al*. 2002). All rehab and control sites were in A condition throughout the trial. Five of the BMK sites were in A condition, one in B, one in C and another in D condition. Poorer condition reduced average production of the BMK sites from their potential if all were in A condition. Bennett et al. (in press) found that the control sites were at the lower end of the fertility spectrum when compared with BMK sites for mineral N and Colwell P. Thus, productivity of the BMK sites should average higher than the control sites but average TSDM of the controls was either higher than, or similar to, that of the BMK sites as poor pasture species composition (and consequent poor land condition) was impacting productivity more than soil attributes. Further supporting the importance of pasture species composition relative to soil fertility on productivity was that there was no significant difference in soil Colwell P between BMK sites of land condition A, B or C (Bennett et al. in press). The poor land condition of several BMK sites eg. BMKs 11 and 10, is likely a carryover from their time under commercial crop production and heavy grazing as explained by McKenzie *et al*. (2017).

*Rehab productivity differences and pasture rundown*
Observed TSDM for Rehab 2 and to some extent, Rehab 1, were significantly higher ($P<0.05$) than unmined sites (Table 3a), which suggests they may consist of a different soil type to Rehab 3 and the Control. Land Resource Area (LRA) mapping of the area prior to mining indicate LRA 6a, Brigalow Uplands, covers the entire area that was later mined (Maher *et al.* 1996). However, soil and vegetation maps at a finer scale (Sattler and Williams, 1999; SKM 2013) of the original vegetation and published prior to mining these sites, show a band of soil described as “Rainforest and scrubs” derived from basalt (Regional Ecosystem 11.8.3) that could have been replaced into parts of Rehabs 1 and 2 post mining. These soils, referred to as Softwood Scrub, are naturally more fertile with higher P and N than the surrounding Brigalow and Poplar Box land types that are derived from Walloon sandstones (Biggs et al. 1999). This theory is consistent with Bennett *et al*. (in press) who showed variations in soil fertility between treatment paddocks of the trial. Also, it is likely the Swiftsynd site in Rehab 1 was situated on soil from this higher fertility vegetation/land type and a high proportion of the remaining paddock was on soil from Brigalow uplands derived from Walloon sandstone.

Thus, differences in productivity (TSDM) between Rehab treatments can be explained by their inherent soil properties and plant tissue chemical analyses. N uptake by pasture in Rehab 2 was initially relatively high but declined with time (Figure 4). Rehabs 1 and 2 were sown in 2007 and 2010 respectively, so are older pastures and would be expected to have less plant available N in the soil than a younger pasture such as that in Rehab 3 (Graham et al. 1985, Robbins et al. 1987; Myers and Robbins 1991; Peck et al. 2011). Mean N yields for the last 5 harvests were significantly higher ($P<0.05$) in Rehabs 1 and 2 than Control or BMK sites (Table 4a). This indicates the inherent higher soil fertility of Rehabs 1 and 2 is driving their pasture growth and quality at Swiftsynd sites. The soil N data given in Figure 5, showing total potentially available soil N, supports this theory. Cattle production (mean cumulative liveweight gain) from Rehab 2 was also higher ($P<0.05$) than from Rehab 3 and Rehab 1 which were equal (Melland *et al*. this volume).

Total soil mineral N supply helps explain the differences in uptake of N between sites and consequent productivity, and has potential as a predictor of N uptake in pastures. Figure 6 shows a general relationship between total soil mineral N supply and N yields in pasture across a 2.5-fold range of soil N fertility levels.

However, the soil N indicator was not sensitive enough to reflect declines within paddocks over time in observed pasture TSDM and N uptake (Melland et al. this issue, Bennett et al. in press). Rehab 2 had the highest available soil N (Bennett *et al*. in press), highest N yields in pasture and also, higher cattle production (Clewett *et al*. and Melland *et al*. this volume). This indicates firstly, that rehabilitated mining land can be as productive as unmined land and secondly, that Rehab 2 soil is likely composed of inherently higher fertility soils than other sites, as described above.

Rundown is an issue for all sown grass pastures and is characterised by an initial lift in productivity in the first year or so after pasture establishment followed by a rapid then slower exponential decline in productivity with time from sowing, ie age of pasture (Graham et al. 1985, Robbins et al. 1987; Myers and Robbins 1991; Peck et al. 2011). Rehab 1 was the oldest pasture, sown in 2007, where expected productivity decline should be greatest but appeared stable over the five years of the trial, with higher productivity and N yields than Rehab 3 and Control sites (Figures 4 and 5). Rehab 2 was also an older pasture than the Control and Rehab 3 but was more productive with higher N yields.

When grouping the sites according to the land type from which the soil was likely derived, there was a significant linear decline in pasture N yield with increasing age of the pasture (**Error! Reference source not found.**4) for both the Softwood Scrub sites (Rehabs 1 and 2) and the Brigalow Uplands sites (Rehab 3, Control 1 and Control 2), although the latter regression explained less than 10% of the variation in pasture N yield. The decline in pasture N yield was more rapid in the Softwood Scrub soil pastures (regression slope of -0.36 v -0.13. Figure 4) but even after about 9 years N yields were significantly ($P<0.05$) higher in the Softwood Scrub soils than in the Brigalow soils (Table 4a). The rapid but delayed decline in pasture N yield in pastures grown on the softwood scrub soils could be explained by their inherently higher fertility soils (Figure 4 and Bennett *et al*. this volume).

Additionally, grass pastures exhibit preferences for soil types and fertility levels (Partridge *et al*. 2009). Rhodes grass, a high N demanding pasture species, dominated Rehab and Control site plots in 2014 with Bissett creeping blue grass, a lower fertility succession grass (Partridge 2003; Partridge *et al*. 2009) a sub-dominant, a reflection of high available soil N at the trial's commencement. At the trial's completion in May 2018 and in the absence of grazing, Bissett creeping blue dominated both Control plots and Rehab 2 Swiftsynd sites, a further indication of the extent of pasture rundown without any potential influence of selective grazing affecting this change.

Symptoms of rundown in grass pastures include declining N yields, pasture growth and animal productivity (Robbins et al. 1987). While declining N yields were evident in Swiftsynd exclusion areas of this trial no significant ($P<0.05$) pattern of declining pasture productivity was detected, other than in grazed pasture assessments in the Control and Rehab 3 paddocks (Melland *et al.* this volume), possibly for several reasons. Firstly, at the commencement of the trial the Rehab 1 and 2 pastures were in their 8th and 5th seasons of growth respectively. The rundown process was very close to complete for Rehab 1 and more than half complete for Rehab 2 and thus lack of any clear evidence in the field observations of rundown in TSDM was to be expected. The expected duration of rundown to 5% of the initial lift was estimated to be 7 and 9 years after the establishment year for Rehab 1 and 2 (Clewett *et al.* this volume) and in less time (4 years) for the Rehab 3 and control paddocks because of their lower fertility (N uptake). TSDM observations on Rehab 3 and Control 2 started in the 3rd and 4th years of growth and declined over time (Figure 2) but the declines were not significant at $P<0.05$. No decline of TSDM was evident in Control 1. It was likely to have been impacted by a local rainfall event in year 5 (i.e. the 7th year of growth) and the same event probably impacted BMK 18 (Figure 2, open triangles). Following calibration of the GRASP model to the Swiftsynd pasture data in this paper and the Botanal pasture data in Melland *et al.* (this volume) the estimated loss in pasture growth of the Rehab 1, 2 and 3 and control paddocks due to pasture rundown over the 5-year duration of the trial was 1, 16, 17 and 14% respectively of mean annual growth (Clewett et al. this volume). It is likely that larger reductions in TSDM would have been observed if observations had commenced when pastures were established.

Secondly, variation in seasonal conditions combined with differences in soil types between Rehabs 1 and 2 (higher fertility) and Rehab 3 and the Control plots (lower fertility) were likely to have masked the expression of rundown. In their work on rundown, Robbins *et al*. (1987) had pastures of differing ages in each year growing on the same soil type ie pastures that were one, two, three, four and five years old in any year. This allowed valid comparisons each year irrespective of season. That wasn't possible in the Acland trial where soils differed in their fertility levels which confounded the pasture age effect for comparisons in any single year. Thus, while rundown was evident in N uptake data, not all symptoms of rundown were expressed clearly in this trial.

Two important messages can be gleaned from the trend lines in Figure 4, which indicate declining N uptake by pastures as they age: 1) the data can be split into two groups viz. Rehabs 1 and 2 reflect high fertility land types, most likely Softwood Scrub derived from basalt, as suggested above, and Rehab 3 and Controls reflect Brigalow Uplands of lower fertility; and 2), the rate of rundown was more rapid in Rehabs 1 and 2 than in Rehab 3 and the Controls.

The trends in N yield decline in Rehab and Control sites pose the questions, "How much more will rundown reduce the productivity of rehabilitated land?" and "Where will productivity stabilise?" The productivity of the older pasture site at Colliery Park is a likely indication of stable pastures. The initial lift in productivity associated with subsequent pasture rundown was estimated to have increased mean annual pasture growth over the five years of the Acland Grazing Trial by 12% with the greatest lift of 41% occurring in year 1 in the Rehab 3 and control paddocks (Clewett *et al*. this volume). This compares with an estimated reduction in productivity of 37% at the Colliery Park site where a legume (lucerne) was contributing some N to available soil pools.

*GRASP Predicted pasture productivity, RUE and LTCCs.*

The level of agreement between observed and predicted TSDM (Figure 2) was assessed as sufficient to warrant the use of modelled outputs to assess rainfall use efficiencies and long-term pasture productivity in simulation experiments using the GRASP pasture growth model.

These estimates are useful in defining the long-term livestock carrying capacity of pastures (Alexander *et al*. 2018, Hunt 2008, Hunt *et al.* 2014, Walsh and Cowley 2016), and as a basis for informing grazing management decisions via feed budgeting calculations to estimate pasture growth during the grazing period for calculation of short-term stocking rates. However, there is some uncertainty in GRASP based estimates of LTCC because of assumptions in the model, particularly assumptions about the capacity of GRASP to capture ecological processes that are incrementally causing change through time in pasture composition, productivity and condition.

The GRASP estimates of pasture growth were greatest in Rehab 2 with an estimated mean annual growth and RUE of 6,528 kg/ha and 10.3 kg/ha.mm rainfall respectively (Table 5). This equates to a LTCC of 1.86 ha/AE (Table 5) which is by far the highest LTCC of the land types within the trial. This compares favourably with a similar land type in the Burnett (Softwood Scrub) that had a RUE of 11.5 kg/ha.mm rain (State of Queensland 2014; Bath 2016). Next highest was the Mountain Coolibah land type followed by Brigalow Uplands and then Poplar Box (Table 5). The RUEs of the Mountain Coolibah and Brigalow Uplands land types were similar to the 4.5 kg/ha.mm RUE of native black spear grass (*Heteropogon contortus*) pastures in the Burnett (McKeon *et al.*1990). Sites with low TSDM such as the pastures in poor condition, e.g. BMK 11, had very low RUE (2.9 kg/ha.mm) with lower infiltration rates likely (Fraser and Stone 2016). It is surprising that productivity of the Brigalow uplands land type is less than the Mountain Coolibah as the current estimate of median annual pasture growth for Brigalow Uplands at Bowenville (approximately 23 km from the trial site) is 5,640 kg/ha, whereas Mountain Coolibah for the same climate centre is given as 4,660 kg/ha (State of Queensland 2014) based on field observations throughout northern Australia and modelled estimates of pasture growth (Day et al. 1997; Stone et al. 2019). In the neighbouring Burnett region, RUE of a Brigalow Belah land type was 11.5 kg/ha.mm rain (State of Queensland 2014) compared with 4.5 kg/ha.mm from Brigalow Uplands in this paper. The lower RUE reported in this paper is likely due to soil erosion, soil structural decline and nutrient depletion from years of grain and forage cropping and heavy grazing with near zero nutrient return to the soil (Heijnien 1999, Biggs 2007, McKenzie et al. 2017). The level of rundown in the Burnett study was not stated by the authors (State of Queensland 2014) but it is likely that the predicted annual production of the Brigalow Belah land type in the Burnett is before N rundown has reached its full extent. Similarly, the basaltic soils, Mountain Coolibah from this trial and Silver-leaved Ironbark from the Burnett, have RUEs of 5.5 and 6.3 kg/ha.mm respectively, the former having a history of cropping and rundown. Erosion and nutrient depletion can result in changes to the original land type that preclude returning it to original soil profile, nutrient status and level of productivity (Buisson *et al.* 2019). Thus, it would be useful to add a postscript to land type names that indicate previous land use history such as "*Brigalow Uplands, Old cultivation*" and consequently in practice it becomes a new land type.

These results highlight two important aspects of modelling pasture growth that need to be addressed in future work and stated when quoting predicted pasture productivity derived from modelling. Firstly, do the predicted production and RUE figures represent old cultivations with a history of nutrient depletion and heavy grazing or are they for lands that have been maintained in good condition throughout their cropping and grazing history? Secondly, what stage of N rundown do the stated production figures represent? End users of predicted pasture growth data need this information to make well informed and better decisions regarding LTCCs and performing forage budgets. Knowing the range of production from peak productivity on newly developed country through to productivity of the country at equilibrium once rundown has occurred will better inform decisions around sustainable grazing management.

Forage budgets for determining seasonal pasture availability relative to the number of stock being carried have been employed in the rangelands of northern Australia (Taylor and Paton, 2016) with escalating interest due to satellite imagery facilitating the determination of biomass remotely (P Tickle pers. comm.). Mean daily growth rates of pastures on Rehab and Mountain Coolibah land types were similar and significantly higher ($P<0.05$) than Poplar Box land type, with Brigalow Uplands similar to Mountain Coolibah but less than Rehabs. Mean growth rates were 25.4, 23.5, 16.4 and 11.5 kg/ha.day for Rehab, Mountain Coolibah, Brigalow Uplands and Poplar Box land types respectively (Table 3b). Long-term simulations (60 years) revealed that seasonal growth patterns varied from 15% of the mean annual RUE in winter to 159% of the mean in spring and 156% in summer (Figure 7). This data will be useful for calculating "in grazing" pasture growth for forage budgets in different seasons.

*Swiftsynd methodology*

Swiftsynd provides a valuable method for observing the net primary production of pastures. However, there are several drawbacks. Firstly, clipping the pasture quadrats with shears is time consuming and thus the number and size of samples is usually small (4 quadrats of 0.25 $m^2$ per exclosure at each harvest in this study) and this restricts capacity to measure spatial variability and leads to higher levels of variability in measurement of TSDM. The estimated average time required for 2 experienced operators was 1.25 hrs per exclosure per harvest in this study with the largest proportion of time (90%) measuring pasture height, recording cover, cutting the four quadrats and separating into grasses, forbs and legumes. In total there were 103 Swiftsynd harvests across the 5 years and 16 sites of the Acland Trial. While the mean yield of these harvests was 2879 kg/ha, the average standard deviation of the 4 quadrats at each harvest was 1002 kg/ha and the average coefficient of variation was 33%. This variability in field data was marginally greater than the differences between the GRASP and observed estimates of TSDM. The RMSD was 793 kg/ha or 28% of the mean. The destructive process used in Swiftsynd harvests is a further limitation of the methodology as the same location cannot be repeatedly measured. Non-destructive imaging methods are available such as near infrared and terrestrial laser scanning by LiDAR (Light Detection and Range), and are capable of rapidly estimating TSDM, height, volume, cover and potentially species over large and spatially diverse areas with useful accuracy (Anderson et al. 2018, Schaffer and Lamb 2016 and Schulze-Bruninghoff *et al*. 2019). Inclusion of these methods within the Swiftsynd methodology would help to improve the accuracy of field observations while reducing labour and time inputs. The entire area of the exclosure could be measured at each harvest and more frequently (e.g. to capture the effects of species differences at the start of each growing season when mowing and raking is used to reset the pasture). This would shift the emphasis of cutting quadrats towards verification of optically-based estimates of pasture attributes and collection of samples for chemical analysis. Time saved in sampling might allow more exclosures to be sampled giving greater coverage of variability across paddocks and land types. A review of the Swiftsynd methodology is recommended.

## Conclusions

Data from the Swiftsynd sites showed pastures on rehabilitated and previously mined areas were as productive, or better, than pastures on unmined soils. This data has been successfully employed in the GRASP model which tested the long-term productivity, sustainability and viability of these Anthroposols relative to surrounding unmined land and found rehabilitated land to be as productive and viable as surrounding unmined land. While results suggest a rundown in pasture productivity of 30 to 40% over six years the full extent of productivity decline as pastures age is unknown at this stage. It is possible that pasture species in the rehab paddocks may continue to change with pasture age as a result of rundown. For example, Rhodes grass and panic species may be replaced in time with grasses such as creeping bluegrass and Queensland bluegrass that tolerate and persist in lower nitrogen conditions.

The rainfall use efficiency and long-term pasture productivity data will enable the development of grazing management plans for the sustainable management of both mined and unmined lands. This will allow mining operators to manage sustainably towards the transition of rehab paddocks to commercial agriculture. The data also provides critical information (LTCC, RUE) to allow development of similar grazing management plans for land types on commercial enterprises elsewhere on the Darling Downs.

## Acknowledgements

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## Conflicts of Interest

The authors declare no conflicts of interest.

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## Figures and Tables

**Figure 1.** Location and layout of the Acland Grazing Trial with Swiftsynd exclosures located in rehab paddocks (R1, R2 and R3), the control paddock (C) on a Brigalow uplands land type, benchmark (BMK) sites on three land types: Mountain Coolibah on basalt (triangle sites 2, 3 and 7), brigalow uplands on Walloon sandstone (circle sites 11 and 18), and poplar box on alluvium

(diamond sites 10, 12 and 16). Star shows location of automatic weather station.

**Figure 2.** Estimates of pasture TSDM from GRASP simulations (solid line) versus observed pasture yields (solid points with outliers shown as open triangles) from Swiftsynd exclosures in (a) the three rehab paddocks and the control paddock over five years, and (b) the eight BMK sites over two years. All exclosures were mown each year in spring.

**Figure 3**. Estimates from GRASP simulations of mean annual rainfall use efficiency and pasture growth for the grazing trial rehab, control and BMK Swiftsynd enclosures for the period 2014 to 2018. A grazing pressure of 30% utilization of annual pasture growth was simulated for each exclosure.

**Figure 4.** Linear regressions of pasture N yields in summer and autumn each year for Swiftsynd site harvests in the trial paddocks against age of pasture (months since sowing), separated into two clearly defined groups, Group 1 (closed symbols; Rehab 1 and Rehab 2) and Group 2 (open symbols; Rehab 3, Control 1 and Control 2).

**Figure 5.** Total soil mineral N supply (PMN plus mineral N expressed as kg/ha using T3 bulk density data) for 0-60 cm soil depth across sites and sample times.

**Figure 6.** Pasture N uptake in Swiftsynd sites (kg/ha of N) measured in mid-summer (February) vs total soil mineral N supply (mineral N plus PMN, 0-60 cm, kg/ha) measured in spring showing 95% confidence limits for the fitted regression ($P<0.05$, 58.8% variance accounted for, slope estimate 0.42, constant ns)

**Figure 7**. Seasonal RUE as % of mean annual RUE.

**Table 1.** Land types (State of Qld, 2019) and Land Resource Areas (LRA) (Maher et al. 1996) surrounding the Acland Grazing Trial and found on the two commercial grazing sites at Bell and Clifton. ** Soil types and descriptions are from Harris *et al*. (1999).

**Table 2.** Swiftsynd site locations, year of pasture establishment and initially dominant pasture species.

**Table 3a.** Comparison of observed TSDM, growth rate and rainfall use efficiency (RUE) of pastures in the Rehab Swiftsynd sites to pastures on previously cultivated unmined land across three land types. Pasture age at the start of the trial, land condition and number of years of data (N) are shown. For mid-autumn harvest data from Rehab and Control treatments values with different letters are statistically different at $P<0.05$. Values without letters were not included in statistical analysis. Means were calculated giving equal weight to each observation. Mean TSDM given in last column is the mean of the last 5 harvests (2017-18) N=20 (5 harvests x 4 quadrats) with different letters indicating significant differences at the P<0.05 level.

**Table 3b.** Mean values of observed TSDM, growth rate and RUE of the Rehab pastures compared to mean values of pastures on previously cultivated unmined land on Brigalow, Mountain coolibah and Poplar box land types. Pasture age at the start of the trial, land condition and number of years of data are shown. Values with different letters are statistically different at P<0.05. Values without letters were not included in statistical analysis. Means were calculated giving equal weight to each observation.

**Table 4a).** Mean N concentrations and mean N yields for harvests in early summer, mid-summer and mid-autumn for Swiftsynd sites at Acland, Bell and Clifton. Mean N yield given in last column is the mean of the last 5 harvests (2017-18) N=5 (5 harvests) with different letters indicating significant differences at the P<0.05 level.

**Table 4b)** Mean N concentrations and N yields in harvested pasture for Rehab, Brigalow uplands, Mountain Coolibah and Poplar box land types.

**Table 5.** Estimates of long-term (60 year) mean annual productivity and variation around the mean (percentile) of rehab lands compared with the productivity of unmined land types in the district and calculated LTCCs at a safe utilisation rate of 30%. Estimates are from GRASP simulations of pasture growth and rainfall use efficiency (RUE) are at a grazing pressure of 30 % utilisation of pasture growth.

**NAC Attachment 2 - Acland Grazing Trial: GRASP simulation analyses**

**Target Journal:** Animal Production Science

**Title:**

# Sustainability of beef production from brigalow lands after cultivation and mining: (3) pasture rundown, climate and grazing pressure effects

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**Keywords**

Sustainable grazing systems, pasture production, modelling, mine rehabilitation, residual risk

**Short Title** for running header: Acland Grazing Trial: GRASP simulation analyses

**Summary** (text for table of contents in journal)

Sustainable production is essential in agriculture and required for land rehabilitation. Field studies, modelling and long-term simulations showed pasture growth, beef production and economic returns from rehabilitated lands after open cut coal mining at Acland in Southern Queensland were equal to or greater than from unmined nearby lands retired from cultivation. Effects of environment (land type, pasture rundown, climate variability and grazing pressure) on outcomes are quantified to derive improved grazing management practices that help reduce risks of overgrazing.

## Abstract

The sustainability and economic viability of beef production from sown pastures established on rehabilitated land after open cut coal mining, and on unmined lands previously cultivated for grain and forage crops is evaluated using a modelling and simulation approach. The study area in southern Queensland is marginal for cropping but well suited to grazing. It has a subhumid subtropical climate, clay soils, a mosaic of land types and a nutrient depleted landscape caused by erosion and cultivation giving rise to pastures with reduced productivity. The GRASP grazing systems model was modified and calibrated with short-term (five-year) field observations from the Acland Grazing Trial, and then used with long-term (60-year) weather data to estimate effects of land type, pasture rundown, climate and grazing pressure on productivity and economic returns. Soil, pasture and cattle observations from the grazing trial were supplemented with pasture observations on six commercial properties. Potential nitrogen uptake in GRASP was used to influence key pasture growth processes and accounted for 64% of variation in observed annual growth. The initial lift in productivity associated with pasture rundown was estimated to have increased pasture and cattle productivity during the trial period by 12% and 14% respectively. Estimates of long-term mean annual growth of pastures on unmined lands retired from cultivation on three land types (Mountain Coolibah, Brigalow Uplands and Poplar Box) were 3398, 2817 and 2325 kg/ha respectively. Pasture growth was greater on rehabilitated lands; 3736 kg/ha on the site most typical of rehabilitated lands and a mean of 4959 kg/ha across three sites. Seasonal conditions had large effects on cattle liveweight gain (133-213 kg/head per year during the trial), however, pasture growth was the main driver of beef production and economic returns per hectare. Results show the rehabilitated lands to be sustainable for beef production at grazing pressures up to 30% utilisation of annual pasture growth, and comparable with grazing systems on native and sown pastures in good condition with overgrazing quantified as a significant residual risk to sustainable production if not managed effectively. While research needs on pasture rundown and building soil fertility are identified, the methods used here could be applied more generally.

# Introduction

Sustainable land use is a pivotal concept in agriculture and is defined as an ability to continue through time (Hansen 1996). Thus, a sustainable land use is one resilient to the threats of climate risk and changes in the environment that affect productivity in both the short-term such as pasture rundown (Radford *et al.* 2007, Peck *et al.* 2011, 2017) and also the long-term with land management practices in place to overcome threats of soil erosion and nutrient depletion (McKenzie *et al.* 2017), and threats of overgrazing on pasture condition and productivity (McKeon *et al.* 2004). Sustainability also includes biophysical, economic and social factors operating at field, farm and wider scales (Smith and McDonald 1998) with sustainability a required attribute in assessing land use suitability for alternative agricultural uses (Queensland Government 2013).

Rehabilitation of land after mining is the process of making a former mine site safe, stable and self-sustaining, and is a requirement of mining best practice and certification of lands as ecologically sustainable (Bell 1996, Roe *et al.* 1996, Queensland Government 2014, Butler and Anderson 2018, McCullough *et al.* 2018). In rehabilitating land for return to commercial agriculture, the aim is to achieve an equal or improved level of land use suitability compared to land use prior to mining. For example, where grazing lands are used for open cut coal mining then successful rehabilitation requires operations to backfill the mine, restore the landform, replace top soil and re-establish pastures that once again provide the capacity for sustainable grazing, economic returns and social benefits that equal or exceed levels prior to mining. Rehabilitated lands or lands retired from cultivation to grazing are novel ecosystems (Hobbs *et al*. 2006, Buisson *et al*. 2019) and thus a period of transience is expected before stability is achieved.

This paper is the fourth in a series evaluating results from the Acland Grazing Trial located on rehabilitated lands at the New Acland open-cut coal mine (27.27 S, 151.72 E) in the sub-tropical central Darling Downs region of southern Queensland, Australia. The trial aimed was to assess the sustainability and viability of cattle production from rehabilitated mined land compared to beef production from nearby unmined pasture lands (Newsome 2014). Field observations from the trial are described in three papers regarding the soils, pastures, grazing system and beef production (Bennett *et al. submitted*, Paton *et al. this volume*, and Melland *et al. this volume*). The grazing trial was established in 2013 by the Acland Pastoral Company on land previously used for dairy, beef and crop production before open cut coal mining began in 2002. The area forms part of the Acland Land System (Vandersee 1975) of the Brigalow region and has a mean annual rainfall of 642 mm. Local soils, typically Dermosols and Vertosols (Isbell, 2002) derived from the underlying labile fine-grained sandstone of the Walloon coal measures (Wainman and McCabe 2019), or overlying tertiary basalt flows (Vandersee 1975), are suited to grazing but are marginal for cropping because of susceptibility to erosion, sodic subsoils and shallow depths that limit soil water availability. The soils vary in depth and fertility causing spatial variability in agricultural production and have been subject to severe erosion, structural decline and nutrient depletion from intensive agriculture (cultivation, dryland grain/forage cropping and dairying with high intensity grazing) (Biggs *et al.* 1999, Heijnen *et al.* 1999, Partridge *et al.* 2009, McKenzie *et al.* 2017, Bennett *et al.* submitted). This has led to a large proportion of marginal crop lands in the region such as those in the Acland Land System being retired to pasture with 50,000 ha retired in the region (Biggs 2007, Partridge *et al.* 2009). Vegetation in the area prior to clearing formed a mosaic of ecosystems (Sattler and Williams 1999) with mountain coolibah (*Eucalyptus orgadophila*), brigalow (*Acacia harpophylla*) and poplar box (*Eucalyptus populnea*) being indicative of geology, soils and productivity, and hence these species are valuable for defining land types (Whish 2019) for use in land management (Alexander *et al.* 2018). While high grazing pressures can return short-term economic benefits (Bowen and Chudleigh 2018), history shows that a key challenge and risk in managing both native and sown pastures in the region for beef production is to avoid losses in pasture condition and productivity through overgrazing (Tothill and Gillies 1992, McKeon *et al.* 2004, Bortolussi *et al.* 2005, Maczkowiack *et al.* 2011).

The GRASP grazing systems model (McKeon *et al.* 1990, 2000 and 2010, Day *et al. 1997a and* 2005, Clewett *et al.* 1998) adapted for sown pastures (Clewett 2015) is used in this paper to assess the effects of land type, pasture rundown, climate and grazing management on the productivity and economic returns from beef production based on sown pastures established on: (a) rehabilitated mining land, or (b) lands previously cultivated for dryland grain and forage crops. An overarching aim was to integrate the short-term (five-year) field observations from the Acland Grazing Trial with GRASP modelling and simulation to assess the long-term productivity and economic viability of beef production from rehabilitated mined land compared with surrounding unmined lands. The initial lift and subsequent rundown of sown pastures caused by short-term changes in availability of soil nitrogen (N) on the productivity of the grazing system (Graham *et al.* 1985, Robbins *et al.* 1986, Peck *et al.* 2011 and 2017) is considered together with the effects of long-term cultivation on nutrient depletion and productivity (McKenzie *et al.* 2017). Effects of climate and grazing pressure on pasture condition and losses in productivity from overgrazing are evaluated to assess residual risk and to identify grazing management guidelines for sustainable production.

## Methods

The GRASP model was used to estimate pasture growth, cattle production and economic returns for the Acland Grazing Trial's experimental period (23 Jan 2014 to 22 June 2018) and then evaluate the sustainability of pastures and beef production via simulation experiments based on long-term (60-year) analyses of the grazing system. Parameters in GRASP were calibrated to the soil, pasture and cattle observations on rehabilitated (rehab) and unmined land of the Acland Grazing Trial. Methods for these observations are fully described in companion papers by Bennett *et al. (submitted),* Paton *et al.* (*this volume*) and Melland *et al.* (*this volume*) and are summarised below to provide adequate context for this paper. The trial had three rehab paddocks and an unmined control paddock plus a series of eight benchmark (BMK) sites surrounding the Acland coal mine on unmined commercially managed pasture lands that had a history of cultivation. These observations were supported by field data from a parallel study (Clewett 2015) of pasture growth on six commercial beef properties in the region (Figure 1). All unmined sites (control paddock, BMK sites and commercial properties) were grouped by the three main land types (Whish 2019 and Alexander *in prep*) of the Acland Land System surrounding the mine. This grouping of unmined sites by land type provided a basis for comparison of productivity; particularly for comparisons with rehab lands.

### Site Descriptions

All sites had a long history of intensive land use through dairying and/or cultivation and cropping (often > 50 years) and were cleared of trees except for the Mirrabooka site which had mature trees (basal area of 3 $m^2$/ha) on steep topography with shallow soil. The Control paddock and BMK sites on gently undulating rises and hills surrounding the

Acland mine were located on clay soils (mainly vertosols and dermosols) on three land types named after the original vegetation. These land types and some key characteristics (Harris *et al.* 1999, SKM 2008, Whish 2019, Alexander (*in prep*) are:

- Mountain Coolibah open woodlands (BMK sites 2, 3 and 7) formed on tertiary basalt commonly on low hills and often with high phosphate soils but can be very shallow as in the case of BMK 2 because of the underlying basalt rock
- Brigalow Uplands (Control paddock plus BMK sites 11 and 18) usually on mid to lower slopes and formed on Walloon sandstones with low to high phosphate soils and often with saline sodic subsoils
- Poplar Box Uplands (BMK sites 10, 12 and 16) usually on lower slopes and drainage lines with soils derived from the Walloon sandstones that are often low in phosphorous and have saline sodic subsoils.

This stratification also fitted four of the six commercial properties (Roundview, Cattle Camp, Colliery Park and Mirrabooka) as shown in Figure 1. The Oakleigh paddock was a Brigalow plains land type and was added to the Brigalow Uplands group, and the Canimbla paddock on Poplar Box plains was added to the Poplar Box Uplands group.

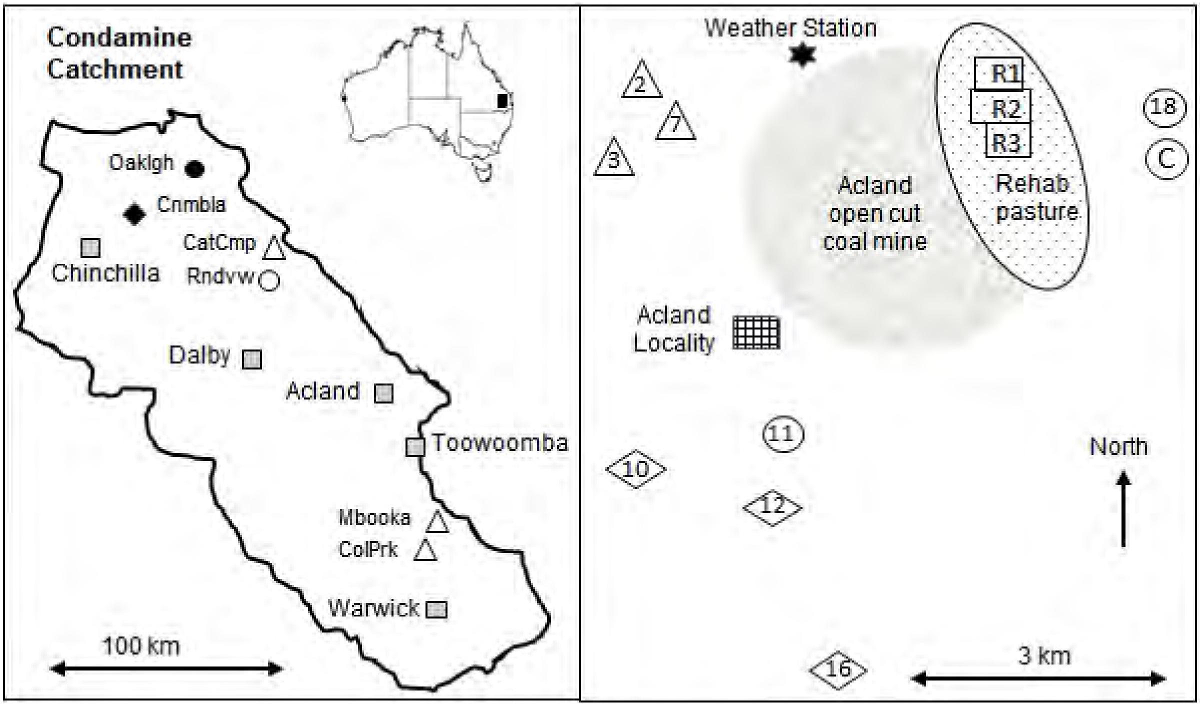


**Figure 1.** Location of field observations sites and townships across the Condamine River catchment in the Darling Downs region (left panel), and layout of the Acland Grazing Trial (right panel) with: (1) pasture and cattle observations from three rehab paddocks (R1, R2 and R3), and one unmined control paddock (C) on Brigalow Uplands, and (2) pasture observations from the following unmined sites: eight benchmark sites at Acland (numbered 2, 3, 7, 10, 11, 12, 16 and 18), and six commercial beef properties: Canimbla (Cnmbla), Cattle Camp (CatCmp), Colliery Park (ColPrk), Mirrabooka (Mbooka), Oakleigh (Oaklgh) and Roundview (Rndvw). Symbols for land types are: Mountain Coolibah on basalt (△), Brigalow Uplands (○), Brigalow Plains (●), Poplar Box Uplands (◇) and Poplar Box Plains (◆). Squares show locations of townships. Star shows location of automatic weather station.

Rehab pastures on the Acland mine site were first sown to pasture with a mix of tropical pasture species in 2005 and continued each year as the continuous mining and rehabilitation process progressed to the south-west. Topsoil and the Walloon sandstone overburden (mine spoil) was removed in strips from the mine's leading edge and then hauled to backfill and rehabilitate the mine's trailing edge (SKM 2008). The new undulating landform of mine spoil was shaped, contour ripped, top-dressed with soil to a target depth of 30 cm and then seeded without fertiliser. The rehab lands used for the Acland Grazing Trial were established by 2007, 2010 and 2012 and were fenced as the following paddocks: Rehab 1 (22 ha), Rehab 2 (32 ha) and Rehab 3 (22 ha) respectively. The unmined control paddock (21 ha) was sown to pasture in 2012. This five-year span in pasture establishment enabled evaluation of differences in pasture rundown pathways.

The Acland Mine is located within the mapped boundary of a Brigalow Uplands Land Resource Area (LRA) (Harris *et al.* 1999) and combines a range of land types across the mine site including Brigalow Uplands and Mountain Coolibah (Harris *et al.* 1999, SKM 2008, Queensland Historical Atlas 2011). It is likely that the vertosol and dermosol topsoils retrieved for the rehab paddocks were derived from both of these land types creating large differences in soil nutrient levels (Biggs *et al.* 1999). Soil analyses showed the Rehab 2 paddock to have the highest fertility (highest levels of phosphate, organic carbon and total nitrogen) while the rehab 3 paddock had the lowest fertility of the rehab paddocks (Bennett *et al.* submitted). These soil analyses also showed the vertosol and dermosol soils of the control paddock and BMK sites to have low organic carbon and total nitrogen, variable levels of phosphorus, and to be nutrient depleted compared to the nutrient status of virgin soils.

Most unmined sites were retired from cultivation to pasture in the period 2003-2012. Rhodes grass (*Chloris gayana*) and creeping blue grass (*Bothriochloa insculpta*) were the most frequently encountered species across sites (Paton *et al. this volume*, Melland *et al. this volume*, Clewett 2015). Some notable variations in species composition and condition were: Gatton and green panic (*Panicum maximum)* in the Rehab 1 and 2 paddocks, Gatton panic at Colliery Park, high proportions of Queensland blue grass (*Dichanthium sericeum*) in BMK sites 3 and 16, Buffel grass (*Cenchrus ciliaris*) in the pastures at Oakleigh and Canimbla, Couch grass (*Cynodon dactylon*) exceeding 95% of the pasture at Roundview, and winter active legumes such as medics (*Medicago spp*), lucerne (*Medicargo sativa*) and vetches *Vicia satia)* present in several paddocks in some years. All unmined sites were in good ("A") pasture condition, except the BMK 11 site and the Roundview and Mirrabooka paddocks were in poor ("C") condition, and BMK 10 site was in very poor ("D") condition. These sites were dominated by annuals and had been in pasture for at least 10 years.

The rehab and control paddocks of the Acland Grazing Trial were maintained in good condition by applying best management practices (Paton *et al.* 2011) and were periodically grazed at stocking rates of 47 to 171 adult equivalents (AE) per 100ha (Melland *et al. this volume*) where an AE represents a 450 kg *Bos taurus* steer. There were 17 grazing periods with either three or four grazings each year of 6 (± 2) weeks followed by a rest period of 8 (± 4) weeks. Cattle were either grazed in "rest" paddocks when not grazing the trial paddocks or were sold with a new cohort (usually young steers) purchased for the next phase of grazing. Livestock numbers were adjusted for each period of grazing and set in accordance with pasture production to maintain an equivalent grazing pressure across all paddocks. Grazing management aimed to achieve 30% utilisation of annual pasture growth; a level considered to be ecologically sustainable, commercially relevant and equal to the “safe” utilisation rate used in defining long-term carrying capacity as discussed below.

### Field Observations

Field observations of pasture TSDM (total standing dry matter) and pasture growth were made on ungrazed fenced exclosures (12 m * 12 m) using the Swiftsynd methodology (Day and Philp 1997) for: (a) three years (2013-2015) on the Colliery Park and Round view sites, (b) five years (2014-2018) on rehab lands and control paddock and (c) two years (2017-2018) on the eight benchmark sites (Paton *et al. this volume*). The exclosures were mown to ground level in September-October at the start of the growing season in spring each year. Pasture growth was recorded by measuring TSDM (separated to grass and dicots) from four quadrats of the exclosure in early summer, mid-summer and at the end of the growing season in mid-autumn. This data and analyses of pasture nitrogen content at each harvest were used to calibrate parameters in the GRASP model.

Estimates of TSDM under grazing were also made across each of the Acland Grazing Trial paddocks (Melland *et al. this volume*) and across each of the grazed paddocks on the commercial property sites. These observations were made using the Botanal methodology (Tothill *et al.* 1992) of visually estimating pasture TSDM (validated against measured quadrats), cover and percent green and recording species present in approximately 50 quadrats (0.5m * 0.5m) along 4 transects in each paddock at regular times throughout the year. Botanal observations were made immediately before each period of grazing of the Acland Grazing Trial with the observations used to set stocking rates. Cattle liveweights were recorded at the start and end of each grazing period. On commercial properties the Botanal observations were made at the end of the growing season. Grazing management on all properties varied with seasons and all employed pasture spelling.

### Grasp Description

The GRASP (Grass Production) model (McKeon *et al.* 1990 and 2010, Clewett *et al.* 1998, Day *et al. 1997a and* 2005 and Rickert *et al.* 2000) has been routinely used for analysis of grazing systems (e.g. McKeon *et al.* 2000, Scanlan *et al.* 2011 and 2014, Clewett 2015, Peck *et al.* 2017). It was developed as a robust weather-driven, daily time-step model for simulating the growth and condition of grazed and un-grazed native pastures in Northern Australia through time periods of several seasons to > 100 years.

Weather inputs to GRASP are daily historical values of rainfall, minimum and maximum temperature, vapour pressure, solar radiation and synthetic pan evaporation. This enables simulation of the daily soil water balance and estimates of water losses via runoff, deep drainage, soil evaporation and plant transpiration. The main driver of pasture growth in GRASP is transpiration and is adjusted for the effects of nitrogen availability, light interception, temperature, potential growth rate, pasture condition and tree competition. Estimates of pasture quality, senescence and detachment rates enable daily estimates of pasture TSDM and nitrogen uptake. The initial lift and rundown of sown pastures over several years after establishment is estimated. While plant phenology and root dry matter are not calculated, changes in soil carbon are estimated using a module based on the ROTHC model (Coleman and Jenkinson 1999). Annual beef production (per head and per hectare) is estimated as a function of length of growing season, annual pasture utilisation (quantity of pasture eaten by livestock as a percentage of pasture growth) and stocking rate. Daily changes in animal liveweight have consequent effects on intake of pasture and provide feedback effects of grazing pressure on pasture growth. There is also a feedback of pasture utilisation on pasture condition that operates on an annual basis and this enables simulation experiments to assess the influence of grazing pressure on pastures, beef production and sustainability. An economics module calculates annual gross margins.

Gridded daily weather data (Jan 1889 to June 2018) from the SILO database (Jeffrey *et al.* 2001) on the LongPaddock website (Stone *et al.* 2019) was used for input to GRASP simulations for the Acland Grazing Trial sites and for sites on commercial properties. A location near the Acland township (-27.30 S, 151.70 E) was used for the grazing trial paddocks and benchmark sites. This was supplemented by rainfall and temperature data from an automatic weather station located on the mine site (27.267 S, 151.698 E) for the 2014 to 2018 trial period with several gaps in-filled with SILO data. The Acland Grazing Trial and benchmark sites were within 7 km of the mine site weather station. The Rainman software (Clewett *et al*. 2003) was used for climate analyses.

Parameters defining plant available water in GRASP were estimated from: (1) field measurements of soil texture, bulk density and root distribution (Bennett *et al.* submitted), (2) estimates of field capacity as a function of soil texture (% clay) using the data and equations of Rab *et al.* (2011), and (3) parameters in the GRASP model derived from field data (Day *et al.* 1997a, McKeon *et al.* 2010) to define the lower limit of soil water in each layer as a function of field capacity. Soil water was estimated for two upper soil layers of fixed depth (0-10 cm and 10-50 cm) and a third layer below 50 cm of variable depth to a maximum of 120 cm. The depth of topsoil covering the mine spoil in the rehab paddocks was variable (45 ± 30 cm) and these paddocks were modelled as two layers of topsoil and the third layer as mine spoil with the texture of light clay containing 40% rock fragments. The mine spoil should be a potentially useful contributor to soil water storage and plant growth because it is a labile argillaceous material of medium to very fine-grained sandstone derived from volcanic fragments with a high proportion of pore space filled by smectite clays (Wainman and McCabe 2019). It is explored by plant roots, is moderately alkaline (pH 8.3), has a high cation exchange capacity and the salinity, sodicity and toxicities levels are of no concern (Bennett *et al.* submitted). Basalt rocks at depth and near the surface of the BMK 2 and Mirrabooka sites were modelled to reduce water storage by 30% in the lower layers.

Several components in GRASP for estimating pasture growth were modified to capture annual changes in soil fertility associated with the initial lift and subsequent rundown of sown pasture productivity, and more generally to recognise the key role of nitrogen in regulating plant growth rates. Firstly, the nitrogen uptake parameter identified as parameter 99 (p99), and defined here as the nitrogen content of pasture multiplied by pasture TSDM, was changed to become a variable to reflect changes in the availability of soil nitrogen through time. However, the parameter specifying the minimum level of nitrogen concentration in green leaves (p101) was not changed and was thus held as a constant through time for each site. Secondly, the potential regrowth rate of pasture (p6), the growth rate per unit of plant transpiration (p7), radiation use efficiency (p8) and the rate of nitrogen uptake (p98) were changed to become variables dependent on nitrogen uptake and were increased between limits as a function of p99. Equations derived for these modifications were based on the data of Day *et al.* (1997a) and McKeon *et al.* (2010).

The economics module in GRASP was set up to calculate operating gross margins for a steer growing operation. This included cattle costs per head for purchase, transport, health and sale but excluded capital costs for land and labour, and costs of pasture establishment and maintenance. An interest cost on cattle purchased (5% p.a.) was applied to enable estimates of stocking rate effects on economic returns. Cattle costs were based on purchase of young steers landed on farm on 1st July which then grow 130-230 kg over 12 months to produce feeder steers (e.g. 410 – 510 kg at 22 months) for sale to feedlot on 30th June. Cattle sale prices were based on mean values (2014-18) of the MLA Eastern Young Cattle Indicator (EYCI) and Dalby saleyard price margin for young steers (3% higher than the EYCI). After adding transport costs this gave a purchase price of $2.73 /kg liveweight for young cattle landed on farm. Sale price ($/kg) of feeder steers (400-500 kg) were generally lower than young cattle and averaged 86% of yearling price ($/kg) over the trial period. Costs for animal health ($7/head), marketing (5.5% of sale price) and mortality (0.5%) were applied.

### Model Calibration

The objective function used in model calibration was the minimum root mean square of differences (RMSD) between observed values and model estimates. Some observed values rated as outliers (possibly caused by experimental factors such as rainfall variability) were excluded from the calibration process but included in comparative statics such as regression of predicted versus observed. Pasture growth parameters were first calibrated using the Swiftsynd data from the ungrazed exclosures. These parameter values were then carried forward to the second stage of calibrating where pasture senescence and detachment parameters were calibrated to Botanal estimates of TSDM under grazing. Cattle production parameters were calibrated to the observed liveweight gain data recorded on entry and exit from the trial's 17 grazing periods with cattle numbers in the model the same as those applied in the field. During the trial's "rest" periods, the continuity of animal liveweight and liveweight gain estimates for the trial paddocks were maintained in GRASP by reducing stocking rates to 1% of the "trial" rate and thus: (a) modelled pastures could recover from grazing under this very light grazing regime, and (b) modelled estimates of annual liveweight gain (1 July to 30 June) could be calculated. Animal liveweight was initially set to the first observed value of a cattle cohort and this value was excluded from calculations of RMSD, means and linear regression statistics of slope and coefficient of determination ($R^2$). The "warm up" period for GRASP is generally 3 years, however, this was extended to the first 10 years of simulation when calculating long-term means so that effects of pasture rundown were removed. Weather conditions in 2016-17 were conducive to the growth of legumes (Melland *et al. this volume*) contributing greatly to annual cattle liveweight gain. Legume growth was estimated to add 25 kg/hd to liveweight in the Rehab 1, Rehab 3 and the control paddock and 28 kg/hd in Rehab 2. This is consistent with Peck *et al.* (2017). The episodic and phosphate dependent growth of legumes and their potential to supply nitrogen to pastures and protein to cattle (Clarkson 1987 and 1989, Peck *et al.* 2011) were not included in the following simulation experiments.

### Simulation Experiments

The calibrated model was used in simulation experiments to evaluate the grazing system by estimating changes in pasture growth, rainfall use efficiency, stocking rate and livestock carrying capacity, pasture utilisation (percent of annual pasture growth eaten by cattle), cattle live weight gains and gross margins. These outputs are collectively referred to as key performance indicators. Liveweight gain parameters derived for the Acland Grazing Trial were applied to the benchmark and commercial property sites. The same economic parameters were applied across all sites. Nil grazing pressure from other herbivores was assumed. The simulation experiments assessed:

(1) Effects of pasture rundown on productivity. Simulations that gave a mean annual grazing pressure of 30% utilisation of pasture growth were run with and without the effects of pasture rundown.

(2) Effects of land type on long-term (60-year) mean annual key performance indicators calculated for the Mountain Coolibah, Brigalow Uplands and Poplar Box land types in comparison to results for the rehab paddocks. This simulation aimed to achieve a long-term mean annual utilisation of 30% of annual pasture growth. Trial and error adjustment of stocking rates based on estimated TSDM present at the end of the growing season (1st May) was used for each site in a series of simulation runs until the target of 30% utilisation was achieved.

(3) Effects of climate variability on probability distributions of the key performance indicators. This simulation examined changes in the key performance indicators for each 5-year period over the last 120 years. This data was used to assess the presence of increasing or decreasing trends in pasture growth. The relationship of the average Southern Oscillation Index (SOI) during winter and spring with the key performance indicators was examined.

(4) Effects of grazing pressure on the key performance indicators. Stocking rates were adjusted in this simulation with the intake of young cattle on 1st July each year to consume 1, 10, 20, 30, 40 and 50 % of TSDM at the end of the growing season (1st May) over the following 12 months. This simulation examined the effects of adjusting grazing pressure to levels that diverge from the estimated "safe" level of 30% utilisation, and also assumed the parameter settings in GRASP determined for native and sown pastures at other locations concerning the effects of grazing pressure on pasture condition were relevant to the sown pastures being examined. These issues are further addressed in the discussion.

Persistently high grazing pressure was specified in GRASP to cause a loss of pasture condition which then reduces soil water availability, nitrogen uptake and pasture growth. Changes in pasture condition are estimated as a function of annual pasture utilisation using continuous ramp relationships (Clewett 2009) fitted to the stepped functions quantified from the studies of Ash *et al.* (1996 and 2002) and McKeon *et al.* (2000). This approach enables grazing management studies to avoid unstable outcomes where pasture condition and utilisation rates are near the thresholds of stepped processes (Scanlan *et al.* 2014, Clewett 2015). The pasture condition state in GRASP with a range of 0 (pasture in good condition) to 11 (pasture in very poor condition) is: (a) either reduced or improved if annual pasture utilisation is respectively higher or lower than 35%, and then (b) transformed to percent perennial grasses in the pasture (Figure 2). The maximum change in any year is one pasture condition unit if the annual utilisation of pasture growth is < 20% or > 50 %. If pastures are subjected to continuous heavy grazing (exceeding 50% utilisation each year) for 3, 5, and 7 years then pastures are reduced from 90% perennials (pasture in A condition) to 70, 34 and 11% perennials respectively. This is equivalent to pastures at B, C and D levels of pasture condition respectively with productivity reduced to 75, 45 and 25% of pastures in A condition (Quirk and McIvor 2007, Alexander *et al.* 2018) assuming no impediments from soil condition. Recovery in pasture condition (through light grazing) is enabled if in B or C condition but is prevented if pasture is in D condition.

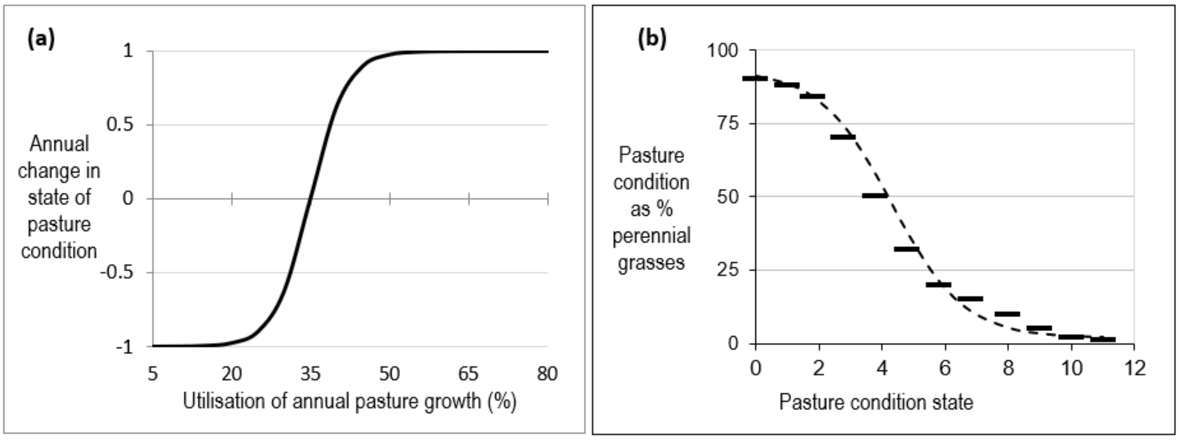


**Figure 2** GRASP functions for estimating changes in pasture condition: (a) Influence of percent utilisation of annual pasture growth on annual changes in pasture condition state, and (b) transformation relationship (dashed line) derived to estimate pasture condition (expressed as percent perennial grasses in the pasture) from the stepped pasture condition states (horizontal bars) quantified by the studies of Ash *et al.* (1996, 2002) and McKeon *et al.* (2000).

## Results and Discussion

The following sections first describe weather conditions during the trial period, changes to GRASP and calibration of the model to the observed data, then results and discussion of the simulation experiments concerning pasture rundown, effects of land type, climate and grazing management before concluding with a general discussion.

### Weather conditions during trial period

Weather conditions during the 5-year trial period at Acland were variable. Mean annual rainfall (July-June) for the trial period (562 mm) was 14% less than the long-term (1898-2018) mean of 642 mm with some periods very dry such as the 2015-16 and 2017-18 seasons when rainfall was 26 and 31% respectively below the long-term mean (Figure 3). Rainfall was summer dominant (38% of average annual rainfall) and least frequent in winter (16% of average annual rainfall). Pasture growth was strongly seasonal with growth mainly following spring and summer rainfall (Figure 4). Winter pastures for grazing were generally characterised by limited pasture growth and 20 frosts/year causing low quality forage and low to negative cattle live weight gain. Winter and spring rainfall during 2016 promoted the growth of winter active legumes and this was then supplemented by autumn rainfall in 2017 that kept pastures green and was estimated to infiltrate to the lower soil layer (Figure 4). Consequently the 2016-17 season had above average rainfall and provided good conditions for grazing and cattle live weight gains. Rainfall during the 3-year observation period on the commercial properties (2013-15) was near average in the first year, 21-34% below average in year 2 and marginally below average (nil to 16%) in year 3. Mean annual rainfall at these locations generally reduces from east to west and was as follows: Mirrabooka (735 mm), Colliery Park (683 mm), Roundview (658 mm), Cattle Camp (720 mm), Oakleigh (643 mm) and Canimbla (618 mm).

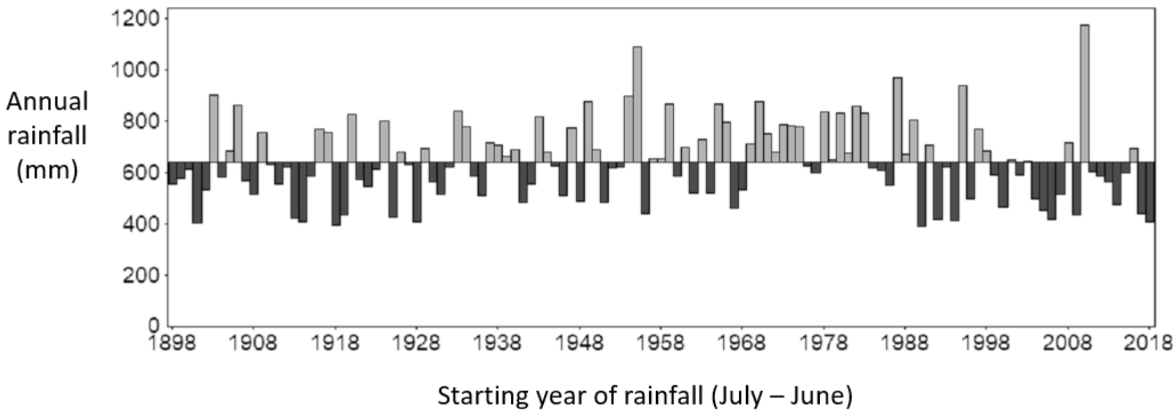


**Figure 3** Departure of annual rainfall (July-June) from mean annual rainfall (642 mm) for the 121-year period July 1898 to June 2019 at Acland with starting year shown on x axis.

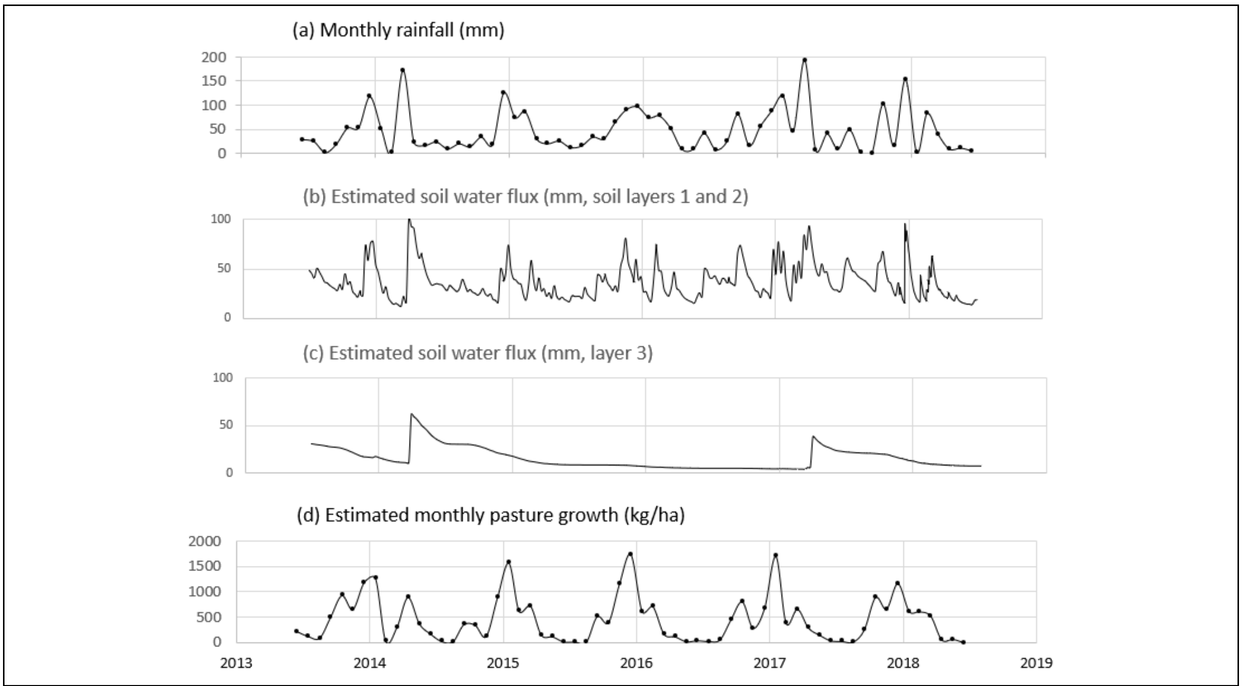


**Figure 4**. Changes during trial period in (a) monthly rainfall, b) daily soil water flux in the upper soil profile (0-50cm), (c) daily soil water flux in the lower profile (50-120 cm layer of mine spoil) of the R1 Swiftsynd exclosure, and d) monthly estimates of monthly pasture growth in the R1 Swiftsynd exclosure.

## Changes to the GRASP model

Pasture rundown was modelled as a rapid rise in potential pasture productivity in the year following pasture establishment followed by a slower rundown in productivity over several years (Figure 5a). The cause of this change in productivity was attributed to an increase in nitrogen availability through the breakdown of soil organic matter and mineralisation of nitrogen followed by the subsequent immobilisation of nitrogen in soil organic matter (Graham *et al.* 1985, Robbins *et al.* 1986, Peck *et al.* 2011 and 2017). This process was estimated as a function of 3 parameters: (1) a long-term mean annual level of potential nitrogen uptake per year (parameter 99 denoted as p99), (2) an initial lift in potential nitrogen uptake in the first year (p543) following land disturbance (e.g. land rehabilitation after mining or cultivation followed by establishment of sown pasture) and associated mineralisation of soil organic N, and (3) a third parameter (p544) governing the rate of pasture rundown defined as the length of time (years) required to reduce the extra nitrogen availability (through re-immobilisation processes to soil organic N) to 5% of the initial lift. These two latter parameters were defined through calibration as functions of p99, with p543 as 0.7*p99, and p544 as 0.3 *p99 -1.0 with minimum and maximum values of 2 and 11 years. Thus, in fertile soils such as in the R1 and R2 paddocks (Bennett *et al.* submitted) pasture rundown was modelled to occur with a larger initial lift and to then decline over a longer period (Figure 5a square symbols) than in less fertile soils such as in the R1 and Control paddocks (Figure 5a circle symbols).

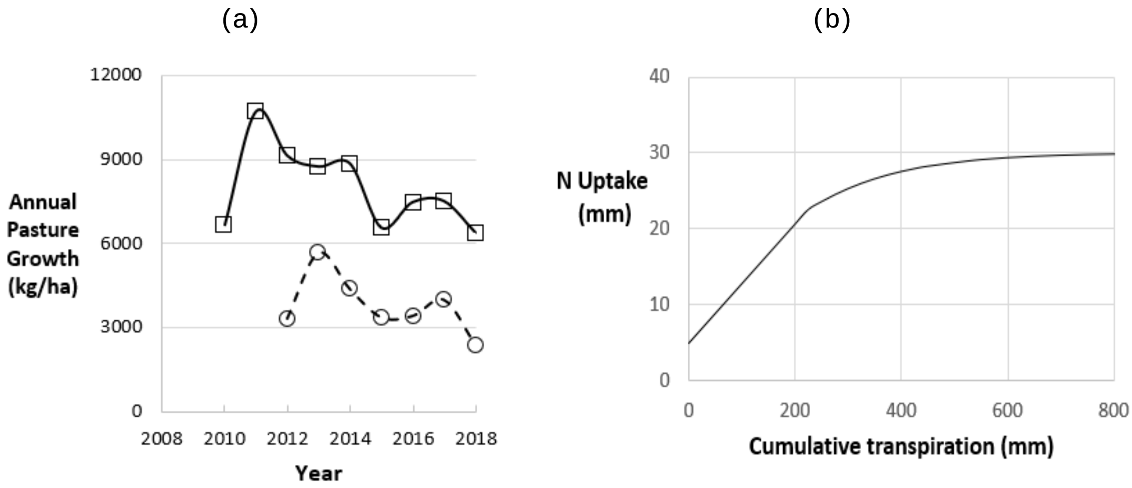


**Figure 5** (a) Estimated annual growth of pasture from GRASP simulations of Rehab 2 (□) and control (○) paddocks from establishment (2010 in rehab 2 and 2012 in control) showing the initial lift in productivity followed by a pasture rundown phase over several years interacting with climate variability, and (b) N uptake as a function of cumulative transpiration with a potential N uptake of 30 kg/ha.

The following exponential decay equation was derived to estimate potential nitrogen uptake ($N_{pot}$) at time t (number of years after sowing):

$$N_{pot} = p99 + p543 * \min(1.0, \exp(-3.0/p544 * (t-1)))$$

Potential regrowth rate (p6), transpiration efficiency (p7), radiation efficiency (p8) and the rate of N uptake (p98) that are normally constants in GRASP (Day *et al.* 2005) were also implemented as functions of soil fertility and were calculated as variables from $N_{pot}$ as follows:

$$p6 = \max(2.0, \min(10.0, 0.150 * N_{pot}))) \quad \text{(kg/ha per day per unit of basal area)}$$

$$p7 = \max(8.0, \min(25.0, 0.625 * N_{pot})) \quad \text{(kg/ha.mm of transpiration)}$$

$$p8 = \max(6.0, \min(24.0, 0.4 * N_{pot} + 4.0)) \quad \text{(kg/ha.mm of transpiration)}$$

The rate of N uptake following an initial uptake of 5 kg/ha of N was estimated as a function of potential N uptake in two stages. Firstly, a linear stage proportional to cumulative transpiration that continued until 70% of N uptake had occurred when cumulative transpiration equalled parameter 680, and secondly, a curvilinear stage that logarithmically reduced the rate of N uptake to near zero as N uptake approached $N_{pot}$ (Figure 5(b)). This curve was defined by a second parameter (p681) specifying the cumulative transpiration when 97% of N uptake had occurred.

Percent nitrogen (%N) content of TSDM and its dilution to minimum levels at the end of the growing season has a strong influence on GRASP estimates of TSDM. Observed values of % N in the grass component of pastures decreased with pasture age (*P<0.05*) across the Acland trial sites (Paton *et al*. *this volume*, Melland *et al. this volume*) and ranged from 0.60±0.20%N in the first three years of the trial to 0.42±0.15%N in the last two years. However, increases in pasture age were not linked to a statistically significant (*P<0.05*) decrease in the diet quality (%N) selected by cattle. The influences of pasture rundown on minimum values of % N were not developed into the model and the normal practice of specifying a constant value for minimum % N (parameter 101) in GRASP was retained. A constant value for parameter 101 equal to the observed mean %N of TSDM in autumn across all Swiftsynd exclosures over the five-year trial at Acland of 0.46% N was assumed for all sites. This resulted in a weak relationship ($R^2$ = 0.566, slope = 0.487, N = 103) of predicted versus observed N uptake (Figure 6(a)). Errors were greatest in the first few years after pasture establishment when % N and N uptake levels were high. Improvements to the nitrogen sub-model in GRASP would be useful.

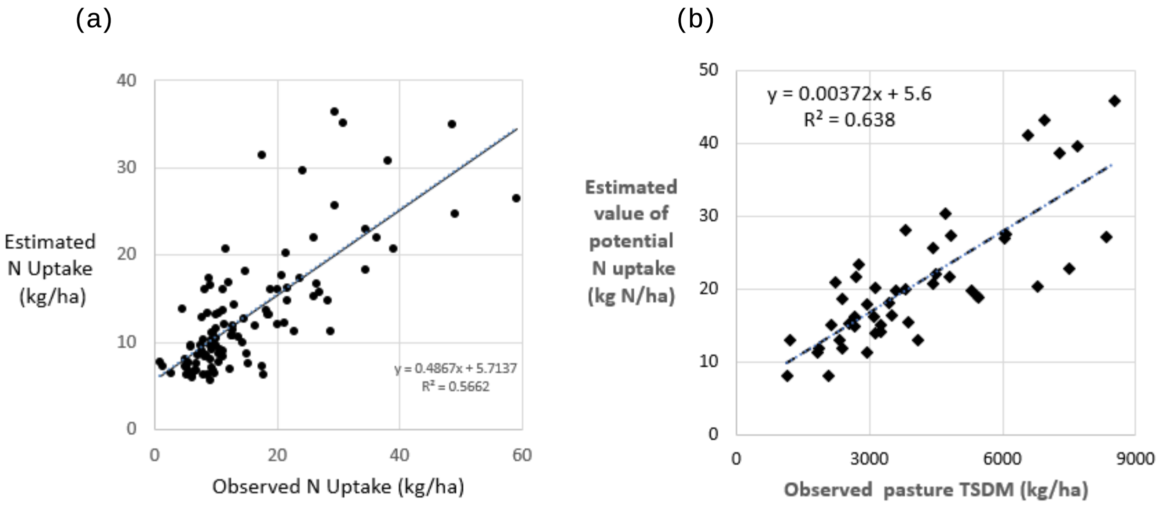


**Figure 6** (a) Estimated versus observed values of N uptake from Swiftsynd exclosures at Acland, and (b) estimated value of potential N uptake ($N_{pot}$) versus observed TSDM in Swiftsynd exclosures in autumn.

### Calibration of GRASP to Swiftsynd Pasture Observations

The parameters above are key drivers of pasture growth in GRASP with many dependent on the long-term value of p99. Thus, in calibrating the model to achieve best estimates of TSDM, a central focus of calibration was to adjust values of p99 to minimise RMSD for TSDM rather than adjusting p99 to observed values of N uptake as is normally the case (Scanlan *et al.* 2008). Consequently, the value of p99 represented more than could be derived from observed values of N uptake. Final values of p99 for each Swiftsynd site (Table 1) led to estimates of potential N uptake that accounted for 64% of variation (*N*=48) in observed pasture TSDM at the end of the growing season in the Swiftsynd exclosures (Figure 6b).

**Table 1**. Location of field sites and estimates of GRASP parameters for each site for: (a) maximum soil water storage (field capacity minus lower limit) in soil layers 1 (0-10cm), 2 (10-50 cm), and 3 (below 50 cm), and (b) potential N uptake (p99) derived from the initial calibration to the Swiftsynd data, and the final values adopted for the grazing simulation studies after minor recalibration to the Botanal data.

| Land Type | Site | Location (Latitude, Longitude) | Maximum soil water storage (mm) | | | Potential N Uptake (kg/ha) | |
|---|---|---|---|---|---|---|---|
| | | | Layer 1 | Layer 2 | Layer 3** | Initial values | Final values |
| Rehab | Rehab 1 | -27.271, 151.720 | 23 | 83 | 62 | 26.7 | 24.1 |
| | Rehab 2 | -27.275, 151.715 | 23 | 83 | 62 | 35.6 | 33.1 |
| | Rehab 3 | -27.278, 151.724 | 23 | 83 | 62 | 17.6 | 19.5 |
| Brigalow Uplands | Control 1 | -27.286, 151.746 | 21 | 83 | 49 | 18.4 | 16.9 |
| | Control 2 | -27.284, 151.743 | 19 | 84 | 49 | 15.0 | |
| | BMK 18 | -27.277, 151.745 | 22 | 83 | 47 | 19.8 | 19.8 |
| | BMK 11 | -27.317, 151.695 | 20 | 83 | 32 | 11.2 | 11.2 |
| | Roundview | -26.876, 151.451 | 20 | 83 | 32 | 13.0 | 13.0 |
| | Oakleigh | -26.549, 151.111 | 21 | 83 | 49 | | 16.7 |
| Mountain Coolibah | BMK 2 | -27.273, 151.667 | 21 | 43 | 23 | 16.2 | 16.2 |
| | BMK 3 | -27.287, 151.651 | 23 | 83 | 49 | 21.3 | 21.3 |
| | BMK 7 | -27.276, 151.680 | 23 | 81 | 48 | 13.9 | 13.9 |
| | Colliery Park 1 | -27.975, 151.923 | 21 | 83 | 32 | 19.8 | 19.8 |
| | Colliery Park 2 | -27.976, 151.933 | 21 | 83 | 32 | 19.7 | 19.7 |
| | Cattle Camp | -26.787, 151.469 | 21 | 83 | 32 | | 21.0 |
| | Mirrabooka | -27.835, 152.059 | 21 | 31 | 8 | | 23.5 |
| Poplar Box | BMK 10 | -27.362, 151.705 | 23 | 83 | 17 | 8.0 | 8.0 |
| | BMK 12 | -27.329, 151.686 | 24 | 83 | 49 | 14.9 | 14.9 |
| | BMK 16 | -27.362, 151.705 | 24 | 83 | 32 | 11.9 | 11.9 |
| | Canimbla | -26.673, 150.748 | 19 | 83 | 56 | | 17.1 |

** Lower boundary of layer 3 set to 80 cm for most sites, 60 cm for BMK 2, BMK 10 and Mirrabooka sites, 70 cm for BMK 11, BMK 16, Colliery Park, Roundview and Cattle Camp sites, and 120 cm for Rehab sites.

The final calibration of GRASP for the grazed paddocks used the same suite of soil and pasture growth parameters identified for the Swiftsynd exclosures, and the same suite of grazing parameters for all paddocks although the dominance and presence of pasture species differed across sites. For example, detachment rates of 0.0039 and 0.0024 kg/kg.day in summer and winter respectively, and the impacts of trampling on pasture TSDM were maintained as constants across all sites. However, there were some exceptions possibly due to spatial differences between the small Swiftsynd exclosures and the larger grazed paddocks. The value of p99 was marginally reduced for Rehab 1 and Rehab 2 and marginally increased for Rehab 3 (Table 1) based on calibration to the observed Botanal pasture TSDM data (Melland *et al. this volume*). Rehab 2 was calibrated to have a marginally higher live weight gain based on the observed live weight gain data (Melland *et al. this volume*). Coefficients of 0.0076 and 0.0065 were derived for Rehab 2 and all other sites respectively to estimate the effects of length of growing season (calculated as the percentage of growth index days above 0.30) in an annual liveweight gain multiple regression equation.

Simulations with the calibrated GRASP model gave estimates of pasture TSDM that were similar to the observed values in both the Swiftsynd exclosures and across grazed paddocks (Botanal observations). Observed and estimated pasture TSDM across all Swiftsynd sites had means of 2902 and 2809 kg/ha respectively (N=114, RMSD = 832 kg/ha, cv = 29%). Regression analyses of GRASP estimates versus observed values gave $R^2$ values of: 0.78 (*N*=114, slope = 0.91) across all sites (Figure 6(b)), 0.93 (*N*=103) for the Swiftsynd exclosures at Acland (rehab and all unmined lands), and 0.74 (*N*=11, slope) for the Swiftsynd sites on commercial properties.

Observed TSDM in rehab exclosures were much greater than on unmined land (Paton *et al. this volume*, Figure 3). In rehab exclosures the mean TSDM for observed and estimated were similar (3962 and 3960 kg/ha respectively), and significantly greater ($P<0.05$) than the observed and estimated TSDMs for unmined land (2351 and 2211 kg/ha respectively). While the Rehab 2 Swiftsynd exclosure had the highest TSDM, the Mountain Coolibah land type had the highest TSDM on unmined land types, and Poplar Box the lowest (Paton *et al. this volume*, Table 3b).

### Calibration of GRASP to Botanal Pasture Observations

The mean observed values of TSDM under grazing of the Acland Grazing Trial paddocks (from 14th January 2014 to 18th April 2018) in the Control was significantly ($P<0.05$) lower (2871 kg/ha) than the other sites, and Rehab 2 had significantly ($P<0.05$) higher TSDM (5656 kg/ha) than other sites (Melland *et al. this volume*). Rehab 1 and Rehab 3 means were similar.

GRASP simulations using the same periodic grazing pattern as used in the trial gave estimates of TSDM very similar to the observed Botanal estimates (Table 2, Figure 7). RMSD values of differences between observed and estimated TSDM were similar to the standard deviations of observed TSDM. The regression slope of estimated TSDM versus observed across all sites was close to unity (slope = 0.999, N = 89, $R^2$ = 0.60) (Figure 7(b)). Regression statistics were $R^2$ = 0.47 (N = 51) for the rehab paddocks, $R^2$ = 0.48 (N = 16) for the control paddock excluding the first data point outlier in Figure 7(b), and $R^2$ = 0.73 (N = 21) for paddocks on commercial properties.

**Table 2.** Observed and GRASP estimates of mean TSDM, AE days grazing and cattle liveweight for the 17 periods of grazing during the five-year trial (147 days/yr on average). Modelled estimates of liveweight were reset each year to the first entry and thus this value was discarded from the comparison. Means followed by letters that differ denote statistically significant differences ($P<0.05$) between sites derived by Melland *et al.* (*this volume*).

| Site | TSDM (kg/ha) | | AE days Grazing/yr | | Liveweight (kg/hd) | |
|---|---|---|---|---|---|---|
| | Observed | GRASP (RMSD) | Observed | GRASP (RMSD) | Observed | GRASP (RMSD) |
| Rehab 1 | 3965 b | 3992 (615) | 37.6 | 37.3 | 386 a | 383 (16.7) |
| Rehab 2 | 5656 c | 5644 (1253) | 47.2 | 48.6 | 403 b | 406 (18.1) |
| Rehab 3 | 3609 b | 3601 (615) | 37.2 | 37.2 | 385 a | 383 (18.5) |
| Control | 2871 a | 3086 (948) | 37.2 | 37.2 | 390 a | 388 (19.9) |
| Mean | 3962 | 3960 (832) | 38.7 | 39.0 | 391 | 390 (18.3) |

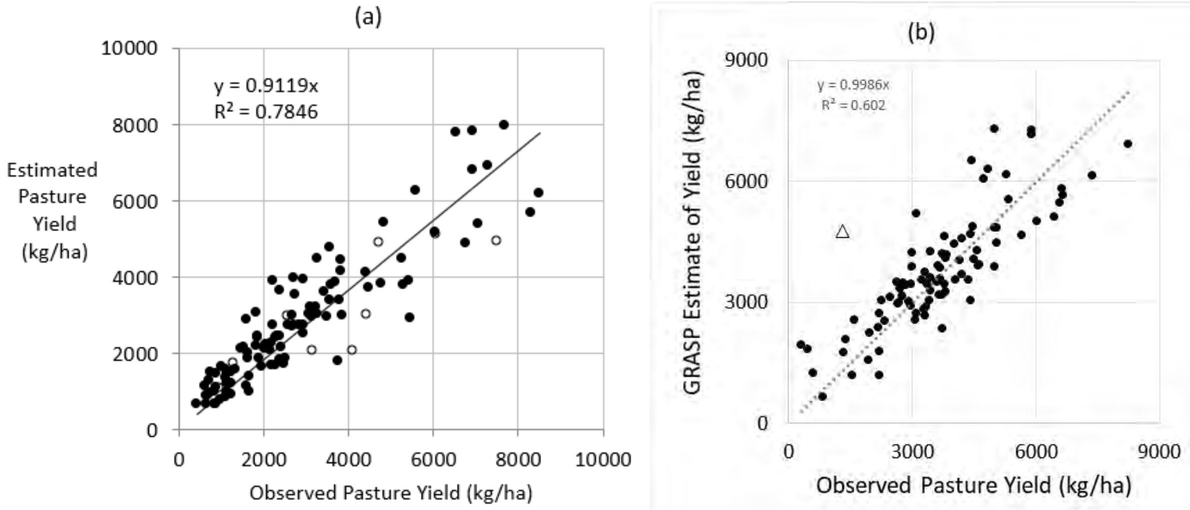


**Figure 7.** GRASP estimates versus field observations of pasture TSDM for (a) Swiftsynd exclosures in the rehab and control paddocks, 8 unmined BMK sites surrounding Acland mine and three exclosures on two commercial properties, and (b) Botanal observations of grazed pasture TSDM from the rehab and control paddocks and six commercial properties. Acland Grazing Trial and BMK site observations shown as solid points and commercial properties as open circles. The outlier observation (Δ) was not included in calibration but was included in regression.

$R^2$ values on grazed paddocks were lower than in the Swiftsynd exclosures, partly because of greater site variability with large paddocks and partly because of increased complexity under grazing conditions (due to senescence, detachment and grazing impacts), and partly because TSDM was maintained at fairly constant levels (Figure 8). This occurred as a result of continual stocking rate adjustments associated with the periodic grazing and feed budgeting regime of the grazing trial to achieve a constant grazing pressure of approximately 30% utilisation of pasture growth. Actual levels of mean annual pasture utilisation during the trial were estimated by GRASP to be 25.8, 27.5, 28.2 and 31.1% for the Rehab 1, 2 and 3 and control paddocks respectively.

### Calibration of GRASP to Cattle Liveweight Observations

The average duration of grazing the trial paddocks was 147 days per year (40% of days) and this varied from 117 days in year 5 to 190 days in year 4. GRASP simulation of pasture and animal production over the trial period using the same periodic grazing regime and livestock numbers gave estimates of adult equivalent days grazing very similar to those calculated from the observed entry and exit weights at each grazing (Table 2) ($R^2$ = 0.99, slope = 1.01, N = 67).

GRASP estimates of cattle liveweight gains for the Acland grazing trial were in close agreement with observed values (Figure 9). The mean observed and estimated cattle liveweights were 391 and 390 kg respectively (RMSD = 18.3 kg/hd, 4.7% of the mean). The regression slope for all paddocks was close to unity (0.995) with $R^2$ = 0.95 (N = 115) and exceeding 0.92 in each paddock. Estimated mean annual liveweight gain (kg/hd from 1 July to 30 June) for the five years of the trial was 157 kg/hd (0.43 kg/hd.day). This varied between paddocks and was 143 in the control paddock, 153 and

146 in Rehab 1 and 3 paddocks respectively and 187 in the Rehab 2 paddock, reflected the observed differences in liveweight gains during the measurement periods of the grazing trial. The gain in Rehab 2 was significantly greater ($P<0.05$) than in the other three paddocks (Melland *et al. this volume*).

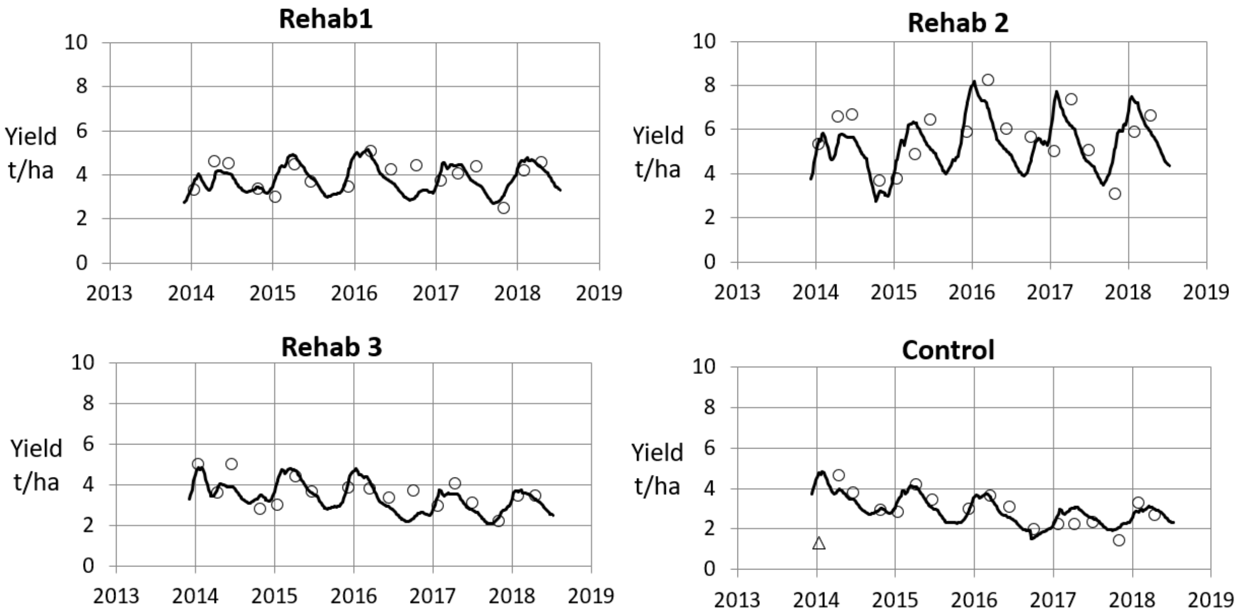


**Figure 8** Changes in pasture TSDM over the 2014-18 trial period for the Rehab 1, 2 and 3 paddocks and the unmined control paddock. GRASP estimates are shown as solid lines and the mean value of Botanal observations as circles. The outlier observation (Δ) was not included in calibration.

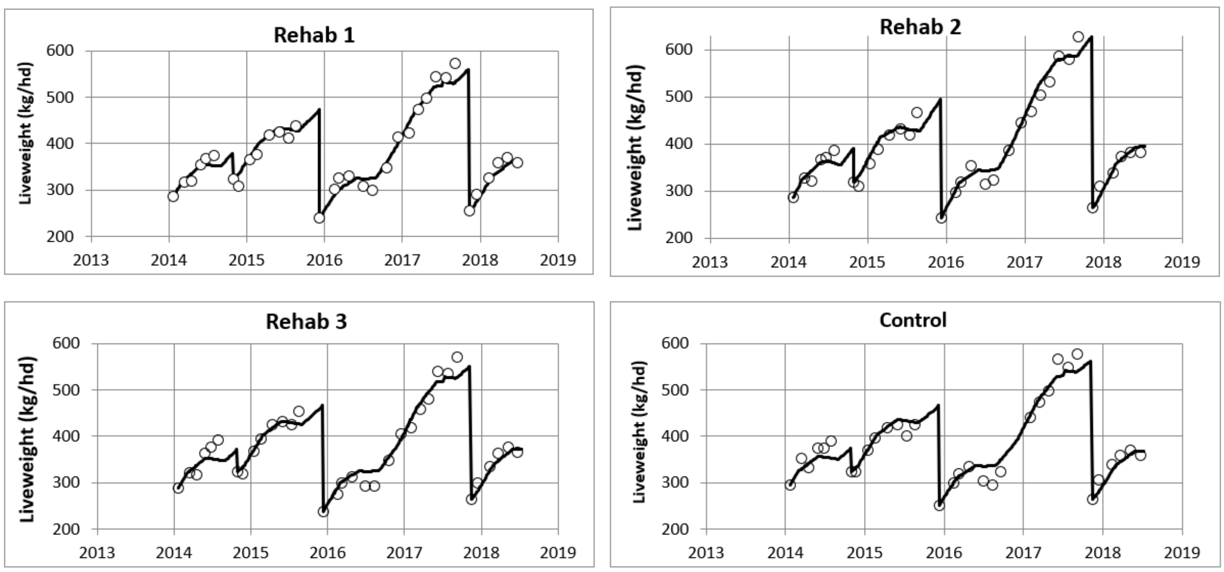


**Figure 9** Changes in animal liveweight over the trial period while grazing the Rehab 1, 2 and 3 paddocks and the unmined control paddock. GRASP estimates are shown as solid lines and observed values as circles.

Weather conditions had large impacts on pastures and liveweight gain with estimated mean liveweight gains across all paddocks for each year of the trial varying from 134 kg/hd in years 2 and 3, 142 kg/hd in year 5, and 169 and 208 kg/hd in years 1 and 4 respectively. Self-regenerating legumes were estimated to have provided a 25 kg/hd live weight gain advantage in year 4. This estimated contribution to liveweight gain was excluded from long-term simulations.

The estimated mean annual utilisation of annual pasture growth across all paddocks was 28% and varied between 17 and 41%. Rehab 1 had the lowest mean grazing pressure of 26%, Rehab 2 and 3 were similar to the overall mean of 28%, and the Control paddock was higher at 31%.

Comparison of productivity from each of the paddocks under the same grazing pressure (30% utilisation of pasture growth) led to small changes in estimates of pasture growth, stocking rates and livestock production during the trial (Table 3). While a mean of 30% utilisation was achieved, variation was 26 to 38% during the trial period.

Tactical variation in stocking rates based on TSDM values at the end of the growing season has several shortcomings (Hunt 2008) and can lead to considerable variation in utilisation of pasture growth (e.g. when years of high TSDM are followed by droughts or vice versa).  Variation in utilisation rates during the 60-year simulation were greatest in the control (11 to 65%) and least in Rehab 2 (16 to 46%).

**Effects of Pasture Rundown on Productivity and Economic Returns**

The effects of pasture rundown on productivity were assessed by comparing: (a) the productivity of the grazing system during the trial period when pasture rundown was actively occurring to (b) estimates of productivity from the same years but from a long-term 60-year simulation in which the parameters specifying the initial lift and subsequent rundown of sown pasture growth were set to negligible levels. The grazing pressure applied in both simulations was adjusted during the trial period to give a mean annual pasture utilisation of 30% estimated as the long-term sustainable “safe” utilisation rate

Estimated mean annual pasture growth for all paddocks during the trial (4991 kg/ha) was 12 % higher than the estimate (4451 kg/ha) for the same period from the long-term simulation.  The effects were strong in recently established pastures (17 and 14% respectively for Rehab 3 and Control) sown in 2012 and least (1%) in the oldest pasture (Rehab 1, sown in 2007) (Table 3). Rehab 3 was estimated to have increased annual N uptake levels by 6.7, 2.2 and 0.2 kg/ha in years 1, 3 and 5 respectively of the trial giving rise to increases in annual pasture growth of 1443, 476 and 43 kg/ha respectively.  The control paddock gave similar increases and rapid loss in productivity. In contrast the estimated increases in N uptake and longevity of rundown were higher in Rehab 2 probably because of its observed higher soil fertility levels concerning soil organic carbon, nitrogen and phosphorous (Bennett *et al.* submitted). Following establishment in 2010, Rehab 2 had estimated increases in 2011-12 of 17 kg/ha N uptake and 3705 kg/ha pasture growth. During the subsequent trial years, the annual N uptake level in Rehab 2 decreased at a slower rate than above and was 9.3, 4.4, and 2.2 kg/ha in years 1, 3 and 5 of the trial respectively. The estimated lift in pasture growth during these years was 2035, 967 and 497 kg/ha respectively and equivalent to lifts in productivity of 34, 15 and 8% respectively.

Consequential effects of increased pasture growth during the trial years led to increased estimates of animal productivity and economic returns with the largest effects on gross margins (Table 3). Observed pasture rundown effects on pasture quality during the trial period (Paton *et al. this volume* and Melland *et al. this volume*) and its likely effects on liveweight gain (Partridge *et al*. 2009, Peck *et al*. 2011) were not included in the model.

**Table 3** Estimates of mean annual productivity and economic returns during the five-year trial period (2013-2018) concerning pasture growth, stocking rate, cattle liveweight gain and gross margin. The elevated levels of productivity and economic returns estimated to have occurred during the trial period due to the initial lift of pasture rundown are shown in brackets as a percentage of the mean. Data are based on a mean annual grazing pressure of 30% utilisation during the trial period.

| Paddock | Pasture growth (kg/ha.yr) | Stocking rate (AE/100 ha.yr) | Liveweight gain (kg/ha.yr) | Gross margin (AUD/ha.yr) |
|---|---|---|---|---|
| Rehab 1 | 4572 (1%) | 43 (2%) | 77 (4%) | 77 (5%) |
| Rehab 2 | 7503 (16%) | 64 (10%) | 134 (15%) | 171 (20%) |
| Rehab 3 | 4320 (17%) | 40 (18%) | 71 (25%) | 69 (44%) |
| Control | 3567 (14%) | 34 (17%) | 58 (18%) | 54 (20%) |
| Mean | 4991 (12%) | 45 (10%) | 85 (14%) | 93 (22%) |

**Effects of Land Type on Productivity and Economic Returns**

Long-term (60 year) simulation of the grazing system across 19 sites gave mean annual production levels of 3505 kg/ha of pasture growth, a stocking rate of 33 hd/100 ha, 142 kg/hd liveweight gain and economic returns of $53/ha equating to $152/hd. Pasture growth was the main driver of estimated cattle production and accounted for 96% of the variation between sites of the long-term means of estimated liveweight gain per hectare and 71% of the variation in gross margins. In contrast, variation between years was mostly due to variation in liveweight gain per head as discussed below. The above results are comparable across sites because the simulated stocking rate applied at each site was at an equivalent level of grazing pressure. This was at an estimated long-term sustainable level of 30% utilisation of mean annual (60-year) pasture growth. Estimated stocking rates were based on the level of TSDM present on 1$^{st}$ May and thus stocking rate in any year was closely related to pasture growth in the previous year.

Rehab lands were estimated to provide the highest levels of production. Mean annual pasture production of the rehab paddocks (4959 kg/ha) was 77% higher than the mean of the unmined sites (2847 kg/ha) (Table 4). This result was strongly influenced by the high productivity of Rehab 2 in comparison to all others. The Mountain Coolibah land type was the most productive of the unmined sites (3398 kg/ha) followed by the Brigalow Uplands (2817 kg/ha) and lastly the Poplar Box land types (2325 kg/ha). These differences align with observed soil nutrient levels (Bennett *et al.* submitted) and carried through to estimates of long-term sustainable stocking rates, beef production and economic returns (Table 4). While the light clay texture of the argillaceous mine spoil in the lower layer of the rehab paddocks was probably a positive contributor to pasture growth as evidenced by development of roots to this layer (Bennett *et al.* submitted), it is also likely that pasture growth at the control and several BMK sites was reduced by structural decline and saline sodic subsoils.

The estimated mean gross margins per head in the rehab paddocks ranged from $155 to $231/AE and thus comparable with estimated mean values for the Darling Downs region ($196/AE) (Holmes *et al.* (2017). Gross margins per head on unmined land were generally below the mean for the Darling Downs region.

**Table 4.** Estimates of long-term (60 year) mean annual productivity of rehab lands compared to the productivity of unmined land types in the district (as in Figure 1). Estimates are from GRASP simulations of pasture growth, rainfall use efficiency (RUE), stocking rates of adult equivalents (AE), beef production and economic returns at a grazing pressure of 30% utilisation of pasture growth.

| Land Type | Pasture Cond'n | Pasture Cond'n | Pasture Growth kg/ha | RUE kg/ha .mm | TSDM 30Jun kg/ha | Stocking Rate AE/100ha | Liveweight Gain kg/hd | kg/ha | Gross Margin $/ha | $/AE |
|---|---|---|---|---|---|---|---|---|---|---|
| Rehab | Rehab 1 | A | 4611 | 7.2 | 3350 | 43 | 148 | 76 | 73 | 169 |
| | Rehab 2 | A | 6528 | 10.3 | 4340 | 59 | 169 | 116 | 137 | 231 |
| | Rehab 3 | A | 3736 | 5.9 | 2646 | 36 | 143 | 61 | 55 | 155 |
| | Mean | | 4959 | 7.8 | 3445 | 46 | 153 | 85 | 88 | 185 |
| Mtn Coolibah | BMK 2 | B | 2977 | 4.7 | 1794 | 28 | 130 | 44 | 33 | 117 |
| | BMK 3 | A | 4091 | 6.4 | 2788 | 39 | 140 | 66 | 57 | 146 |
| | BMK 7 | A | 2659 | 4.2 | 1814 | 25 | 136 | 42 | 34 | 136 |
| | CollieryPark | A | 3856 | 5.7 | 2668 | 37 | 146 | 64 | 58 | 144 |
| | Mirrabooka | C | 2740 | 4.8 | 1383 | 26 | 103 | 33 | 11 | 46 |
| | CattleCamp | A | 4068 | 6.3 | 2751 | 39 | 142 | 66 | 58 | 150 |
| | Mean | | 3398 | 5.3 | 2200 | 32 | 133 | 53 | 42 | 123 |
| Brigalow Uplands | Control | A | 3169 | 5.0 | 2363 | 31 | 146 | 53 | 50 | 164 |
| | BMK 11 | D | 1831 | 2.9 | 1284 | 18 | 144 | 30 | 28 | 160 |
| | BMK 18 | A | 3775 | 5.9 | 2645 | 36 | 141 | 61 | 54 | 151 |
| | Roundview | C | 2309 | 3.7 | 1458 | 22 | 142 | 38 | 33 | 151 |
| | Oakleigh | A | 3002 | 4.9 | 2261 | 29 | 144 | 50 | 46 | 160 |
| | Mean | | 2817 | 4.5 | 2002 | 27 | 143 | 46 | 42 | 157 |
| Poplar Box | BMK 16 | A | 2150 | 3.4 | 1529 | 21 | 140 | 35 | 30 | 147 |
| | BMK 12 | A | 2740 | 4.3 | 2132 | 27 | 150 | 47 | 47 | 177 |
| | BMK 10 | C | 1272 | 1.9 | 948 | 12 | 149 | 22 | 21 | 175 |
| | Canimbla | A | 3136 | 5.3 | 2031 | 29 | 127 | 46 | 33 | 112 |
| | Mean | | 2325 | 3.7 | 1660 | 22 | 142 | 37 | 33 | 152 |
| | Mean *** | | 2847 | 4.5 | 1954 | 27 | 139 | 45 | 39 | 144 |
| Overall Mean | | | 3505 | 5.5 | 2400 | 33 | 142 | 57 | 53 | 152 |

*** Mean of the unmined lands giving equal weight to each land type

### Effects of Climate on Productivity and Economic Returns

Climate variability was estimated to cause large year to year variations in productivity across all sites. For example, drought conditions such as those in 2006-07 (Figure 3) reduced mean annual rainfall by 37% and estimates of pasture growth by 55%, beef production by 51% and economic returns by up to 114% to negative values. In contrast, high rainfall years produced relatively smaller changes in production because of estimated soil fertility restrictions to pasture growth due to limited plant-available soil nitrogen. Differences in mean annual production between simulations over the last 60 years and 120 years were negligible: pasture growth was 0.2% higher (8 kg/ha) and liveweight gain 1% higher (0.6 kg/ha) over the last 60 years. Regression analysis of time series data over the 120-year period (1898-2018) formed as 24 sets of five-year means showed no trend in pasture growth (slope =0.4 kg/ha per year, $R^2$=0.005) mainly because of the high frequency of drought years at both the start and end of the 120 year period (Figure 3). However, the most recent 60-year period (1958-2018) also showed a significant upward trend in mean temperature (0.22 deg C per decade) and vapour pressure deficit (0.58 hPa per decade), and a significant ($P<0.05$, $R^2$ =0.46) downward trend in estimated annual pasture growth of 70 kg/ha per decade. This is consistent with climate change projections that are likely to cause reduced long-term carrying capacity (McKeon *et al*. 2009, Stokes and Howden 2010, Whish *et al.* 2014) and will therefore require ongoing advances and communication of best management practices (Paton *et al.* 2011, George *et al.* 2018) for managing climate risk.

Variations in mean annual production and economic returns were also high when estimated from five years of data sampled as 24 sequences of 5 years in the period July 1898 to June 2018 (120 years) (Figure 10). This data derived at an average grazing pressure of 30% utilisation highlights several issues. Firstly, and in regard to the estimated productivity of the rehab paddocks: Rehab 2 is very high and an outlier compared to the 18 other sites, Rehab 1 is above all sites other than Rehab 2, and Rehab 3 is equivalent to several unmined sites and above most unmined sites. Secondly, the movement in 5-year means is substantial (though much less than annual variation) and deviations from the median were persistent over long periods as illustrated by the annual rainfall pattern in Figure 3. Five-year means for pasture growth, liveweight gain and gross margin during the 2013-2018 trial period were similar to, though marginally less than the medians of the five-year means during the 120-year 1898 – 2018 period. The median value of the five-year mean for pasture growth when averaged across all sites was 3466 kg/ha and during the trial it was 3394 (percentile rank = 0.26). While the liveweight gain and gross margin medians were 142 kg/hd and $48/ha the five-year means during the trial years were 137 kg/hd and $45/ha respectively (percentile rankings of 0.30 and 0.34 respectively). It was concluded that the Acland Grazing Trial was conducted during a period of marginally reduced productivity and economic returns but quite typical of the climate and production risk environment.

A third finding evident in the data of Figure 10 was that differences between sites were much greater than effects of climate on the five-year means of estimated pasture growth and consequently on stocking rates and liveweight gains/ha. In contrast, differences in liveweight gain per head between sites tended to be relatively small. However, at any one site the impacts of climate variability on liveweight gains per head were larger than on pasture growth.

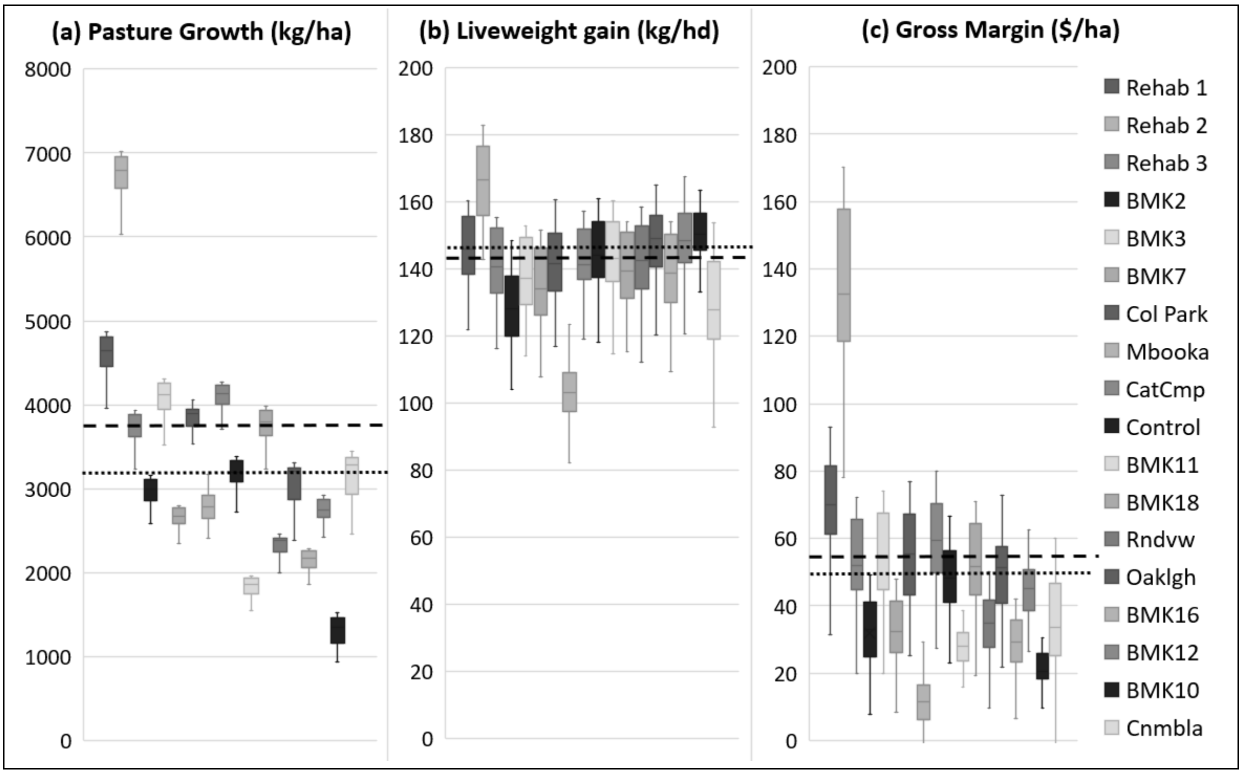


**Figure 10** Frequency distribution of five-year means of annual productivity and economic returns estimated from 24 sets of 5 sequential years of data sampled from July 1898 to June 2018 for: (a) pasture growth, (b) liveweight gain per head and (c) gross margin. Box plots show minimum, maximum and quartiles, and are arranged in same order left to right as legend shows top down. Dashed and dotted lines are the five-year means for Rehab 3 and Control paddocks respectively for the observation period of the Acland Grazing Trial (Jul 2013 to Jun 2018).

Variation in the amount and timing of rainfall caused large variations in liveweight gain between years ranging from 74 kg/hd in drought years to 192 kg/hd (mean of 146) in the Control paddock, 102 to 224 kg/ha (mean of 169) in Rehab 2, and 56 to 176 kg/ha (mean of 130) for the shallow soil BMK 2 site with limited soil water holding capacity. Variability of liveweight gain caused by seasonal weather conditions is typical of pastures in the Brigalow region (Bortolussi *et al.* 2005a, Radford *et al.* 2007, Burrows *et al.* 2010) and was observed during the trial together with large changes in liveweight gain during the year (-0.26 to 1.62 kg/hd.day) (Melland *et al. this volume*). Variability is further amplified where pasture quality is also impacted by the episodic occurrence of winter growing legumes such as medics (Clarkson 1989). Gross margins had the greatest variation in proportion to the mean. The coefficients of variation (standard deviation of five-year mean as a percent of the five-year mean) for estimated pasture growth, liveweight gain/hd and gross margin/ha were 6%, 8% and 26% respectively.

The El Nino Southern Oscillation (ENSO) was found to have a large influence on pasture productivity in spring and early summer. When the monthly average of the Southern Oscillation Index (SOI) for the June to November period was either below -5 or above +5 then estimated pasture growth was decreased by 22% or increased by 36% respectively in the spring-early summer period. However, as expected the influence on the longer period of annual pasture production was low (<7%) and thus changes in annual stocking rates of 10 and 20% in accordance with the SOI (decrease when SOI is negative, increase when positive) had little to no effect on beef production and economic returns. This was in part due to climate factors but was mainly due to: (a) pasture growth under high rainfall/soil moisture conditions being constrained by limited availability of soil N, and (b) the resilience of the grazing system to withstand occasional high levels of utilisation during drought years. Thus, ENSO information is likely to be most useful to short-term tactical management choices relevant to spring and early summer such as input to short-term feed budgeting for rotational grazing decisions, or variation in methods for establishing pastures. This finding is consistent with conclusions by McKeon *et al.* (2000), Clewett and Clarkson (2007) and O'Reagain and Bushell (2011).

**Effects of Grazing Pressure on Pasture Condition and Sustainability**

Simulated changes in grazing pressure from 1 to 50% utilisation of TSDM at the end of the growing season ($1^{st}$ May) were estimated to have large effects on key performance indicators for production and economic returns when tested in long-term (60 year) simulations of the Rehab 3, BMK 3 (Mountain Coolibah), Control (Brigalow) and Canimbla (Poplar Box) paddocks. Grazing pressures of 1, 10, 20 and 30% utilisation of TSDM at the end of the growing season translated in the following year to long-term means across the four land types of 1.4, 12.4, 21.8 and 28.9% utilisation of pasture growth with all pastures ending the 60-year simulation in A condition. However, higher grazing pressures (40 and 50% utilisation of TSDM) reduced the long-term mean utilisation of pasture growth to 35 and 41.1% respectively, had large impacts over time on pasture condition and led to pastures in C and D condition with 25 and 2% perennials respectively after 60 years of simulation. Maximum returns of liveweight gain/ha and gross margin/ha were maximised at 50% utilisation in the initial years of simulation but fell rapidly over time as pasture condition deteriorated under high grazing pressure.

As grazing pressure was increased from 1 to 30% utilisation of pasture growth there was little effect on estimated mean annual pasture growth and pasture condition and almost proportional increases in stocking rate, AE days grazing, beef production and economic returns with equivalent reductions in pasture TSDM. However, as grazing pressure increased to 40 and 50% utilisation there were rapid reductions in pasture condition that led to reductions in mean annual pasture growth, TSDM, soil organic matter, stocking rates, live weight gain and economic returns (Figure 11). Liveweight gain/hd and gross margin/AE were different because they firstly decreased then increased at high levels of utilisation. This upturn is consistent with liveweight gain observations on pastures in poor condition (Ash *et al.* 1995, O'Reagain and Bushell 2011) where sufficient forage is available to not limit intake. The upturn in economic returns per head plus high initial rates of economic returns per hectare are likely contributing causes to use of high utilisation rates by industry (Bowen and Chudleigh 2018).

The grazing pressure simulation results in Figure 11 illustrate the relationships between the production performance indicators, and highlight the residual risk of persistent overgrazing leading to a degraded pasture condition and reduced productivity. However, there is some uncertainty. The influence of grazing pressure on productivity was not observed in this study, and thus the authors cannot be certain of the points of inflection shown in Figure 11. While this uncertainty is also part of the residual risk it is mitigated by the modelling approach with GRASP that enables use of data from other studies.

The safe utilisation rate of 30% used in this study when estimating effects of pasture rundown, land type and climate variability on productivity and economic returns is consistent with best management practice guidelines. This includes utilisation rates specified in data supporting the Stocktake package (Aisthorpe *et al.* 2004 and Bath 2016) developed for use in the Darling Downs region by primary producers and agri-business. While safe utilisation rates of 22 and 27% were derived for native pastures in south east Queensland (Day *et al.* 1997a, Hall *et al.* 1998) and the Central Burnett (Day *et al.* 1997b) respectively, utilisation rates of 30% are also recommended for native and sown pastures across a range of land types in the neighbouring Moreton and Burnett regions (Partridge 1993, Whish 2019), for brigalow land types in the Maranoa region (Paton *et al.* 2011) and native spear grass pastures in southern and central Queensland (Hunt *et al.* 2008, Burrows *et al.* 2010).

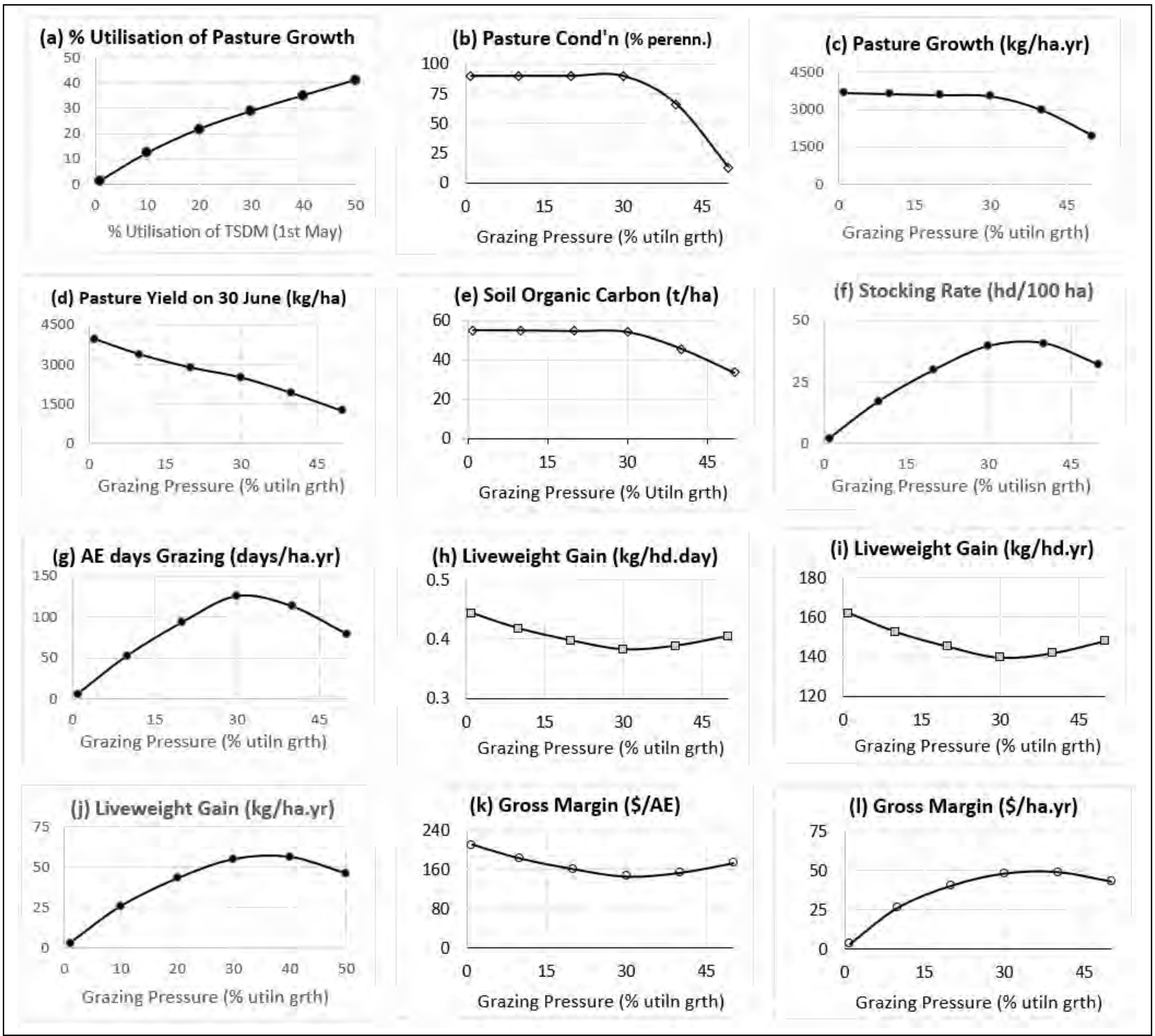


**Figure 11** Estimates from GRASP simulations of grazing pressure (estimated as percent utilisation of pasture growth) on the long-term (60-year) mean annual productivity of the grazing system, economic returns, pasture condition index (percent perennials) and soil organic carbon. Values calculated as the mean of 4 sites: Rehab 3, BMK3, Control and Canimbla representing the rehab lands and the Mountain Coolibah, Brigalow Uplands and Poplar Box land types respectively.

The safe utilisation rate of 30% is marginally less than the point of inflection for pasture condition and pasture growth in Figure 11. Maximum values of stocking rate, liveweight gain/ha and gross margin/ha occurred at 32% utilisation. Utilisation rates above 34% resulted in pastures with less than 70% perennials (B condition) because there were insufficient years for pastures to recover from losses in pasture condition caused by utilisation rates above the 35% threshold. This is consistent with Scanlan *et al.* (2010) who defined safe utilisation as being able to maintain pastures in A condition and found safe utilisation decreased with increasing aridity from 35% at Calliope (929 mm annual rainfall), to 22% at Duaringa (712 mm annual rainfall and thus similar to Acland) and 18 % at Longreach (428 mm annual rainfall) on fertile soils. Safe utilisation rates were lower on less fertile soils and 25% utilisation guidelines are recommended for lower fertility box and sandalwood land types in the Maranoa (Paton *et al.* 2011) or soils that had been eroded (Chillcott 2004). Therefore, it follows that the previously cultivated and nutrient depleted soils of the BMK sites (Bennett *et al.* submitted) and more generally across the region (McKenzie *et al.* 2017) may have safe utilisation rates lower than 30%.

The stocking rates in Table 4 derived at 30% utilisation provide estimates of sustainable ("safe") stocking rates and hence long-term carrying capacities (LTCC). These values are proportional to pasture growth and are very similar to estimates of LTCC calculated in the companion paper by Paton *et al.* (*this volume*) where LTCC is simply estimated from the long-term median of annual pasture growth and an animal intake of 9 kg/AE.day. The LTCC for the rehab paddocks (36-59 AE/100 ha, Table 4) is similar to stocking rates used in the NSW Hunter valley region of 38 hd/100 ha for rehab pastures of Rhodes grass, panic and kikuyu (Griffiths and Rose 2017) but marginally higher than LTCC estimated for buffel grass rehab pastures in Central Queensland of 17 – 45 AE/100ha (Griggs *et al*. 2002).

The difficulties of adopting a grazing management regime in a variable climate that achieves productive returns while avoiding loss of productivity through overgrazing is well documented (McKeon *et al.* 2004, McIvor 2010). Loss of pasture condition (and thus productivity) is a frequent occurrence in the Darling Downs region and more generally in northern Australia (Tothill and Gillies 1992, Bortolussi *et al.* 2005b, Bray et al. 2016). Examples in this study are pastures in C and D condition at the BMK 10 and 11 sites and the Roundview and Mirrabooka paddocks (Table 4). Thus, future management of grazing pressure to maintain pastures in "A" condition is a significant ongoing challenge and residual risk to sustainable production that will require astute application of best management practices (Paton *et al.* 2011, George *et al.* 2018) with an on-going monitoring program and capacity to adjust so that pasture condition is maintained.

## General Discussion

Sustainable levels of pasture and animal production are assessed in this paper as equal to the long-term mean of the 60-year simulations at 30% utilisation. This has many assumptions. For example, it is assumed that historical weather data is indicative of future conditions which ignores projected influences of climate change and higher atmospheric carbon dioxide levels (McKeon *et al.* 2009). Rehab lands and pastures on retired cultivations are novel ecosystems (Hobbs *et al*. 2006, Buisson *et al*. 2019) and can thus be expected to have a range of factors causing change including long-term changes to soil attributes and species composition. Here it is assumed that changes in the ecosystem are limited to the effects of climate variability, pasture rundown and grazing pressure with changes in productivity due to pasture rundown successfully captured through changes to TSDM. However, the observed influence of pasture rundown on pasture quality (Paton *et al. this volume* and Melland *et al. this volume*) could lead to substantial long-term changes in pasture composition with reduced productivity and liveweight gain (Partridge *et al.* 2009). It is assumed that improvements in productivity do not occur. Such improvement may occur by rebuilding soil fertility through the contribution of pastures to soil organic matter (Partridge *et al.* 2009, Sanderman *et al.* 2010, Clewett 2015, Bray *et al.* 2016) and particularly through use of both summer and winter active legumes (Peck *et al. 2011,* Paton and Clewett 2016, Whish 2017). Further development of GRASP to more adequately represent legume-based pastures, soil nitrogen availability and changes in pasture quality would be useful. It is also assumed that the economic viability aspect of sustainability can be captured through simple gross margin analyses without reference to factors such as overhead and labour costs, cash flow and whole of enterprise issues.

The Land Resource Area (LRA) map for the Central Darling Downs (Harris *et al.* 1999) shows the Acland mine area as Brigalow Uplands formed on Walloon sandstones. This parent material commonly gives rise to soils with lower phosphorus levels (Biggs *et al.* 1999). However, the area has a mosaic of both sandstone and basalt derived soils (SKM 2008, Queensland Historical Atlas 2011) and ecosystems (Sattler and Williams 1999) with a variability finer than the LRA mapping scale. The evidence of higher plant available phosphorus levels in the Rehab 1 and Rehab 2 paddocks (Bennett *et al. submitted)* suggest that the topsoil for the Rehab 1 and 2 paddocks was derived from fertile and productive softwood scrub soils of basaltic origin rather than from the less fertile soils of the Walloon sandstones. In contrast, the low plant-available phosphorus levels of Rehab 3 indicate the topsoil for that paddock was probably derived from Walloon sandstones and thus similar to the control paddock and BMK sites representing the Brigalow Uplands and Poplar Box Walloons. Softwood scrub soils are less common than Brigalow and Poplar Box Walloon soils across the mining lease and surrounding region. Consequently, productivity of rehabilitated lands outside the Acland Grazing Trial paddocks is likely to be best represented by the lower productivity of Rehab 3 rather than the higher productivity of Rehabs 1 and 2. Continuing assessments to substantiate this view would be required to develop effective grazing management plans.

Significant areas of cultivated land in the Darling Downs region are described by farmers as being *"rundown"* or *"tired"*, and science-based assessments (Biggs 2007, Baldock *et al.* 2009, Partridge *et al.* 2009 and McKenzie *et al.* 2017) show the region to have high levels of soil erosion, nutrient depletion and loss of soil carbon. This was also the case for sites in the Acland Land System. Bennett *et al.* (submitted) found mean levels of soil organic carbon (1.4%) and total nitrogen (0.11%) for the control and BMK sites to be less than half of the base-line levels reported by Biggs *et al.* (1999) for virgin soil profiles or grazed sites without a history of continuous cropping, and more than four times lower than carbon stocks in remnant brigalow soils (Collard and Zammit 2006, Allen *et al.* 2016). Consequently, the observed and estimated levels of sown pasture productivity reported in this study are likely to be lower than the productivity of lands that have not been cultivated and cropped for long periods.

Estimates of pasture production at paddock scale across Australia using the AussieGrass version of GRASP (Carter *et al.* 2000) are provided by the Forage App (Zhang and Carter 2018) on the LongPaddock website (https://www.longpaddock.qld.gov.au/forage/) (Stone *et al.* 2019) for use by industry. These estimates are based on extensive field observations and are for pastures without trees in A condition but unknown pasture rundown status. The pasture growth data for the Acland Land System and broader region typically range from 4000 to 7000 kg/ha and are thus similar to the observed productivity of the Rehab 1 and 2 pastures but generally well above those reported in this study for sown pastures on previously cultivated lands. For example, the long-term mean annual pasture growth for the Brigalow land type in the control paddock of 3169 kg/ha (estimated by GRASP in Table 4) is just 46% of the 6845 kg/ha estimate for the Brigalow Uplands land type in the Control paddock on the LongPaddock website (Stone *et al.* 2019) (accessed 4 June 2019). Similar comparisons for other Swiftsynd sites with pastures in A condition were: 63% for the BMK 18 site on Brigalow Uplands, 68, 37 and 56% respectively for the BMK 3, BMK 7 and Colliery Park on Mountain Coolibah sites, and 57 and 46% respectively for the BMK 12 and BMK 16 sites on Poplar Box. The mean across all Swiftsynd sites on unmined but previously cultivated land with pastures in A condition was 53% with poorer soil characteristics from cultivation, erosion and nutrient depletion the likely cause of reduced productivity. Land condition is a function of both soil condition and pasture condition and therefore it would be appropriate to have these previously cultivated lands with productivity between 45 and 75% of lands in "A" condition graded as equivalent to lands in "B" condition (Quirk and McIvor 2007, Alexander *et al.* 2018) or be identified with a new land type name (Paton *et al. this volume*). These findings reveal major challenges for research and industry in rebuilding pasture productivity on lands retired from cultivation.

## Conclusion

The integration of modelling and simulation with soil, pasture and grazing trial observations in this study has value added to the research investment in field studies, and has also provided a useful way to assess land use suitability that includes economic viability as a component of sustainability concepts. It has evaluated effects of pasture rundown, enabled calculation of long-term carrying capacity and rainfall use efficiency for feed budgeting, provided estimates of the mean and variability of pasture production, livestock performance and economic returns, and has enabled comparison of land types with analyses of climate risk and the risk of overgrazing to sustainable production. The main conclusions were: (1) pastures sown on unmined cultivated lands had reduced growth with soil erosion, structural decline and nutrient depletion as likely causes, and (2) the rehabilitated lands at Acland provided a sustainable grazing system for economically viable beef production although this is conditional on pastures being safely managed into the future to prevent overgrazing. Maintaining pastures in "A" condition will be an ongoing challenge. An effective way to mitigate this residual risk is via a pasture monitoring program and best practice grazing management that capably adjusts for pasture condition and the effects of climate variability and climate change.

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## Conflicts of Interest

The authors declare no conflicts of interest.

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**NAC Attachment 3 - Acland Grazing Trial: pasture & cattle performance**

**Sustainability of beef production from brigalow lands after cultivation and mining: (2) Acland Grazing Trial pasture and cattle performance**

Short title: Acland Grazing Trial: pasture & cattle performance

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**Abstract**

Agricultural land used for open-cut coal mining in Queensland is required by law to be returned to a safe, stable and self-sustaining state for agriculture. The objective of this research was to identify whether rehabilitated pastures on post-mine soil at a site near Acland could viably support cattle production. Five years of field data from Botanal pasture assessments, pasture quality, cattle liveweights and faecal NIRS observations plus supplementary meat quality data were used to compare pasture and cattle performance from mined and unmined previously cultivated Brigalow land. Subtropical pasture species were sown in 2007 (Rehab1, 22 ha), 2010 (Rehab 2, 32 ha) and 2012 (Rehab3, 22 ha) in three rehabilitated paddocks and in 2012 in an unmined (Control, 21 ha) paddock. The paddocks were grazed for 117 to 190 days of each year by Angus cattle.

Mean total standing dry matter in grazed pasture over the five trial years was consistently higher ($P$<0.05) in Rehab 2 (5656 kg/ha) than in the other sites. Rehab 1 (3965 kg/ha) and Rehab 3 (3609 kg/ha) performed at an intermediate level and the Control paddock produced less pasture ($P$<0.05, 2871 kg/ha). Grass leaf protein was higher ($P$<0.05) in Rehab 2 than the other sites and declined across all sites as pasture aged. Pasture species remained perennial, palatable and productive throughout the trial on all sites, however, pasture yield, quality and composition trends over time suggested that pasture rundown occurred across all sites. The mean observed total liveweight gain (LWG) per head when grazing the trial paddocks was higher ($P$<0.05) in the Rehab 2 cohort than the other paddock cohorts in years 3 and 5, and mean total LWG in the Control cohort was equal to one or more of the rehab paddock cohorts each year. Observed cattle production per hectare during the trial's grazing periods was also consistently highest in Rehab 2 (five-year mean trial LWG 131 kg/ha) compared with the other sites (67-80 kg/ha). No meat safety or eating quality impacts were detected. The rehabilitation process in use by the mine was considered no less productive than the surrounding unmined brigalow landscape.

**Keywords**: Rehab, rehabilitation, Botanal, nitrogen, Brigalow, subtropical pasture, nitrogen, GRASP

## Introduction

Agricultural land used for open-cut coal mining in Queensland, Australia, is required by law to be returned to a safe, stable and self-sustaining state for agriculture (Queensland Government 2014; Butler and Anderson 2018). The performance of pasture rehabilitation programs has been measured at numerous mines, with a justifiable focus on environmental (e.g. stability and erosion control) more so than agricultural benchmarks (Grigg *et al.* 2000). Authentic examples of post-mine land uses can help stakeholder discussions aimed at increasing the rate of transition of post-mined land into productive uses (Maczkowiack *et al.* 2012; Everingham *et al.* 2018). Livestock grazing of pastures on rehabilitated land is a potential post-mine land use (Mentis 1999; Ditsch *et al.* 2006), however, there are few published examples of the viability of such rehabilitation in Australia. Bisrat *et al.* (2004) and Grigg *et al.* (2002) found that the calculated safe stocking rate for sown Buffel grass pastures and cattle liveweight gain observed over 18 months on rehabilitated mining land at two sites in central Queensland was comparable with unmined land in the region. At a third mine the safe stocking rates were lower due to steep slopes and sodic soils. Vickers *et al.* (2012) also concluded that steep and dissected terrain and low biomass production made rehabilitated native grassland in north-west Queensland unsuitable for grazing. Two trials in the Hunter Valley region of New South Wales found that cattle grazing sown pastures on rehabilitated mining land performed well compared with cattle grazing nearby native pastures (Anonymous 2015; Griffiths and Rose 2017). A comparison of the viability of sown Rhodes and Panic grass pastures for cattle production on rehabilitated and unmined land has not been published.

The Acland open-cut coal mine is located near Oakey (27 °S 151 °E) in sub-tropical south-east Queensland and has been in operation since 2002, mining the underlying Jurassic Walloon coal measures. Prior to mining, the mining lease was used for dairying, beef and crops. Since mining began, unmined land on the mining lease has been used mainly for cattle grazing and partially for dryland winter wheat and barley cropping. The land is within the Acland Land System (Vandersee and Mullins 1977), and the lease sits on the Poplar Box Walloon landform, which supports several land resource areas, including the Brigalow Uplands upon which the majority of mining has occurred (Bennett *et al.* in preparation). Brigalow Uplands typically support Brigalow (*Acacia harpophylla*), Belah (*Casuarina cristata*) and Wilga (*Geijera parviflora*) open forest vegetation on soils derived from the Walloon sandstones but also Mountain coolibah (*Eucalyptus orgadophila*) and softwood scrub species such as bottle tree (*Brachychiton*) and crows ash (*Flindersia australis*) with brigalow on basalt rises. Dermosol (gradational clay) and Vertosol (cracking clay) soils derived from the fine-grained Walloon sandstones and/or overlying basalt flows dominate the lease.

The post-mining objective of the mine was to return mined land to pastures that can support commercial livestock grazing. During and after mining for coal, the rehabilitation process used by the mine was firstly to dump the fine-grained argillaceous Walloon sandstone inter- and over- burden (mine spoil) on the rehabilitation site until it reached a pre-defined level, secondly, to deep rip to about 1 m depth using bulldozers, then to spread the soil removed from mining areas to a target depth of 0.3 m using large bulldozers and level it using small bulldozers, stick rakes, blades, rippers, offsets, harrows and level bars, and lastly to sow tropical grass pastures species. Rehabilitation soils in post-mine settings are often nutrient deficient and fertiliser is commonly applied (Mentis 1999; Grigg *et al.* 2000), but fertiliser was not applied in this study. In the early years of rehabilitation, soil was stockpiled on top of the dump site prior to spreading. In 2018, about 350 ha of the mining lease was certified as rehabilitated by the state government, representing the largest single area of certified rehabilitation for an open cut coal mine in the state of Queensland (New Hope Group 2018). The next step is for environmental authority for public release of the land.

The aim of this research was to test the hypothesis that the Acland rehabilitated pastures can viably and sustainably support commercial cattle production. For an enterprise to be considered viable it must achieve comparable livestock performance to similar unmined land in the district and provide an acceptable economic return. For an enterprise to be considered sustainable it must remain productive and economically viable (Smith and McDonald 1998) over a reasonable period of time (e.g. more than 30 years, (McKeon *et al.* 2009)). To test the hypothesis, soil, pasture and livestock performance on the Acland rehabilitated mining land was measured over five years, modelled and compared with performance on nearby unmined land. This paper evaluates measured key performance indicators of pasture and livestock productivity based on field data from Botanal pasture assessments, cattle weights and faecal NIRS observations. The paper also draws on performance indicators evaluated in companion papers for soil (Bennett *et al.* in preparation), pasture carrying capacity (Paton *et al.* this volume), and economic viability and long-term sustainability modelled using GRASP (Clewett *et al.* this volume).

## Methods

*Grazing system*

The enterprise chosen for the Acland Grazing Trial was growing out young cattle to feedlot entry weight, which was consistent with common commercial land use for the area in the absence of mining.

Four paddocks that were sown to pasture were used for the grazing trial from December 2013 until June 2018 and are referred to as the trial paddocks. The paddocks were three rehabilitated sites on land that was previously mined and one unmined site:

- Rehab 1 (22 ha) was the oldest of the mined and rehabilitated sites and was returned to pasture in 2007
- Rehab 2 (32 ha) was a rehabilitated site that was returned to pasture in 2010
- Rehab 3 (22 ha) was a rehabilitated site that was returned to pasture in 2012
- Control (21 ha) was an unmined site, sown to pasture with similar species and in the same year as Rehab 3, in 2012.

The species sown included Rhodes (*Chloris gayana*), Bissett creeping blue (*Bothriochloa insculpta* cv Bisset), green and Gatton panic (*Panicum maximum*), and the native Queensland blue grass (*Dicanthium sericeum*), as well as Bambatsi panic (*Panicum coloratum*), silk sorghum (*Sorghum spp.* hybrid), purple pigeon grass (*Setaria incrassata* cv. Inverell), vetch (*Vicia spp.*), lucerne (*Medicago sativa*) and some medics (*Medicago spp*.). Young cattle, approximately 300 to 400 kg average weight, were concurrently grazed in each paddock for short periods of each of the annual seasons when possible. The grazing was designed to mimic a rotational grazing system and forage budgets were used to decide stock numbers and the number of grazing days for each rotation. Pasture average yields, proportions of unpalatable pasture and anticipated growth were used to derive the number of grazing days and numbers of stock required for each grazing period and paddock based on 10% utilisation of pasture on offer. The aim was to achieve stocking rates consistent with the long-term carrying capacity (derived from 30% utilisation of annual pasture growth) to avoid risks of over-grazing and land degradation (McKeon *et al.* 2004; Paton *et al.* this volume). A second aim was for trial grazing periods to be 6 weeks each to allow for meaningful weight gain. As a result, trial grazing periods were 6 (± 2) weeks followed by a rest period of 8 (± 4) weeks. The rest period was 16 weeks in the dry winter-spring of 2015. For grazing periods during the summer, when rainfall and pasture growth could be expected, “in grazing” pasture growth was predicted using rainfall estimates and included in the forage budgets. Prior to the first grazing period (December, 2013), the Rehab sites were slashed to remove dead and unpalatable feed. The unmined control site had been grazed heavily and then given the same rest period as the Rehab sites to allow adequate pasture growth and availability prior to cattle entering the sites. Twelve-month grazing years were assumed to start on September 8$^{th}$ (early spring) of each year of the trial. The trial paddocks were grazed for 17 periods over the five grazing years of the trial (Table 1Cattle were managed in accordance with the Australian Code for the Care and Use of Animals for Scientific Purposes´ (National Health and Medical Research Council 2013). Upon arrival the cattle were grazed in a single cohort on unmined areas. All cattle were treated with the same treatments with the exception of animals affected by infectious bovine kerato-conjunctivitis (pink eye), which were treated individually with Terramycin spray when required. Treatments administered to all cattle were 5 in 1 vaccine for clostridial diseases, anthelmintic drench for parasitic worms, and a Buffalo Fly repellent (Coopers Easy Dose). All animals were visually monitored each time they were weighed and any animals that exhibited attributes that have a negative impact on weight gain were excluded. This included unhealthy, structurally incorrect or injured animals. Stock water was Class A+ recycled water from the Toowoomba Regional Council's Wetalla wastewater reclamation facility treatment plant and was supplied via a single trough in each trial paddock.

*Pasture observations*

The Botanal Technique (Tothill JC *et al.* 1992) was used to assess pasture total standing dry matter (TSDM) and composition in the trial paddocks prior to each of the 17 grazing periods (Table 1). Information gathered from approximately 50 quadrat points located in a grid pattern within each paddock and sampling time was:

- Pasture TSDM (kg/ha), species composition (percentage by mass), species frequency of occurrence (presence/absence),
- Percentage of ground covered by green pasture material, organic matter and rock; and
- Proportion of unpalatable pasture (i.e. pasture that stock are unlikely to consume when grazing).

Land condition ratings were then assigned to each site according to the proportion of perennial, productive and palatable pasture species present and soil surface condition (McIvor *et al.* 1995; Aisthorpe *et al.* 2004; Alexander *et al.* 2018).

Pasture quality was assessed by collecting samples of grass leaf from four transects across treatment paddocks immediately prior to each grazing for analysis and calculation of digestibility (%), protein (%) and metabolisable energy (MJ/kg DM) contents. Samples were dried at 80 $^{oC}$ for 48 hours and analyses were conducted by SGS Australia Pty Ltd using NIRS techniques.

A key performance indicator (KPIs) of pasture production measured was the stock grazing days per hectare. This KPI is a reflection of a paddock’s pasture growth and another way of expressing stocking rates for rotational grazing systems that are not continuously stocked. Stock grazing days per hectare was calculated for each grazing period as the product of grazing days and stock number divided by the number of hectares in each paddock. Stock numbers were also converted to Adult Equivalents (AE) using the metabolic weight formula (NRDR 2007) of liveweight to the power of 0.75 to give more fair comparisons across years. An adult equivalent is a 450 kg steer consuming 10 kg DM/day. The total stock grazing days per hectare per annual observed grazing cycle was calculated as the sum of the grazing period KPIs. To account for the periods of the grazing year (‘ungrazed’, in Table 3) that were outside the cattle observation period (‘trial’ and ‘rest’ periods in Table 3), mean annual equivalent KPIs were calculated. The annual equivalent means were weighted according to the number of grazing days in each trial paddock and grazing period.

Table **1**). Only three grazing periods occurred in years 1, 3 and 5 due to seasonal limitations. Rehab 3 was over-allocated with stock in G1 due to an overestimation of the size of the paddock. The Control paddock was not grazed in October 2016 (spring, G13) due to an unintended crash grazing event just prior.

In years 1 and 2, Angus steers and heifers were used in equal number and from year 3 onwards, only steers were used. An exception to this was Rehab 3 in G2 of year 1 which was grazed by steers only. A single herd was used across years 3 and 4 and consisted of 157 Angus steers bought from a single vendor with an average purchase weight of 235kg, which was lighter than the previous cohorts. Lighter cattle were used so that the cattle could be kept in the trial for two years (i.e. years 3 and 4) without them becoming too heavy. In year 5 (2017-18), Angus steers bred on the Acland pastoral lease were used. Animals considered unsuitable for the trial were excluded on the basis that structural or health defects may affect growth rate. Eligible animals were randomly allocated to one of the four treatment paddocks. Cattle that were outside the preferred weight ranges of 250-350 kg (years 1, 2 and 5) or 200-325 kg in year 3, or were surplus to requirements were defined as 'filler' cattle. The filler group was grazed on an unmined 'rest' paddock. Filler cattle were added into trial groups at grazing period entry times, when variations to the stocking rate were required.

Cattle were managed in accordance with the Australian Code for the Care and Use of Animals for Scientific Purposes´ (National Health and Medical Research Council 2013). Upon arrival the cattle were grazed in a single cohort on unmined areas. All cattle were treated with the same treatments with the exception of animals affected by infectious bovine kerato-conjunctivitis (pink eye), which were treated individually with Terramycin spray when required. Treatments administered to all cattle were 5 in 1 vaccine for clostridial diseases, anthelmintic drench for parasitic worms, and a Buffalo Fly repellent (Coopers Easy Dose). All animals were visually monitored each time they were weighed and any animals that exhibited attributes that have a negative impact on weight gain were excluded. This included unhealthy, structurally incorrect or injured animals. Stock water was Class A+ recycled water from the Toowoomba Regional Council's Wetalla wastewater reclamation facility treatment plant and was supplied via a single trough in each trial paddock.

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- Percentage of ground covered by green pasture material, organic matter and rock; and
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Table 1. Grazing periods, pasture and cattle observation dates

| Grazing year | Year 1 (Sep 8th 2013 - Sep 7th 2014) | | | | Year 2 (Sep 8th 2014 - Sep 7th 2015) | | | | Year 3 (Sep 8th 2015 - Sep 7th 2016) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grazing period | - | G1 | G2 | G3 | G5 | G6 | G7 | G8 | - | G9 | G10 | G11 |
| Season | Spring 2013 | Summer 2014 | Autumn 2014 | Winter 2014 | Spring 2014 | Summer 2015 | Autumn 2015 | Winter 2015 | Spring 2015 | Summer 2016 | Autumn 2016 | Winter 2016 |
| Cattle entry | - | 23-Jan 2014 | 16-Apr 2014 | 24-Jun 2014 | 30-Oct 2014 | 14-Jan 2015 | 14-Apr 2015 | 14-Jul 2015 | - | 09-Dec 2015 | 08-Mar 2016 | 29-June 2016 |
| Cattle exit | - | 13-Mar 2014 | 28-May 2014 | 31-Jul 2014 | 21-Nov 2014 | 17-Feb 2015 | 2-Jun 2015 | 19-Aug 2015 | - | 15-Feb 2016 | 26-Apr 2016 | 10-Aug 2016 |
| No. days | - | 49 | 42 | 37 | 22 | 34 | 49 | 36 | - | 68 | 49 | 42 |
| Faecal sampling | - | - | 14-May 2014 | 8-Jul 2014 | 20-Nov 2014 | 11-Feb 2015 | 1-Jun 2015 | 18-Aug 2015 | - | 21-Jan 2016 | 1-Apr 2016 | 1-Aug 2016 |
| Botanal sampling | - | 14-Jan 2014 | 15-Apr 2014 | 19-Jun 2014 | 27-Oct 2014 | 14-Jan 2015 | 9-Apr 2015 | 22-Jun 2015 | - | 7-Dec 2015 | 16-Mar 2016 | 13-Jun 2016 |
| | Year 4 (Sep 8th 2016 - Sep 7th 2017) | | | | Year 5 (Sep 8th 2017 - Sep 7th 2018) | | | | | | | |
| Grazing period | G13 | G14 | G15 | G16 | G17 | G18 | G19 | - | | | | |
| Season | Spring 2016 | Summer 2017 | Autumn 2017 | Winter 2017 | Spring 2017 | Summer 2018 | Autumn 2018 | - | | | | |
| Cattle entry | 17-Oct 2016 | 31-Jan 2017 | 24-Apr 2017 | 24-Jul 2017 | 13-Nov 2017 | 12-Feb 2018 | 7-May 2018 | - | | | | |
| Cattle exit | 13-Dec 2016 | 17-Mar 2017 | 6-Jun 2017 | 7-Sep 2017 | 15-Dec 2017 | 23-Mar 2018 | 22-Jun 2018 | - | | | | |
| No. days | 57 | 45 | 43 | 45 | 32 | 39 | 46 | - | | | | |
| Faecal sampling | - | 17-Mar 2017 | 12-May 2017 | - | 20-Dec 2017 | - | - | - | | | | |
| Botanal sampling | 5-Oct 2016 | 23-Jan 2017 | 12-Apr 2017 | 3-Jul 2017 | 1-Nov 2017 | 29-Jan 2018 | 18-Apr 2018 | - | | | | |

### *Cattle observations*

#### *Cattle liveweights*

Cattle were weighed at entry and exit of each grazing period. All animals were weighed on a 2.5-hour dry (no water available) curfew period with the time between the start of mustering and the end of weighing being 5.5-6 hours. Cattle were co-mingled between groups and weighed in random order. The scales were calibrated every 25 animals and tared to zero every 10 animals, if required.

Key performance indicators (KPIs) of cattle production measured were average daily liveweight gain (ADG, kg/head/day), liveweight gain per head of cattle (LWG, kg/head) and liveweight production per hectare. The ADG and LWG per head were calculated using the number of grazing days and the weights of cattle at the entry and exit of each grazing and rest period. Cumulative LWG and associated ADG over the periods of grazing the trial paddocks each year was calculated using the sum of LWG and days in each trial grazing period. Cumulative weight gains that included the rest periods were not calculated. Liveweight production per hectare (LWG kg/ha) was calculated as the product of stocking rate and ADG for each trial grazing period. Cumulative LWG per hectare for the trial grazing periods in each year was calculated as the sum of production per hectare for each trial grazing period.

#### *Faecal NIRS*

Near Infrared Spectrophotometry (NIRS) was used to estimate the quality of feed being consumed. NIRS analysis was conducted on single bulked faecal samples that were collected from each paddock cohort at or around the mid-point of each grazing period and/or when feed was not limited (Table 1). Following collection, faecal samples were kept cool, then sundried to remove moisture and then delivered to the Symbio Alliance laboratory for analysis using methods of Jackson *et al.* (2009). Differences between sites could not be tested statistically. Due to resource limitations, there were no samples taken in the grazing periods G1 (Summer 2014), G13 (Spring 2016), G16 (Winter 2017), G18 (Summer 2018) or G19 (Autumn 2018). The indicators measured directly were N content (%, which has a component of rumen and digestive tract N contributed by bacteria and fungi) and P content (%). The ash content (%) and dry matter digestibility (DMD) of the diet were predicted (Coates and Dixon 2011). Faecal N was used to predict dietary crude protein (CP), and DMD was used to estimate metabolisable energy (ME) of the diet (Dixon and Coates 2010). The ratios of P:N and DMD:CP were also calculated and the non-grass component of the diet was also predicted.

*Meat safety and quality*

Carcase samples from the Rehab 2 cohort of cattle (n=19) in year 1 (2013-14) were tested for heavy metal contamination and eating quality. Liver samples were collected at the abattoir on 12th December 2014, stored and transported by road to the Biosecurity Queensland Veterinary Laboratories for analysis of copper, arsenic, cadmium, lead, mercury and zinc concentrations. An assessment of the eating quality of all carcases was undertaken using the Meat Standards Australia methodology for beef grading (Meat Standards Australia 2007).

*Statistical Analysis*

The experimental design included a degree of replication in the rehabilitated pastures (albeit different pasture ages) and no replication of the unmined control site, due to practical limitations. To mitigate the lack of replication of the control site, soil, pasture and cattle liveweight gain were compared with measurements from unmined land at other sites in the region (Bennett *et al.* in preparation; Clewett *et al.* this volume; Paton *et al.* this volume). Statistical summaries and analyses of paddock effects on cattle performance indicators were conducted based on data from steers that remained in the same cohort throughout an annual cycle. Heifer data were excluded because there were some significant differences in KPIs between heifers and steers in Years 1 and 2 (data not shown). Filler cattle were also excluded from the statistical testing. For analysis of rest period data, cattle were grouped according to the site they grazed prior to, and after, the rest period. Statistically significant differences between KPI means for each paddock's pasture and cohort of cattle were tested using Analysis of Variance using Genstat software (19th Edition, VSN International Ltd, Hemel Hempstead, England). Differences between means were considered significant at the 95th percent confidence level (i.e. $P<0.05$). Statistical comparison between paddocks for production per hectare was not possible because the trial sites were not replicated. Trends over time in KPIs were tested using linear regression analysis, but cattle LWG was excluded from the regression analysis because of the high inter-annual variability in cattle entry weights.

## Results

*Observed climate data*

The long-term annual average rainfall for the Oakey Aerodrome, the nearest rainfall station, is 659 mm. Monthly rainfall during the trial period was aggregated from daily rainfall recorded by the automatic weather station at the Acland mine office (Figure 1). The rain in April 2014 was too late to grow much pasture but probably extended the season for cattle liveweight gain. Similarly, rain in late March 2017 probably also extended the season for cattle liveweight gain. Annual rainfall only exceeded the long-term average in year 4 (2017) and was lowest in year 5 (2018). The only seasons that had above average rainfall were autumn 2014 (year 1), summer 2015 (year 2), spring 2015 (year 3) and autumn 2017 (year 4). Mean annual rainfall for the trial site was 562 mm during the trial and this was 14% below the long-term average of the 60-year period (July 1958-June 2018) used in GRASP model simulations of pasture and cattle performance at the site (Clewett *et al.* this volume). Annual rainfall (mm) and GRASP estimates of annual pasture growth (kg/ha, mean for control and all rehab paddocks) for years 1 to 5 of the trial were respectively: 564 and 5427 (year 1), 476 and 5105 (year 2), 600 and 4946 (year 3), 695 and 5029 (year 4), and 478 and 4447 (year 5).

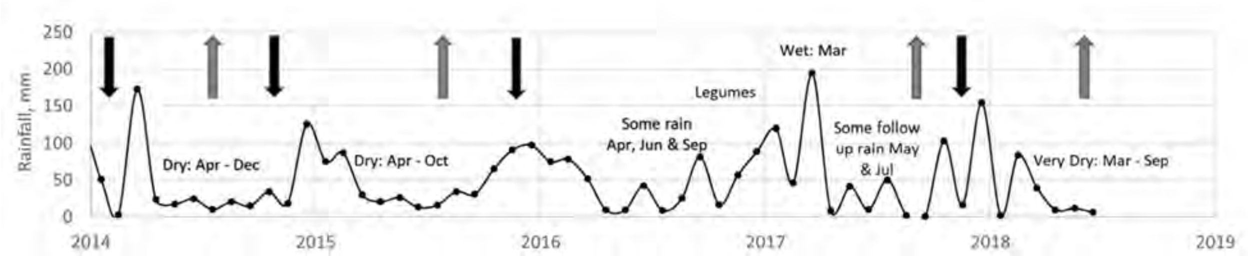
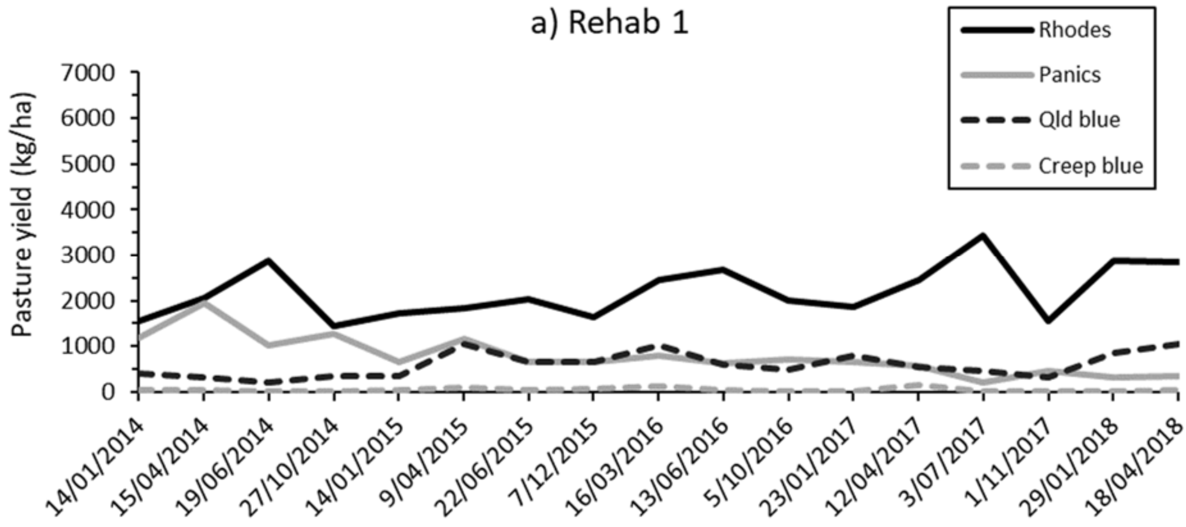



**Figure 1 Monthly rainfall (mm) plotted mid-month and cattle movements at Acland. Text annotations highlight key rainfall features and the period when winter rain in 2016 promoted the growth of legumes. Black downward arrows indicate the start of grazing each year and grey upward arrows indicate the end of grazing each year.**

*Pasture composition and quality*

In Rehab 1 Rhodes grass remained dominant throughout the trial (Figure 2a). Green and Gatton panics were initially co-dominant with Rhodes grass but the yield of the panics declined significantly over time (Table 6). Queensland blue grass, a native grass, maintained a presence as one of the dominant species. In Rehab 2 Green and Gatton Panics dominated through the trial period (Figure 2b). Creeping bluegrass was present but at low yields. In both Rehab 3 and the Control paddocks yields of Rhodes grass declined significantly with time (i.e. equivalent to age of pasture) and the yield of creeping blue grass increased significantly (Table 6, Figure 2c and Figure 2d).


a) Rehab 1
Rhodes
Panics
Qld blue
Creep blue
Pasture yield (kg/ha)
7000
6000
5000
4000
3000
2000
1000
0
14/01/2014
15/04/2014
19/06/2014
27/10/2014
14/01/2015
9/04/2015
22/06/2015
7/12/2015
16/03/2016
13/06/2016
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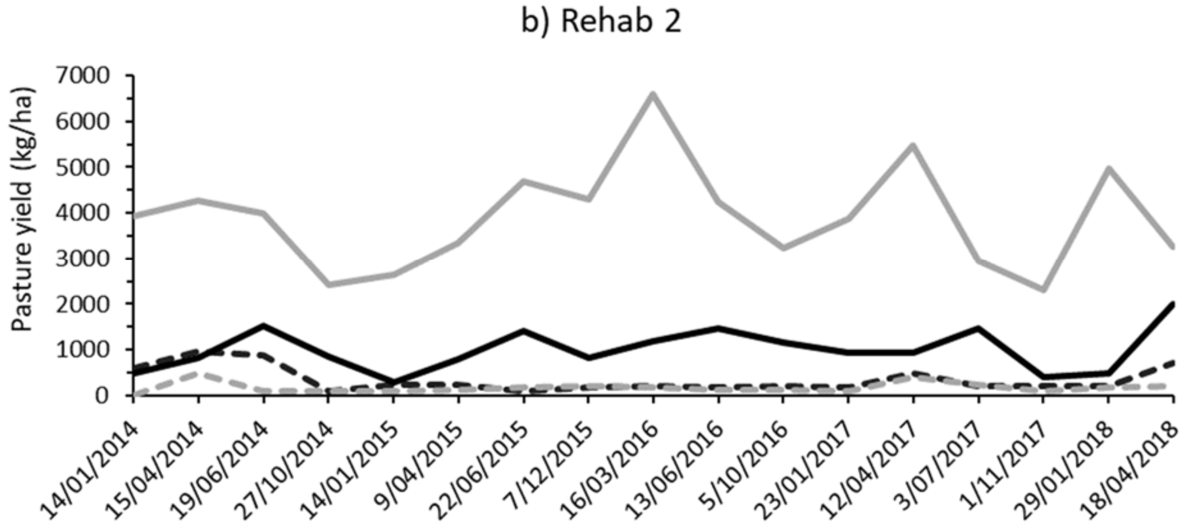
23/01/2017
12/04/2017
3/07/2017
1/11/2017
29/01/2018
18/04/2018


b) Rehab 2
Pasture yield (kg/ha)
7000
6000
5000
4000
3000
2000
1000
0
14/01/2014
15/04/2014
19/06/2014
27/10/2014
14/01/2015
9/04/2015
22/06/2015
7/12/2015
16/03/2016
13/06/2016
5/10/2016
23/01/2017
12/04/2017
3/07/2017
1/11/2017
29/01/2018
18/04/2018

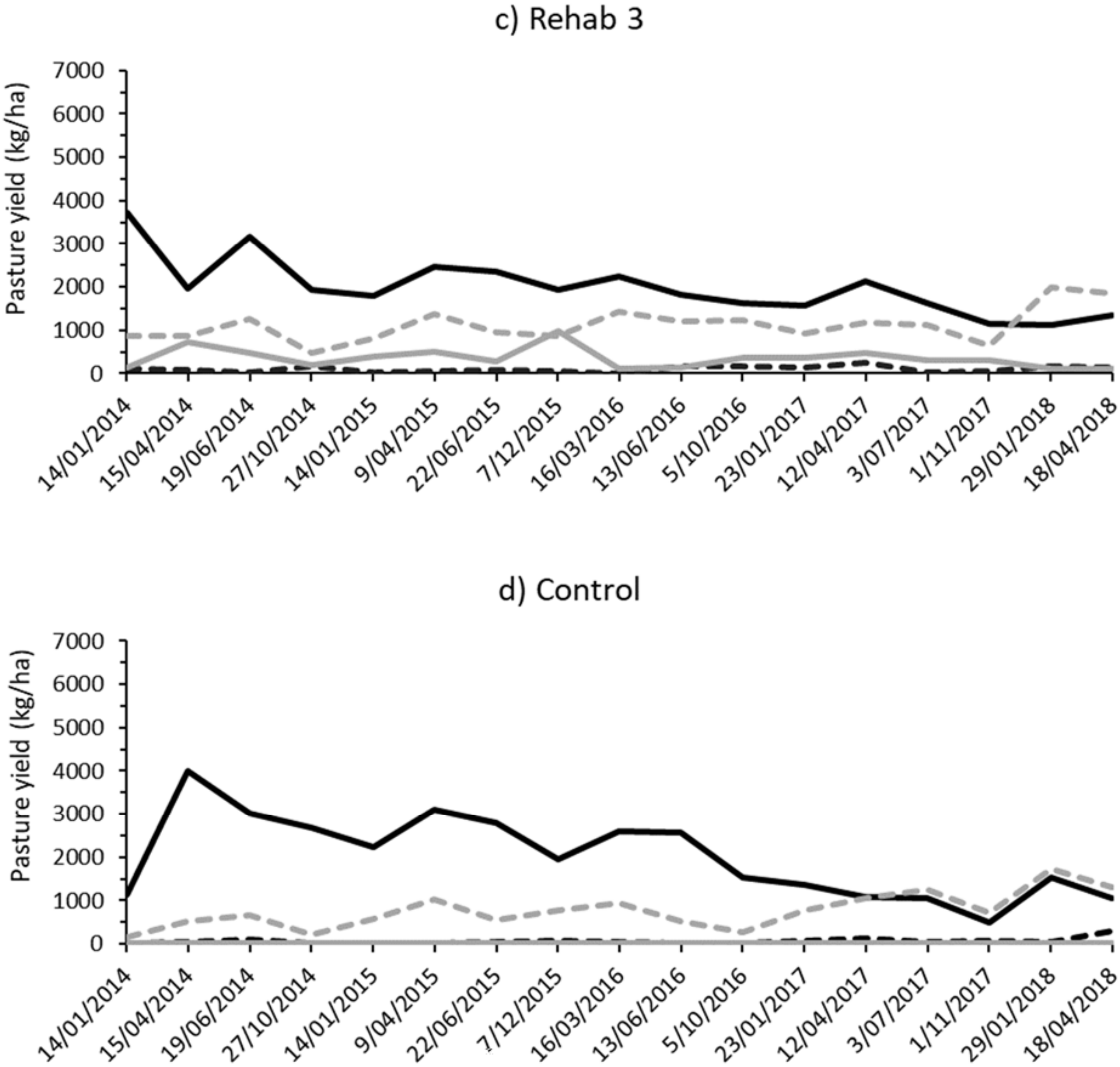



**Figure 2. Pasture yields (DM kg/ha) of the major species Rhodes grass (solid black line), Panic grasses (solid grey line), Queensland bluegrass (dashed black line) and Creeping bluegrass (dashed grey line) in the a) Rehab 1, b) Rehab 2, c) Rehab 3 and d) Control trial paddocks.**

Only in spring (October) 2016 were there significant quantities of legumes (Figure 3), reaching 21.4%, 10.7%, 11.1% and 4.0% of pasture yield in Rehab 1, Rehab 2, Rehab 3 and Control paddocks, respectively. The legumes included Vetch (*Vicia* spp.) and medics (*Medicago* spp.) which were sown during pasture establishment, and self-regenerating Hexham scent (*Melilotus indica*). In winter and spring 2017 legumes were present but only at levels of 1 to 4%. At all other samplings, legume content was less than 3% of pasture yield.

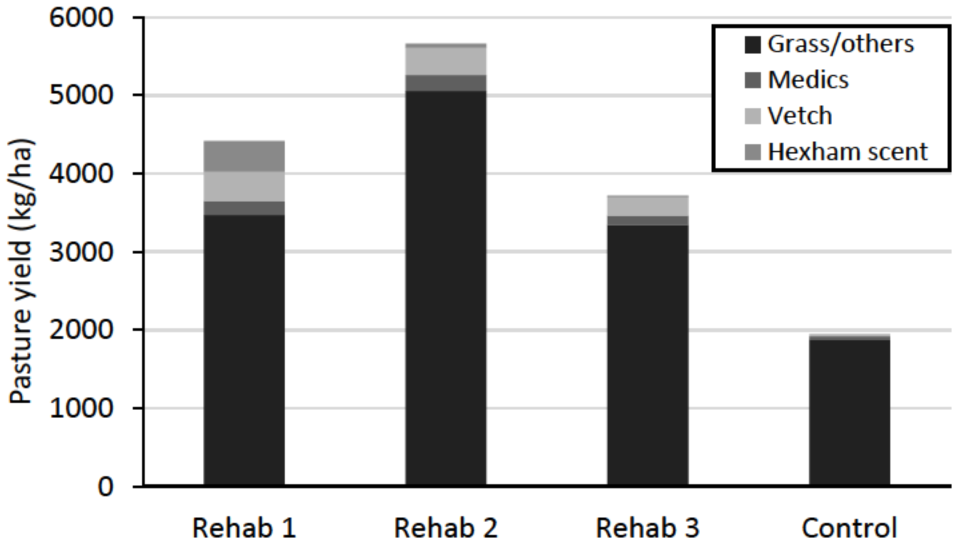



**Figure 3. Yields of grasses and legumes (medics, vetch and hexham scent) in trial paddocks in Spring (October) 2016.**

Grass leaf samples collected before each grazing showed Rehab 2 had the highest mean protein levels, and there was no difference between sites in the mean dry matter metabolisable energy or digestibility over the trial period (Table 2). There was a significant ($P$<0.001) and similar decline in leaf protein as pasture age (months since sowing) increased across all sites (Figure 4a). The strength of the relationship increased when including only the samples taken in summer and autumn (December to April inclusive)(Figure 4b) and similar relationships were found for the trends in leaf protein over time (as opposed to pasture age) (Table 6).

All paddocks remained in land condition A (i.e best) throughout the trial, maintaining >80% of the 3Ps (Perennial, Productive and Palatable pasture species) at all times. Ground cover was maintained above 80% in all paddocks throughout the trial and was 90% or better on most sampling occasions.

**Table 2. Pasture quality. Grass leaf protein, metabolisable energy and digestibility (mean ± sd) over the trial period in each paddock. Means followed by letters that differ denote statistically significant differences ($P$<0.05) between sites.**

| Site | N sampling times | Protein (%) | Metabolisable energy (MJ/kg DM) | Digestibility (%) |
|---|---|---|---|---|
| Control | 16 | 8.22 ± 3.197 a | 8.19 ± 1.132 a | 59.3 ± 5.88 a |
| Rehab 1 | 17 | 9.74 ± 2.769 a | 8.32 ± 1.088 a | 60.6 ± 5.75 a |
| Rehab 2 | 17 | 12.69 ± 2.885 b | 8.78 ± 1.236 a | 63.4 ± 6.10 a |

| | | | | |
|---|---|---|---|---|
| Rehab 3 | 17 | 9.75 ± 2.723 a | 8.53 ± 0.990 a | 61.8 ± 4.92 a |

(a) (b)

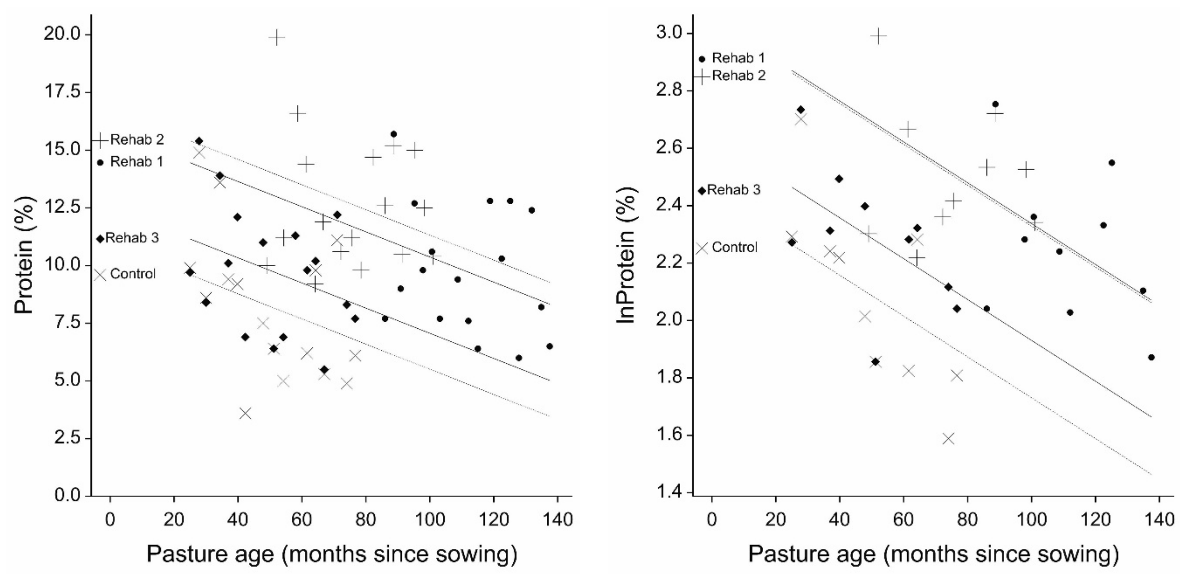



**Figure 4. Grass leaf protein vs pasture age (months since sowing) for a) all sample dates and b) summer (December to April) sample dates with fitted linear regression models for a) response protein %, slope -0.055 and constants for Rehab 1 (15.8) and Rehab 2 (16.8) significantly higher than the Control (11.0) and for Rehab 3 (12.5) not significantly different from the Control, overall model *P*<0.001. $R^2$ adjusted for the number of model parameters was 28.3, and for b) response *ln* protein%, slope -0.007 and constants for Rehab 1 (3.05) and Rehab 2 (3.04) significantly higher than the Control (2.44) and for Rehab 3 (2.64) not significantly different from the Control, overall model *P*<0.001. $R^2$ adjusted for the number of model parameters was 37.1.**

*Pasture production*

The mean (± sd) pasture total standing dry matter (TSDM) (for the trial period, from 14th January 2014 to 18th April 2018, $n_{\text{sampling times}} = 17$) in the Control (2871 ± 907.8 kg/ha) was lower (P<0.05) than in the other sites and in Rehab 2 (5656 ± 1343.3 kg/ha) was higher (P<0.05) than in the other sites. Rehab 1 (3965 ± 678.4 kg/ha) and Rehab 3 (3609 ± 739.7 kg/ha) means were statistically equivalent.

Rehab 2 maintained the highest observed pasture TSDM throughout the trial reaching a yield of 8236 kg/ha on 16th March 2016 (Figure 5). Observed pasture presentation yields in the Rehab 3 and Control paddocks showed a trend of declining yields over the length of the trial, consistent with patterns of rundown in pastures. However, natural variation in pasture yields due to seasonal growth patterns and grazing resulted in the trends being not significant (*P*>0.05). However, the first yield point for the Control paddock was an outlier as it was measured in a period of pasture recovery after an unintended crash grazing event in spring

2013. Taking that point out of the analysis increased the mean observed TSDM to 2969 kg/ha and strengthened the regression model such that the decline was significant ($P$<0.001) for the Control and weakly significant ($P$<0.1) for Rehab 3. Consequently, the same trend was evident for a regression of TSDM against pasture age (Figure 6).

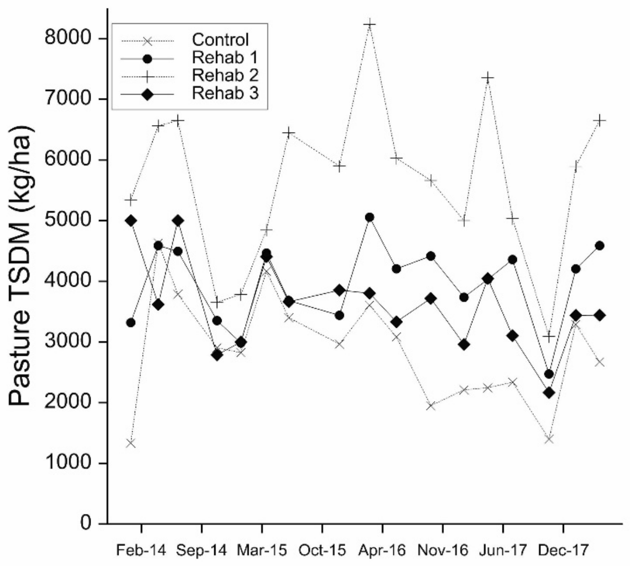



**Figure 5. Pasture total standing dry matter (TSDM, kg/ha) for Rehab and Control paddocks between January 2014 and April 2018.**

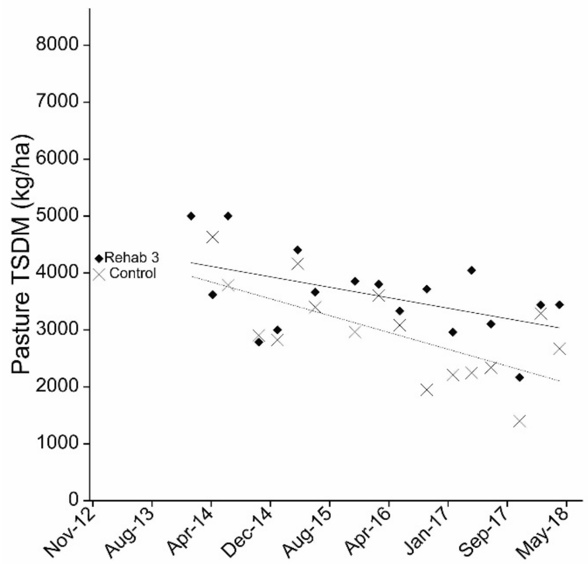



**Figure 6 Mean pasture total standing dry matter (TSDM, kg/ha) over time for Rehab 3 and Control paddocks with linear regression trend lines, with one Control outlier point removed. Fitted model ($P$<0.001) equations were $ln$TSDM Control = -0.00041*date +70.6 $ln$TSDM Rehab 3 = -0.0002*date +38.1 and $R^2$ adjusted for the number of model parameters was 55.4.**

*Pasture stocking rates*

Due to a dry season and commensurately short grazing periods, in year 5 cattle grazed the trial paddocks for 117 days, which was fewer days than all previous years (128 days in year 1, 141 days in Year 2, 159 days in year 3 and 190 days in year 4, Table 3). Cattle grazed the trial paddocks for 48-68% of the total grazing time (i.e. trial plus rest period grazing) each year. Cattle grazed trial or rest pasture for 52, 80, 67, 89 and 61%, and grazed trial pasture only for 35, 39, 43, 52 and 32% of the twelve-month grazing year in years 1 to 5, respectively.

In years three to five of the trial there were more AE grazing days per hectare per year in the Rehab paddocks than in the Control paddock whereas earlier, the Control paddock supported more grazing days than Rehab 1 (year 1) and similar grazing days to Rehab 3 (year 2). Over the five years, Rehab 2 had the highest trial mean AE grazing days per ha of 160. Rehab 1 and Rehab 3 had 128 and 127 AE grazing days per ha, respectively, and the Control was lowest with 105 AE grazing days per ha. In G1 Rehab 3 was over-stocked and consequently over-grazed due to an overestimation of the size of the paddock. Including that over-graze, but excluding the G13 crash graze in the Control, the mean annual equivalent stocking rate over the five years was highest in Rehab 2 (44 AE 100 $ha^{-1}$), lowest in the Control (29 AE 100 $ha^{-1}$) and intermediate in Rehab 1 and Rehab 3 (35 AE 100 $ha^{-1}$) (Table 3).

Table 3. Date stock entered trial paddocks, number of days stock remained in paddocks during trial, rest and ungrazed (when cattle were not observed) periods, number of head (hd) per paddock and per hectare, stocking rate as adult equivalent (AE) head per 100 hectare, and head and adult equivalent grazing days per hectare for each grazing period and trial site cohort. Annual (12 month) equivalent means are shown for stocking rates.

| | | Control | | | | | Rehab 1 | | | | | Rehab 2 | | | | | Rehab 3 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days | Stocking rate | | | Grazing days | | Stocking rate | | | Grazing days | | Stocking rate | | | Grazing days | | Stocking rate | | | Grazing days | |
| | | **head** | **hd/ha** | **AE hd/100ha** | **Grazing days/ha** | **AE Grazing days/ha** | **head** | **hd/ha** | **AE hd/100ha** | **Grazing days/ha** | **AE Grazing days/ha** | **head** | **hd/ha** | **AE hd/100ha** | **Grazing days/ha** | **AE Grazing days/ha** | **head** | **hd/ha** | **AE hd/100ha** | **Grazing days/ha** | **AE Grazing days/ha** |
| **Year 1** | | | | | | | | | | | | | | | | | | | | | |
| G1 | 49 | 20 | 0.95 | 74 | 47 | 36 | 20 | 0.91 | 67 | 45 | 33 | 40 | 1.25 | 94 | 61 | 46 | 40** | 1.82 | 134 | 89 | 65 |
| G2 | 42 | 25 | 1.19 | 97 | 50 | 41 | 20 | 0.91 | 73 | 38 | 31 | 40 | 1.25 | 102 | 53 | 43 | 20 | 0.91 | 74 | 38 | 31 |
| G3 | 37 | 20 | 0.95 | 84 | 35 | 31 | 25 | 1.14 | 98 | 42 | 36 | 37 | 1.16 | 102 | 43 | 38 | 23 | 1.05 | 90 | 39 | 33 |
| **Trial** | **128** | **22** | **1.03** | **85** | **132** | **109** | **22** | **0.98** | **80** | **125** | **100** | **39** | **1.22** | **99** | **157** | **127** | **28** | **1.26** | **99** | **166** | **130** |
| **Rest** | **61** | | | | | | | | | | | | | | | | | | | | |
| **Ungrazed** | **176** | | | | | | | | | | | | | | | | | | | | |
| **Annual equivalent** | **365** | | **0.36** | **30** | | | | **0.34** | **27** | | | | **0.43** | **35** | | | | **0.45** | **36** | | |
| **Year 2** | | | | | | | | | | | | | | | | | | | | | |
| G5 | 22 | 20 | 0.95 | 74 | 21 | 16 | 23 | 1.05 | 80 | 23 | 18 | 36 | 1.13 | 86 | 25 | 19 | 20 | 0.91 | 72 | 20 | 16 |
| G6 | 34 | 18 | 0.86 | 75 | 29 | 26 | 22 | 1.00 | 86 | 34 | 29 | 35 | 1.09 | 95 | 37 | 32 | 20 | 0.91 | 81 | 31 | 28 |
| G7 | 49 | 20 | 0.95 | 89 | 47 | 44 | 20 | 0.91 | 88 | 45 | 43 | 30 | 0.94 | 90 | 46 | 44 | 20 | 0.91 | 88 | 45 | 43 |
| G8 | 36 | 20 | 0.95 | 90 | 34 | 32 | 22 | 1.00 | 94 | 36 | 34 | 35 | 1.09 | 108 | 39 | 39 | 20 | 0.91 | 88 | 33 | 32 |
| **Trial** | **141** | **20** | **0.93** | **82** | **131** | **118** | **22** | **0.99** | **87** | **138** | **124** | **34** | **1.06** | **95** | **147** | **134** | **20** | **0.91** | **82** | **128** | **118** |
| **Rest** | **152** | | | | | | | | | | | | | | | | | | | | |
| **Ungrazed** | **72** | | | | | | | | | | | | | | | | | | | | |
| **Annual equivalent** | **365** | | **0.36** | **32** | | | | **0.38** | **34** | | | | **0.40** | **37** | | | | **0.35** | **32** | | |
| **Year 3** | | | | | | | | | | | | | | | | | | | | | |
| G9 | 68 | 20 | 0.95 | 66 | 65 | 45 | 23 | 1.05 | 72 | 71 | 49 | 46 | 1.44 | 99 | 98 | 67 | 25 | 1.14 | 76 | 77 | 52 |
| G10 | 49 | 27 | 1.29 | 101 | 63 | 50 | 32 | 1.45 | 113 | 71 | 55 | 63 | 1.97 | 157 | 96 | 77 | 35 | 1.59 | 119 | 78 | 59 |
| G11 | 42 | 20 | 0.95 | 71 | 40 | 30 | 21 | 0.95 | 71 | 40 | 30 | 38 | 1.19 | 92 | 50 | 39 | 20 | 0.91 | 67 | 38 | 28 |
| **Trial** | **159** | **22** | **1.06** | **79** | **168** | **124** | **25** | **1.15** | **85** | **182** | **134** | **49** | **1.53** | **116** | **244** | **183** | **27** | **1.21** | **87** | **193** | **138** |
| **Rest** | **86** | | | | | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ungrazed** | **121** | | | | | | | | | | | | | | | | | | | | |
| **Annual equivalent** | **366** | | **0.46** | **34** | | | | **0.50** | **37** | | | | **0.67** | **50** | | | | **0.53** | **38** | | |
| **Year 4** | | | | | | | | | | | | | | | | | | | | | |
| G13 | 57 | 157* | * | * | 37* | 30* | 16 | 0.73 | 66 | 41 | 38 | 26 | 0.81 | 76 | 46 | 43 | 16 | 0.73 | 64 | 41 | 37 |
| G14 | 45 | 20 | 0.95 | 96 | 43 | 43 | 25 | 1.14 | 114 | 51 | 51 | 39 | 1.22 | 128 | 55 | 57 | 21 | 0.95 | 95 | 43 | 43 |
| G15 | 43 | 13 | 0.62 | 71 | 27 | 30 | 23 | 1.05 | 117 | 45 | 50 | 47 | 1.47 | 171 | 63 | 73 | 22 | 1.00 | 110 | 43 | 47 |
| G16 | 45 | 11 | 0.52 | 62 | 24 | 28 | 20 | 0.91 | 106 | 41 | 48 | 34 | 1.06 | 131 | 48 | 59 | 15 | 0.68 | 79 | 31 | 36 |
| **Trial** | **190** | **15** | **0.70** | **76** | **93** | **101** | **21** | **0.95** | **101** | **178** | **187** | **37** | **1.14** | **126** | **212** | **233** | **19** | **0.84** | **87** | **158** | **162** |
| **Rest** | **135** | | | | | | | | | | | | | | | | | | | | |
| **Ungrazed** | **40** | | | | | | | | | | | | | | | | | | | | |
| **Annual equivalent** | **365** | | **0.25** | **28** | | | | **0.49** | **51** | | | | **0.58** | **64** | | | | **0.43** | **44** | | |
| **Year 5** | | | | | | | | | | | | | | | | | | | | | |
| G17 | 32 | 14 | 0.67 | 47 | 21 | 15 | 20 | 0.91 | 63 | 29 | 20 | 36 | 1.13 | 80 | 36 | 26 | 19 | 0.86 | 61 | 28 | 20 |
| G18 | 39 | 20 | 0.95 | 79 | 37 | 31 | 25 | 1.14 | 92 | 44 | 36 | 48 | 1.50 | 125 | 59 | 49 | 22 | 1.00 | 83 | 39 | 32 |
| G19 | 46 | 14 | 0.67 | 57 | 31 | 26 | 21 | 0.95 | 82 | 44 | 38 | 40 | 1.25 | 111 | 58 | 51 | 18 | 0.82 | 71 | 38 | 33 |
| **Trial** | **117** | **16** | **0.76** | **61** | **89** | **72** | **22** | **1.00** | **79** | **117** | **94** | **41** | **1.29** | **105** | **152** | **125** | **20** | **0.89** | **72** | **104** | **85** |
| **Rest** | **104** | | | | | | | | | | | | | | | | | | | | |
| **Ungrazed** | **144** | | | | | | | | | | | | | | | | | | | | |
| **Annual equivalent** | **365** | | **0.24** | **20** | | | | **0.32** | **26** | | | | **0.42** | **34** | | | | **0.29** | **23** | | |
| **All years** | | | | | | | | | | | | | | | | | | | | | |
| **Trial total** | | | | | **613** | **524** | | | | **741** | **639** | | | | **912** | **802** | | | | **750** | **633** |
| **Trial mean** | **147** | **19** | **0.90** | **77** | **123** | **105** | **22** | **1.02** | **86** | **148** | **128** | **40** | **1.25** | **108** | **182** | **160** | **23** | **1.02** | **86** | **150** | **127** |
| **Annual equivalent** | | | **0.34** | **29** | | | | **0.41** | **35** | | | | **0.50** | **44** | | | | **0.41** | **35** | | |

*The Control fence was broken and 157 head grazed the paddock for 5 days. Not included in weight gain data but included here for completeness. Weights of 13 filler cattle that were returned to the Control for G14 were used for annual weight gain comparisons. The annual equivalent mean stocking rate including the crash grazing stock data for the G13 period was 0.36 head/ha for both year 4 and over all five years.**overgrazing of Site 3 due to incorrect estimate (37 ha) of actual paddock size (22 ha)

*Cattle liveweight gain*

Grazing of the trial paddocks occurred on 46 % of days in the trial period from 23 Jan 2014 to 22 Jun 2018 (1611 days). The intervening rest periods for each year accounted for a further 33 % of days. There were no significant differences ($P>0.05$) in entry weights between site cohorts for the first grazing period in any year that new cattle were introduced (data not shown). This reflects successful equal distribution of cattle weights amongst cohorts at the start of the trial years. Mean cattle entry weights were 289 kg, 334 kg, 244 kg and 263 in years 1, 2, 3 and 5 respectively. In year 4, when cattle were carried over from year 3, the Rehab 2 cohort was heaviest (386 kg) and there was no significant difference ($P>0.05$) in cohort weight between the other three sites (Rehab 1 347 kg, Rehab 3 347 kg and Control 363 kg). There were strong positive correlations ($0.81 < r <0.98$ except for Rehab 3 in year 2 $0.57<r<0.80$), as expected, across all cattle cohorts between cattle entry and exit weights for each of the trial grazing periods.

Over the five years of the trial, the total liveweight gain of cattle grazing the Rehab 2 paddock averaged 98 kg/hd (Table 4). This was significantly higher ($P<0.05$) than other paddocks (65-75 kg/hd), however, there was also a significant ($P<0.05$) interaction with years. This interaction was mainly due to the high liveweight gain of cattle grazing the youngest pastures (Control and Rehab 3) during the first year when leaf N was highest (Figure 4), and also during year 4 when the liveweight gain was high in all paddocks due to favourable rainfall conditions and the growth of legumes. In addition, the liveweight gains in year 1 were disrupted during the 4 week rest period between G1 and G2 by 135 mm of rain that occurred over the last week of March. The wet weather was the likely cause of temporary liveweight losses in all paddocks (8 kg/hd on average and particularly Control 21 kg/hd) which was then regained in G2. The high compensatory gain of the control boosted the total liveweight gain of the control for year 1 that was not reflected in the cumulative liveweight gains from the start of G1 to the end of G3 (23 Jan to 31 July 2014) (Table 4). The higher weight gains of Rehab 2 were most pronounced during seasons when rainfall and productivity were low (years 2, 3 and 5), and conversely least pronounced when average productivity was higher (years 1 and 4) with autumn rains extending the presence of green pastures into winter. The five-year mean cumulative liveweight gain (116 kg/hd) was significantly higher ($P<0{,}05$) in Rehab 2 than in the other trial paddocks without an interaction with year. The total liveweight gain of Rehab 2 when averaged over all years was 37 % higher than the average of the other paddocks (Table 4). Field observations of cattle beef production per hectare were also consistently highest in Rehab 2 compared with the other sites with values strongly influenced by differences in rainfall and pasture growth with consequential effects on stocking rates (Table 4).

**Table 4. Cattle liveweight gain. Observed mean (±sd) total liveweight gain per head (trial LWG per head, kg/hd), average daily liveweight gain per head (trial ADG, kg/hd/d) and total liveweight gain per hectare (trial LWG per hectare, kg/ha) during trial grazing periods only, and cumulative LWG per head from the first to last grazing period, for each paddock and year of the trial. Letters that differ denote significant (P<0.05) differences between paddock cohorts. The sum of number of days grazing was constant within year so the statistical differences were the same for trial ADG and total LWG.**

| | Year 1[1] | Year 2 | Year 3 | Year 4[2] | Year 5 | All years[3] |
|---|---|---|---|---|---|---|
| | | | Trial LWG per head (kg/hd) | | | |
| Control | 121±21.1c (56b) | 49±24.8b | 56±17.1a | 130±32.9a (-) | 49±14.6a | 74 ± 39.2 |
| Rehab 1 | 66±12.8a (36a) | 22±15.1a | 56±18.0a | 128±28.5a (194a) | 55±18.0a | 65 ± 35.9 |
| Rehab 2 | 108±16.4c (59b) | 85±36.3c | 95±26.3b | 139±27.8a (198a) | 79±16.4b | 98 ± 31.1 |
| Rehab 3 | 95±13.6b (62b) | 55±22.7bc | 51±20.1a | 131±26.6a (190a) | 52±18.2a | 75 ± 36.2 |
| | | | Cumulative LWG per head (kg/hd) | | | |
| Control | 89±16.3ab | 91 ±20.9a | 43±15.6a | 136±19.2a (-) | 94±17.3a | 81 ±34.6a |
| Rehab 1 | 85±11.3a | 112±15.5b | 58±17.1a | 149±18.3a (226a) | 103±17.2a | 97 ±34.0b |
| Rehab 2 | 102±16.8b | 141±23.9c | 80±27.8b | 160±26.5a (242a) | 117±21.4b | 116 ±35.2c |
| Rehab 3 | 102±21.1b | 114±8.3b | 55±25.3a | 151±22.8a (223a) | 101±14.7a | 103 ±34.0b |
| | | | Trial ADG (kg/hd.day) | | | |
| Control | 0.95±0.166 | 0.35±0.177 | 0.35±0.107 | 0.98±0.248 | 0.42±0.125 | 0.54±0.309 |
| Rehab 1 | 0.51±0.100 | 0.15±0.107 | 0.35±0.113 | 0.96±0.214 | 0.47±0.153 | 0.49±0.276 |
| Rehab 2 | 0.84±0.128 | 0.61±0.258 | 0.60±0.165 | 1.05±0.209 | 0.68±0.140 | 0.73±0.231 |
| Rehab 3 | 0.74±0.107 | 0.39±0.161b | 0.32±0.126 | 0.98±0.200 | 0.45±0.155 | 0.57±0.277 |
| | | | Trial LWG per hectare (kg/ha) | | | |
| Control | 124 | 44 | 58 | 89 | 39 | 71 |
| Rehab 1 | 61 | 21 | 62 | 134 | 57 | 67 |
| Rehab 2 | 132 | 91 | 153 | 175 | 102 | 131 |
| Rehab 3 | 118 | 50 | 64 | 118 | 50 | 80 |

[1] Mean LWG excluding G1 is reported in parentheses [2] excludes G13 because the Control site was not grazed. LWG including G13 is reported in parentheses [3]There was a significant year x site interaction for trial LWG per head so an all year statistical summary was not justified

The average daily liveweight gain (ADG) of Rehab 2 over the five years was 0.73 kg/hd.day compared with 0.49, 0.57 and 0.54 in the Rehab 1, Rehab 3 and Control paddocks, respectively (Table 4). In terms of ADG within each trial grazing period, cattle grazing the Rehab 3 site (range over 17 grazing periods -0.49 to 1.36 kg/hd.day) performed equally or significantly better (P<0.05) than cattle grazing the Control site (range over 17 grazing periods -0.26 to 1.62 kg/hd.day) except for G1 when the Control outperformed all other sites, as previously described. Cattle in Rehab 1 had a significantly lower ADG than the Control cohort in G2, G3, G5, G10, G15 and G17, and Rehab 2 had a significantly lower ADG than the Control cohort in G5 and G15 only (Figure 7, statistical summaries not shown). The seasonal variation within sites (smallest range -0.49 to 1.36, in Rehab 3 and largest range -0.61-1.56 in Rehab2) was more than double the within-season variation between sites (smallest range 1.03 to 1.16 kg/hd.day, in G13 and largest range 0.79 to 1.56 kg/hd.day, in G8), reflecting a strong influence of weather on pasture growth and cattle performance relative to the influence of paddock treatment.

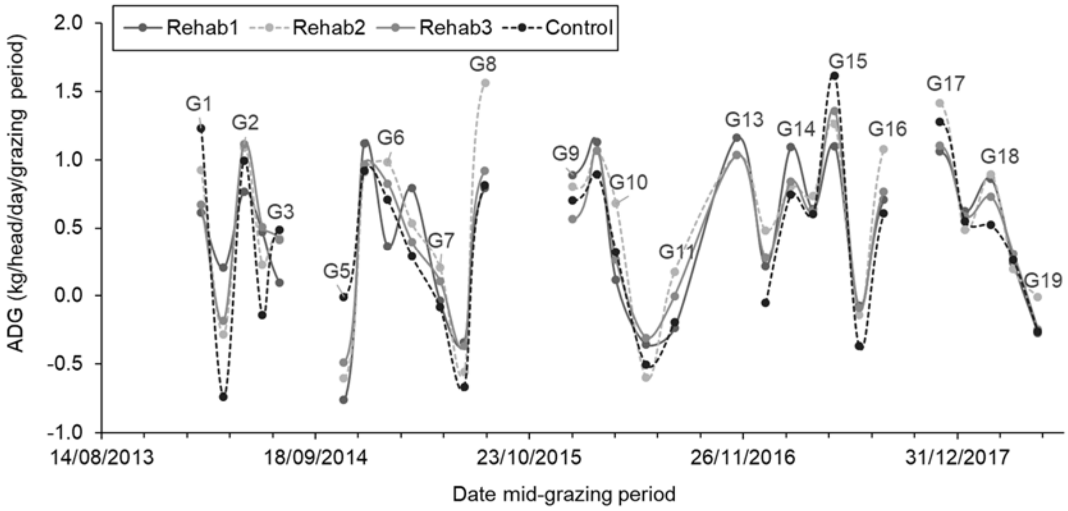



**Figure 7. Average daily growth (ADG, kg/head.day per grazing period) for cattle grazing the Rehab 1, Rehab 2, Rehab 3 and Control paddocks over time. Points include trial grazing periods (labelled) and rest grazing periods. The dashed line indicates cattle were retained over two years.**

For most grazing or rest periods, there were weak to moderate negative correlations (unpublished data) with ADG in the subsequent rest or grazing period for each paddock cohort, suggesting compensatory weight gains or losses usually occurred when cattle moved between the trial and rest paddocks. For example, in the cohorts that suffered the largest weight losses in winter 2018 (year 5, Control, Rehab 1 and Rehab 3) there were moderate negative correlations (-0.3 > r < -0.6) between the positive ADGs during the previous rest period and the negative ADGs in the winter trial period. Cattle with higher rest period growth rates tended to suffer larger weight loss during the subsequent trial grazing. Across grazing periods and paddocks there were no other systematic patterns of compensatory weight gains and losses indicating that the rest paddocks used for the trial were not consistently biasing the measurement of liveweight gain.

*Faecal NIRS Indicators*

Across the 12 grazing periods sampled for faecal NIRS measurements, there were no significant differences (P>0.05) between trial sites in the ash percentage, dry matter digestibility or the ratio of dry matter digestibility to crude protein (Table 5). Rehab 2 had significantly higher predicted dietary crude protein (9.3%) than the other sites (7.3-7.9%), a significantly higher predicted non-grass diet content (13%) than the other sites (4-8%), and a significantly higher percentage of N (1.7%) than the other sites (1.5%). The percentage of P was also significantly higher in Rehab 2 (0.68%) than in the other Rehab sites (0.48-0.54%) and was significantly lower in the Control site (0.31%) than in any of the Rehab sites. The P:N ratio was significantly lower in the Control site (0.27%) than in Rehab 1 and Rehab 2 (both 0.48%) but was similar to that in Rehab 3 (0.40%). Across the 11 grazing periods sampled for faecal NIRS metabolisable energy, and within a 90% confidence interval, metabolisable energy was significantly higher in Rehab2 than in the other sites.

**Table 5. Faecal NIRS indicators (mean ± sd) over the trial period for cohorts from each trial paddock. DMD – dry matter digestibility, ME – metabolisable energy, N – nitrogen, P- phosphorus. Lower case letters that differ denote significant (P<0.05) differences between paddock cohorts. Upper case letters that differ denote significant (P<0.1) differences between paddock cohorts.**

| Site | n | Ash (%) | Diet crude protein (%) | Non-grass diet (%) | DMD (%) | DMD: CP | N (%) | n | P (%) | P:N | n | ME (MJ/100kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 12 | 21±2.2a | 7.3±1.20a | 4±3.8a | 56.2±3.64a | 8±1.5a | 1.5±0.13a | 12 | 0.31±0.061a | 0.27±0.07a | 11 | 15.7±2.09A |
| Rehab1 | 12 | 22±4.4a | 7.5±1.27a | 7±6.4a | 56.5±3.65a | 8±1.6a | 1.5±0.12a | 10 | 0.54±0.107b | 0.48±0.12b | 11 | 16.1±1.40A |
| Rehab2 | 12 | 21±3.7a | 9.3±2.08b | 13±4.1b | 58.0±2.92a | 7±1.5a | 1.7±0.14b | 12 | 0.68±0.212c | 0.48±0.20b | 11 | 17.8±1.68B |
| Rehab3 | 12 | 21±3.2a | 7.9±1.62a | 8±6.2a | 56.6±4.44a | 7±1.4a | 1.5±0.18a | 12 | 0.48±0.181b | 0.40±0.20ab | 11 | 16.3±2.23A |

General trends in faecal NIRS indicators with increasing pasture age (months since sowing) were that crude protein decreased across all sites, and dry matter digestibility, the phosphorus content and the P:N increased across all sites, and the nitrogen percentage didn't change (Figure 8). Changes over time were similar to changes with increasing pasture age.  Grouping sites as Control with Rehab3 and Rehab1 with Rehab2 only (marginally) improved the linear regression model against pasture age for crude protein.

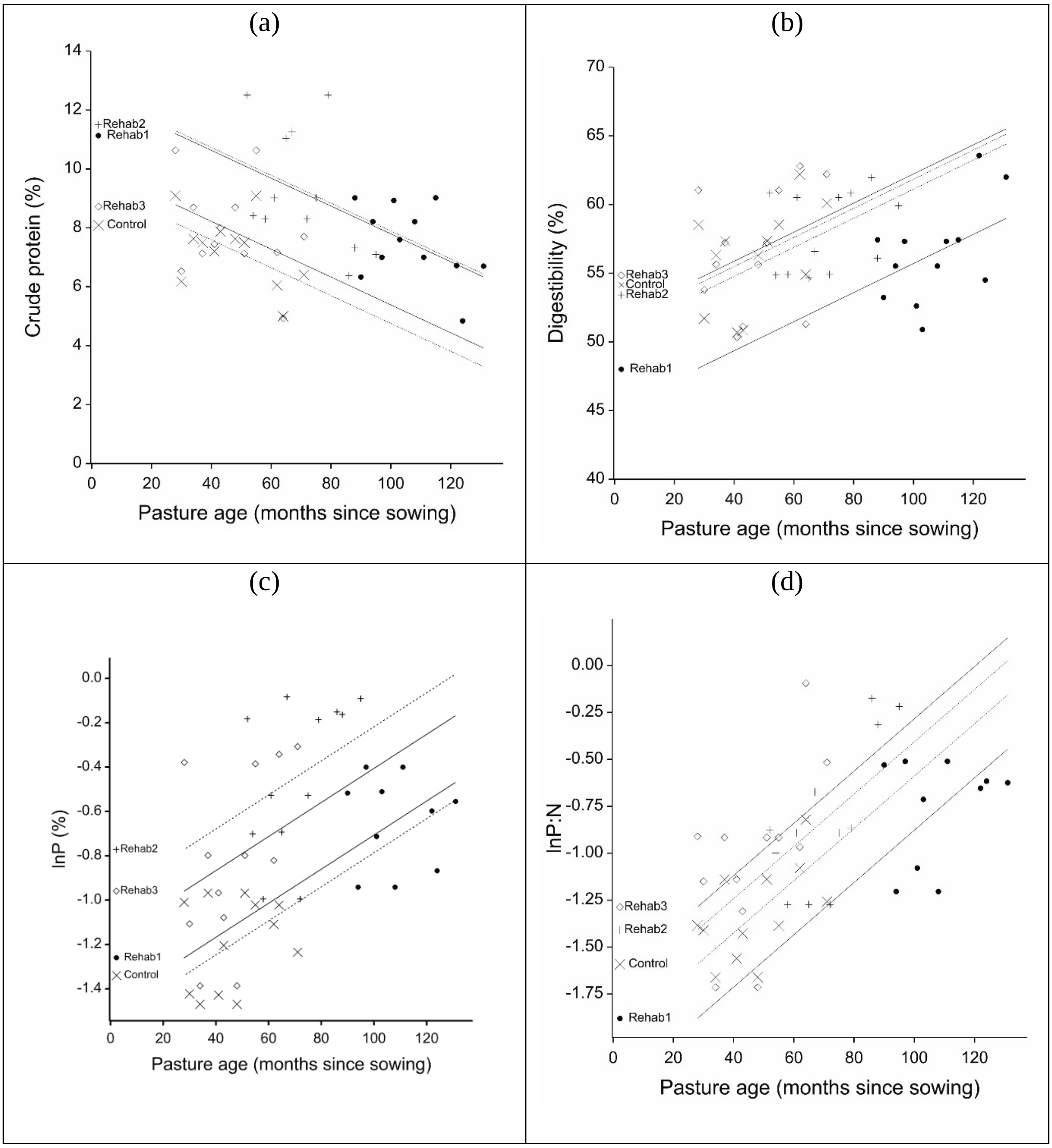



**Figure 8. Trends in faecal NIRS indicators of a) dietary crude protein, b) dry matter digestibility, c) phosphorus percentage and d) the P:N ratio with increasing pasture age (months since sowing) in each trial paddock. Regression equations were a) CP% (Control) = -0.047*Pasture age+9.5, Rehab 1 constant = 12.5, Rehab 2 constant = 12.6, Rehab 3 constant = 10.1, b) DMD% (Control) = 0.11*age_mo+51.3, Rehab 1 constant = 45.1, Rehab 2 constant = 50.5, Rehab 3 constant = 51.6, c) lnP% (Control) = 0.008*age_mo-1.6, Rehab 1 constant = -1.5, Rehab 2 constant = -1.0, Rehab 3 constant = -1.2, d) lnP:N (Control) = 0.014*age_mo-1.98, Rehab 1 constant = -2.27, Rehab 2 constant = -1.80, Rehab 3 constant = -1.68. Note non-zero y-axis minimum value in b).**

*Changes in KPIs over time*

Changes in observed values over time throughout the Acland Grazing Trial or with increasing pasture age since sowing were evaluated for key soil, pasture and cattle indicators (Table 6).

Across all sites there was evidence for an increase in soil N, faecal P, faecal P:N and predicted pasture DMD over time and/or pasture age. There was no change in faecal N. There was a decrease in pasture TSDM in the Control and Rehab 3 and no change in Rehab 1 and Rehab 2 with increasing pasture age and across all sites there was a decrease in leaf protein, predicted diet CP and pasture N uptake over time. Predicted diet CP also decreased with increasing pasture age.

**Table 6. Summary of KPI changes over time and/or pasture age. Ns; not significant (*P*>0.05)**

| | Regression by pasture age | *P* (fitted model) | $R^2$ | Model description for sites | Regression by time | *P* (fitted model) | $R^2$ | Model description for sites | Data source |
|---|---|---|---|---|---|---|---|---|---|
| **Soil** | | | | | | | | | |
| Colwell P | | | | | Decreasing trend across sites but failed model assumptions | | | | (Bennett *et al.* in preparation) |
| PMN plus mineral N | | | | | increase | <0.001 | 42.2 | Same slopes, different constants | (Bennett *et al.* in preparation) |
| **Pasture** | | | | | | | | | |
| TSDM, kg/ha | decrease<br>no change | <0.001<br>ns | 55.4<br>- | C, R3 same slope and constant (one C outlier removed)<br>R1, R2 | decrease<br>no change | <0.001<br>ns | 55.4<br>- | C, R3 same slope and constant (one C outlier removed)<br>R1, R2 | This paper |
| Rhodes, kg/ha | not tested | | | | decrease<br>decrease<br>no change | <0.05<br><0.001<br>ns | 56.1<br>45.3<br>- | C<br>R3<br>R1, R2 | This paper |
| Panic spp., kg/ha | not tested | | | | decrease<br>no change | <0.001<br>ns | 64.2<br>- | R1<br>C, R2, R3 | This paper |
| Creeping blue, kg/ha | not tested | | | | increase<br>increase<br>no change | <0.05<br><0.05<br>ns | 43.9<br>19.8<br>- | C<br>R3<br>R1, R2 | This paper |
| QLD blue, kg/ha | not tested | | | | increase<br>increase | <0.1<br><0.05 | 13.9<br>18.8 | R1<br>C | This paper |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | no change | ns | - | R2. R3 | |
| Leaf protein, % | decrease | <0.001 | 28.2 | Same slopes, constants R1&R2 > C | decrease | <0.001 | 28.1 | Same slopes, constant R2>C | This paper |
| | Dec-Apr only; decrease | <0.001 | 37.1 | Same slopes, constants R1&R2 > C | Dec-Apr only; decrease | <0.001 | 37.0 | Same slopes, constant R2>C | |
| N uptake, kg/ha (excluding legumes) | decrease<br>decrease | *<0.1*<br>*<0.05* | 9.2<br>34.7 | C&R3 grouped<br>R1&R2 grouped | not tested | | | | (Paton *et al.* this volume) |
| **Cattle** | | | | | | | | | |
| Faecal NIRS N | no change | >0.05 | - | - | no change | >0.05 | - | - | This paper |
| Faecal NIRS Diet crude protein | decrease | <0.001 | 28.6 | Same slopes, constants R1&R2>C | decrease | <0.05 | 28.8 | Same slopes, constant R2>C | This paper |
| Faecal NIRS P | increase | <0.001 | 50.6 | Same slopes, constants R2&R3>C | increase | <0.001 | 50.4 | Same slopes, constants R1, R2 & R3 >C | This paper |
| Faecal NIRS DMD | increase | <0.1 | 11.7 | Same slopes, constant R1<C | failed regression assumption s | - | - | - | This paper |
| Faecal NIRS P:N | increase | <0.001 | 45.5 | Same slopes, constant R3>C | increase | <0.001 | 45.2 | Same slopes, constants R1, R2&R3>C | This paper |

*Meat safety and quality*

Of the 19 cattle livers tested for heavy metal contamination in year 1, only one sample had a copper level (103.0 mg/kg) that was higher than the normal range for cattle of all ages (25-100 mg/kg). The other 18 samples had heavy metal levels within the normal ranges. Meat colour for carcases of the 2012 cohort of cattle (n=151) were within the 1C-3 expected range, suggesting that eating quality was acceptable for all samples and that there was no measurable difference in eating quality between samples from cattle grazing rehabilitated sites compared with those grazing the control site.

## Discussion

*Challenges of the experimental procedures*

The experimental procedures used presented a number of expected and unexpected challenges. Firstly, the trial treatments (i.e. age of rehabilitated or unmined sown pasture) could not be replicated. To account for this, statistical comparisons between paddock populations of cattle, pasture and soil attributes were conducted using within paddock variation as pseudo-replication. The paddock-level statistical comparisons provided insight into differences and similarities between the paddock-level grazing systems and differences between paddocks could not be attributed to any single element of the grazing system, such as pasture age. A rehabilitation study by Pauw *et al.* (2018) was similarly affected by a pseudo-replication constraint, which they acknowledged could overestimate the statistical significance of treatment differences. The Acland Grazing Trial field study was extended into a series of modelled simulation experiments (Clewett *et al.* this volume), partly to improve confidence in the generality of the Grazing Trial's results.

A second challenge was that the periods of grazing the trial paddocks were necessarily short relative to total grazing days (48-68%). The effects of the trial paddocks on LWG were therefore somewhat diluted (ie a low signal to noise ratio) by both effects of the communal 'rest' period grazing and by any periods of compensatory gain or loss upon re-entry to the trial paddock. Increasing the number of days grazing the trial sites in proportion to the total number of grazing days increases the potential for trial site, rather than rest site, effects to be measured via cattle weight gains and losses. However, an increase in this proportion would have compromised the sustainability criteria of the forage budget that underpinned the grazing system. Thirdly, the number of cattle 'always in group' was reduced by unintentional swapping during weighing and this reduced the statistical power of comparisons between cattle cohorts for each grazing period. However, in terms of stock numbers, Griffiths and Rose (2017) suggested that stocking rates of no fewer than 10 head per site be used for grazing system studies. Their benchmark was achieved in this study, with the minimum herd sizes being 11 (G16), 16 (G13), 26 (G13) and 15 (G16) in the Control, Rehab 1, Rehab 2 and Rehab 3 sites, respectively.

A fourth challenge was that the effect of season on pasture productivity and liveweight gain was far greater than any treatment effect and the periodic grazing regime did not fairly represent all seasons. Monthly analysis of days grazing show that observations in spring were relatively few compared to summer and autumn. The trial did, however, provide opportunities to study the effect of treatment under a range of seasonal scenarios, and the trends were largely consistent across exceptionally dry (e.g. G11), average moisture (e.g. G9), wetter than average (G13) and frosty (G8) conditions. A fifth challenge was the unplanned crash grazing event which occurred prior to the spring graze in 2016 (G13) on the control site. The Control cohort was therefore retained in the rest paddock for that grazing period. The Control cohort was examined for their ADG during this period to assess any possible bias. The bias was in favour of the unmined land whereby the Control cohort outperformed the Rehab cohorts for G13. This allowed fair inclusion of the control for direct comparison during G14 through G16 grazing. A further challenge was that the short-term (5 year) observation period did not allow sufficient time for full expression of pasture responses in yield, composition and quality and consequential livestock responses of diet selection and LWG.

The challenges faced by this study are not peculiar to this grazing system study. The Wambiana grazing trial, established in 1997 in north Queensland, demonstrated the value of long-term data to prevent overly-good or overly-poor weather and other factors adding bias to short-term outcomes (O'Reagain *et al.* 2014). Griffiths and Rose (2017) also experienced some of the issues although their project only recorded data for 2 years and 9 months, with two grazing periods where animals were set stocked. Fortunately, the five-year Acland Grazing trial with 17 grazing periods provided opportunities for a) a study of the effect of treatment under a range of seasonal scenarios, b) a statistical comparison of paddocks, and (c) calibration of the GRASP model (Clewett *et al.* this volume) which was subsequently used to estimate mean annual productivity (LWG per head and per ha) and thus overcome the bias in the observed values caused by the absence of several grazings. An ongoing pasture and cattle monitoring regime would also help to address these queries.

*Differences in pasture yields, stocking rates and liveweight gains in the rehabilitated and unmined grazing systems*

Up to a 50% difference between paddocks in mean cumulative LWG per head (Table 4) was magnified by up to almost 100% difference between paddocks in pasture growth supporting up to 44-48% difference in stock grazing days and stocking rate (Table 3), resulting in up to almost 100% difference in LWG per hectare (Table 4). Rehab 2 (the second oldest pasture) had the equal highest or highest cattle growth rates per head and per hectare each year. Except in year 1 when Rehab 3 was overgrazed in G1, Rehab 2 also had commensurately higher stock grazing days than the other trial sites. Rehab 2 also had the highest grass leaf protein levels on most occasions during the trial and higher predicted dietary crude protein in faecal samples than the other sites, both of which provide good evidence that the high cattle performance observed was attributable to both pasture quantity and diet quality.

The differences in TSDM between the trial paddocks were similar to pasture growth observed in the absence of grazing in the trial paddocks (Paton *et al.* this volume), and trial period and long-term pasture yields predicted by GRASP model simulation using the same livestock numbers, weights and periodic grazing regime (Clewett *et al.* this volume). The trial pasture yields also compared favourably with production from ungrazed sites on a commercial grazing property of the Darling Downs region, reported elsewhere (Clewett 2015), where annual growth of a pasture sown in 2007 averaged 2730 kg/ha DM and another sown in 2012 averaged 4300 kg/ha. Pastures in Rehab 1, Rehab 2, Rehab 3 and Control paddocks were established in 2007, 2010, 2013 and 2013 respectively making them of similar ages to the commercial pasture.

The differences in pasture productivity between sites were not as a result of changes to Land Condition of paddocks; the presence or absence of 3P pasture species and soil surface condition are key indicators of land condition and 3P pasture species were maintained above 80% at all times with little or no signs of soil erosion (A condition). Differences were instead more likely as a result of initial soil fertility levels and pasture rundown (see next discussion section). Soil fertility levels are affected by both inherent soil properties and management. A history of cultivated cropping, as well as inherently low fertility soil likely constrained the initial soil fertility and pasture production in the control site (Bennett *et al.* in preparation), and the land condition rating system does not account for such constraints.

The differences in cattle production KPIs between the trial paddocks were reflected well by the GRASP modelling. GRASP model simulation of pasture and animal production over the trial period estimated a mean annual utilisation of 28% of annual pasture growth across all paddocks (Clewett *et al.* this volume). This varied between 17 and 41%. Rehab 1 had the lowest mean grazing pressure of 26% with Rehab 2 and 3 equivalent to the overall mean of 28%. Utilisation in the Control paddock was higher at 31% and this higher rate is likely to have provided a marginal increase in the observed cumulative LWG per ha from the Control. These estimated levels of utilisation were close to the target 30% utilisation assessed as the long-term sustainable grazing pressure (Paton *et al.* this volume). Higher rates are often used by industry and lead to short-term benefits in higher liveweight gains and economic returns (Bowen and Chudleigh 2018), however, the continued use of high grazing pressure leads to reduced pasture condition and productivity typical of many pastures in the region (Tothill and Gillies 1992; Clewett *et al.* this volume).

*Influence of soils, seasonal conditions and pasture rundown on results*

The unmined Control site performed most similarly with regard to some pasture and cattle KPIs (species composition, legume content in spring 2016, leaf protein over time, N uptake, TSDM, AE grazing days/ha, cumulative LWG per head, faecal %P) to the Rehab 3 paddock sown in the same year, and for other KPIs (mean leaf protein and ME, cumulative LWG/ha, faecal crude protein and ME) to the Rehab 1 pasture. There was also evidence that of the rehabilitated pastures, Rehab 3 had the most similar soil properties to the unmined control site (Bennett *et al.* in preparation). The Control paddock, which was on a Brigalow land type derived from Walloon sandstones was nutrient depleted. Consequently, pasture and cattle productivity were not expected to be high. In contrast, there is some evidence from land resource and regional ecosystem maps that soils from small areas of reasonably fertile basaltic uplands softwood scrub soils may have been used for Rehab1 and Rehab2 (Paton *et al.* this volume). Characteristically these soils have high levels of P whereas the Brigalow uplands formed on the Walloon sandstones have low P. The faecal NIRS %P results were fairly consistent with the soils data (Bennett *et al.* in preparation) in that there was low faecal P in the control on the low fertility soils derived from the Walloon sandstones and higher faecal P in Rehab 2 on the more fertile high P soil that was likely derived from basalt (Bennett *et al.* in preparation). Bennett *et al.* (in preparation) suggest that the Rehab 3 soil possibly also originated from the low P Brigalow Uplands soils of the Walloon sandstones similar to one of the sites (BMK11) used to benchmark the soil properties of the control site in this study. If this was the case, then Rehab 3 was probably the most analogous pasture for the surrounding Brigalow landscape and likely far more representative of the remainder of the 500 ha of rehabilitated land at the Acland coal mine and its productivity more relevant to future rehabilitation planning at the mine than Rehab 1 ad Rehab 2.

There was some evidence of pasture rundown, a phenomenon that effects all sown pastures, on both rehabilitated and unmined land. There were trends indicating declining pasture TSDM yields in Rehab 3 and Control paddocks, the younger pastures. In contrast, the pasture TSDM in Rehab 1 and Rehab 2 remained high for the trial’s duration. A decline in grass leaf protein levels in grazed pastures (Figure 4), and in N yields (uptake) in ungrazed pasture plots (Paton *et al.* this volume), with increasing pasture age was also evident across all sites. Pasture N yields in Rehab 2 in particular declined markedly from 77 kg/ha in May 2014 to

17.5 kg/ha in April 2018. A decrease in faecal NIRS predicted dietary crude protein with increasing pasture age and time across all sites was consistent with the pasture quality trends. Pasture composition changes in the grazed paddocks of this trial further support the apparent trends in rundown seen in yield and quality data. Rehab 3 and Control paddocks were initially dominated by the N demanding species, Rhodes grass, but by the end of the trial Rhodes grass comprised only about 40% of the pasture yield. Bissett creeping bluegrass survives and competes well at lower soil fertility levels (McIvor 1984; Partridge *et al.* 2009) and was a minor pasture component in the beginning but co-dominant with Rhodes grass at the end of the trial. Conversely, and consistent with high soil fertility (Bennett *et al.* in preparation), green and Gatton panics, which are high fertility demanding grasses, both dominated pasture composition in Rehab 2 throughout the trial, despite declining pasture N yields. There was little change in TSDM of Rehab 1 but both green and Gatton panics declined quickly, perhaps due to selective grazing of the highly palatable species, especially where it grew in small areas of possibly higher fertility soil in a larger paddock. Supporting this theory, Bennett *et al.* (in preparation) found that Colwell P ranged from 35 to 72 mg/kg between transects over time in Rehab 1 and from 26 to 123 mg/kg in Rehab 2, and they observed patches of panic species between some of the soil sampling sites. The spatial diversity in pasture composition and soil fertility suggests that careful characterisation, placement and fencing of rehabilitation soil according to its properties, just as is recommended for unmined pastures (Hunt *et al.* 2014; Alexander *et al.* 2018), will enable selective grazing behaviour by cattle to be managed in a way that optimises pasture and cattle performance.

Patterns of reducing productivity as pastures age are consistent with symptoms of rundown observed in many sown grass pastures in northern Australia (Graham *et al.* 1981; Robbins *et al.* 1987; Myers and Robbins 1991; Peck *et al.* 2011). Declining pasture yield due to “rundown” is mostly due to mineral nitrogen being incorporated into increasing amounts of organic matter as pastures age this reducing the residual amount of soil mineral N available for plant growth. Available N is usually the most limiting soil constraint, even more so than soil moisture. Whilst total soil mineral N supply (estimated as soil mineral N plus potentially mineralisable N (PMN)) was a reasonable indicator of pasture N uptake across the wide fertility range of the trial paddocks (Paton *et al.* this volume), without site specific calibration to field conditions, the soil measure was insensitive as a predictor of changes in actual pasture uptake of N over time within paddocks (Bennett *et al.* in preparation), and therefore associated pasture rundown. Indeed there was evidence of an increase, rather than decrease, in total soil mineral N supply over time at all sites (Table 6).

Legume based sown pastures, particularly those based on leucaena (*Leucaena leucocephala*), can lead to higher levels of productivity and economic returns (Peck *et al.* 2017; Bowen *et al.* 2018). Importantly, they can also slow the rundown process (Paton and Clewett 2016) and help to achieve a higher “plateau” at equilibrium levels once the rundown process has completed (Peck *et al.* 2011; Peck *et al.* 2017) by contributing N to the soil, and boosting organic matter and available N levels for associated grasses. Generally, the more productive the legume the more N it can contribute. Only in spring of 2016 were the winter active legumes, Vetch (Vicia spp.), Hexham scent (*Melilotus indica*) and medics (*Medicago spp.*), present in sufficient quantity to boost liveweight gains of stock and potentially contribute to soil available N pools and subsequent productivity of the remaining grass pastures. The summer growing season (October to March) at Acland receives 70% of the average annual rainfall, so a legume with mainly summer growth (e.g. leucaena, shrubby stylos (*Stylosanthes scabra*) or lucernes (*Medicago sativa*)) would likely have more lasting effects on building soil N and reducing the impact of rundown (Peck *et al.* 2011). Rundown, or conversely a less than 10-year pulse of production due to soil disturbance and mineralisation, affected all the Acland trial sites in some way, albeit at different rates that were seemingly dependant on the inherent soil fertility. Pasture rundown can commensurately constrain production from grazing livestock, with reductions in LWG per head of about 50% over 5-10 years after pastures were sown being observed by Robbins *et al.* (1986) in south-east Queensland. Due to these rundown effects, long-term monitoring or modelling of sown pasture production is needed to evaluate the sustainability of a recently sown (<10 years) pasture. Trends in observed LWG over time were not able to be assessed in this study due to annual changes in the entry weights of the trial cattle. However, simulations using the GRASP pasture growth model estimated the initial lift in productivity associated with rundown in these sub-tropical sown pastures to be short term (7, 9, 4 and 4 years respectively on Rehab 1, Rehab 2, Rehab 3 and control paddocks) and overall to have contributed an extra 12% to pasture growth and 14% to liveweight gains/ha during the 5-year trial period (Clewett *et al.* this volume). Effects were greatest in the youngest pastures.

The effects of pasture rundown were associated with reduced pasture quality (leaf %N) and faecal N content, however, this was not reflected in the estimated rates of cattle liveweight gain per head per year as found by others where observed decreases in annual liveweight gain of 7 to 9 kg/hd.yr were measured over periods of five to eight years (Robbins *et al.* 1986; Radford *et al.* 2007). Seasonal influences of the length of the growing season on liveweight gain (both within and between years) were large and sufficient to hide any potential effects of pasture rundown on annual liveweight gain.

*Comparison of viability and sustainable production from rehab lands to other un-mined lands in the brigalow region*

Simulation by Clewett *et al.* (this volume) of the long-term (60-year) viability and productivity of Rehab 3, the most analogous rehabilitated pasture to the land surrounding the mine, found pasture production, cattle LWG and gross margins per head and per hectare to be comparable or better than that estimated for the unmined Control site established in the same year and for several land types in the Brigalow zone. Long-term estimated mean pasture productivity for Rehab 3 (3736 kg/ha) was similar to that estimated for Mountain Coolibah Basaltic uplands pastures in A, B and C land condition (3398 kg/ha), 32% higher than for Brigalow Uplands pastures in A, C and D condition (mean 2817 kg/ha, which includes the Control site from this study) and 63% higher than for Poplar Box Walloon and Plains pastures in A and C condition (2325 kg/ha). Modelled long-term average annual LWG in Rehab 3 (143 kg/head) and the Control site (146 kg/head), were at the lower end of the ranges estimated for 51 herds across Brigalow (135-220 kg/head) or Brigalow-softwood scrub (104-260 kg/head) pastures in central Queensland in the 1991-2 and 1995-6 financial years (Bortolussi *et al.* 2005). The modelled annual LWG per hectare from Rehab 3 and the Control (61 and 53 kg/ha, respectively) were similar to annual gains of 66 kg/ha (106 kg/steer) from continuous grazing of phosphorus-fertilised Rhodes grass pasture from 1974-9 at Kogan, which is approximately 100 km from the Acland site (Russell 1985), reflecting differences in stocking rate. The long-term liveweight gain of Rehab 2 (116 kg/ha.yr ) was similar to results from the Brigalow catchment study (Radford *et al.* 2007) where liveweight gains averaged 100 kg/ha.yr. In their study, the LWG decline was from 120 to 80 kg/ha.yr over 10 years.

Over the trial years, the modelled estimates of economic returns showed the mined pasture established in 2012 (Rehab 3) to have returned \$15/ha and \$11/AE more annually than the unmined Control pasture (\$54/ha, \$161/AE) established in the same year. However over the long-term, the annual return is predicted to be \$5/ha more from Rehab 3 than the Control (\$50/ha) and \$9/AE higher from the Control (\$164/AE). These annual returns were similar or higher than returns estimated for the Mountain Coolibah Basaltic, Brigalow Uplands and

Plains and the Poplar Box Walloon and Plains land types in the region. The gross margins for all land types were $40-70/AE lower than the $196/AE average observed for commercial enterprises across the Darling Downs of Queensland (Holmes *et al.* 2017). The Holmes *et al.* (2017) data don't account for any declines in land condition that might have occurred as a consequence of the grazing system and most likely included periods of grazing forage crops and feeding supplements when stock grazed poor quality winter pastures where the returns for each dollar spent could be high.

A comparison of the long-term carrying capacities that could be sustained by the trial paddocks and surrounding pastures, estimated using static and dynamic approaches by Paton *et al.* (this volume) and Clewett *et al.* (this volume) suggested that about 50% more area of unmined pasture would be needed to match the carrying capacity of the rehabilitated pastures. The estimated carrying capacities of the unmined sown pasture (3.2-3.8 ha/AE, or 0.38-0.45 ha/dry sheep equivalent based on a conversion of 8.4 DSE: 1 AE) and the rehab pastures (mean 2.17-2.45 ha/AE) were lower or within the range of stocking rates (1-3 ha/AE) recommended by Stone *et al.* (1999) for pasture mainly on uncultivated soil of types that were typical of the Briglow Uplands land resource area in the vicinity of the Acland mine (Moola, Acland, Edgefield, Kenmuir, Walker and Downfall soils, (Bennett *et al.* in preparation)). Carrying capacity in the Control was likely to have been lowered by nutrient decline and erosion throughout a history of cultivated cropping prior to being sown to pasture. The groundcover and land condition data indicated the rotational grazing system employed throughout the trial was consistent with maintaining the landscape in a healthy and productive 'A condition' state in all paddocks throughout the trial. A permanent change in land condition caused by erosion and plant extraction of soil nutrients during a prior period of cultivated annual cropping was likely to constrain actual pasture productivity in this trial. However, soil fertility constraints from previous land uses are not all accounted for in the land condition assessment methodology, which focusses on the potential productivity of the pasture species and soil surface condition. Further research is required on rehabilitated lands to evaluate a legume-based rotational grazing system that has grazing pressures consistent with long-term carrying capacity to avoid overgrazing and seeks to achieve sustainable levels of pre-cultivation productivity. Leucaena based pastures could be very useful. Although sensitive to frost the undulating landform of the rehabilitated lands reduces the influence of frost and it is quite possible that the deep rooting nature of leucaena may be able to exploit water reserves in the underlying argillaceous mine spoil. Assessment of fertiliser management would be required, especially for legumes, on rehabilitated lands top dressed with soils of low P status (McIvor 1984).

Viability of beef production is influenced by the productivity and profitability of a grazing system and also by the market acceptability of the product. There were negligible levels of heavy metal contamination and there was similar eating quality of the beef sourced from cattle grazing on the rehabilitated pastures compared with the meat from animals grazing on the control site. This outcome suggests that the meat from cattle grazing the rehabilitated pastures faced no market barriers in terms of food safety or consumer preference. The ‘rehab’ meat was therefore likely to be acceptable in the market place.  The acceptability of the grazing system in terms of social licence to operate is also informed by animal welfare standards.

The good performance and acceptable meat quality of the cattle grazing the rehab pastures, which were within 2 km of the active Acland mine, suggests that the rehab cattle were not stressed due to their proximity to the mine. The impact of noise, dust and vibration from mining activities were not tested directly in the trial. However, a study over 6 weeks in 2017/18 at the New Acland mine site found that there was no significant difference in stress related measurements between the trial group grazing adjacent to the mine and the control group grazing a relatively quiet location 5.6 km from the mine. Key stress indicators were weight gain, distance travelled per day, ultimate pH and meat colour of the meat post slaughter. Explanatory variables measured were the variability of background noise and dust levels and the noise levels following blasting (Newsome 2018).  Hind-casting of noise that was likely to have occurred at the Acland coal mine over the 2014-2018 period suggests there would also have been no adverse impact on the cattle (SLR Consulting 2018).

## Conclusion

Grazed sown pastures on rehabilitated, previously mined land were as productive, or more productive, than a pasture sown on unmined land at Acland during this trial. The rehabilitated pastures also compared favourably with ungrazed pastures on commercial properties in the region. Pastures established in 2007 and 2010 on rehabilitated land were more productive than either the rehabilitated or unmined pastures that were established in 2012, possibly due to inherently higher fertility of the soil supporting the older pastures. Cumulative LWG over the trial grazing periods in each of the five years of observation were equal in the Control cohort to one or more of the rehab paddock cohorts.

There was some evidence of pasture rundown, a phenomenon that effects all sown pastures, on both rehabilitated and unmined land. Modelling shows it is likely the initial lift in productivity of sown pastures on old cultivations occurs for five years or so and that in the long-term, the productivity of the rehabilitated pasture most analogous to the unmined land (Rehab 3, sown in the same year and probably derived from similar soils) should sustain similar levels of key performance indicators of pasture growth, stocking rate, liveweight gain per head and per hectare and gross margin per head and per hectare. There were no meat quality or heavy metal contamination concerns with cattle that grazed the rehabilitated pastures. The hypothesis that the Acland rehabilitated pastures can viably and sustainably support commercial cattle production was therefore accepted. The research also highlighted a need for further research that evaluates the pasture and livestock productivity of other rehabilitated lands, adds certainty and predictability to the processes of sown pasture rundown, and that demonstrates the ecosystem service benefits of restoring fertility to degraded land.

## Conflicts of Interest

The authors declare no conflicts of interest.

## Acknowledgements

Staff from the New Hope Group at Acland provided weather data and technical information and advice relating to pasture establishment, rehabilitation practices and paddock history and the Acland Pastoral Company managed the trial cattle and paddocks. Soil nitrogen measurements were conducted by Ian Grant at the Agricultural Chemistry Ltd laboratory in Ipswich, Queensland. Dr Peter O'Rourke conducted statistical analyses on the year 1 cattle data. Dr John Armstrong supervised the animal health protocols. Research funding support is acknowledged from the New Hope Corporation for the Acland Grazing Trial and the University of Southern Queensland for over-all research support.

## Figure and Table captions

Table 1. Grazing periods, pasture and cattle observation dates

Table 2. Pasture quality. Grass leaf protein, metabolisable energy and digestibility (mean ± sd) over the trial period in each paddock. Means followed by letters that differ denote statistically significant differences ($P$<0.05) between sites.

Table 3. Date stock entered trial paddocks, number of days stock remained in paddocks during trial, rest and ungrazed (when cattle were not observed) periods, number of head (hd)

per paddock and per hectare, stocking rate as adult equivalent (AE) head per 100 hectare, and head and adult equivalent grazing days per hectare for each grazing period and trial site cohort. Annual (12 month) equivalent means are shown for stocking rates.

Table 4. Cattle liveweight gain. Observed mean (±sd) total liveweight gain per head (trial LWG per head, kg/hd), average daily liveweight gain per head (trial ADG, kg/hd/d) and total liveweight gain per hectare (trial LWG per hectare, kg/ha) during trial grazing periods only, and cumulative LWG per head from the first to last grazing period, for each paddock and year of the trial. Letters that differ denote significant ($P<0.05$) differences between paddock cohorts. The sum of number of days grazing was constant within year so the statistical differences were the same for trial ADG and total LWG.

Table 5. Faecal NIRS indicators (mean ± sd) over the trial period for cohorts from each trial paddock. DMD – dry matter digestibility, ME – metabolisable energy, N – nitrogen, P- phosphorus. Lower case letters that differ denote significant ($P<0.05$) differences between paddock cohorts. Upper case letters that differ denote significant ($P<0.1$) differences between paddock cohorts.

Table 6. Summary of KPI changes over time and/or pasture age. Ns; not significant ($P>0.05$)

Figure 1 Monthly rainfall (mm) plotted mid-month and cattle movements at Acland. Text annotations highlight key rainfall features and the period when winter rain in 2016 promoted the growth of legumes. Black downward arrows indicate the start of grazing each year and grey upward arrows indicate the end of grazing each year.

Figure 2. Pasture yields (DM kg/ha) of the major species Rhodes grass (solid black line), Panic grasses (solid grey line), Queensland bluegrass (dashed black line) and Creeping bluegrass (dashed grey line) in the a) Rehab 1, b) Rehab 2, c) Rehab 3 and d) Control trial paddocks.

Figure 3. Yields of grasses and legumes (medics, vetch and hexham scent) in trial paddocks in Spring (October) 2016.

Figure 4. Grass leaf protein vs pasture age (months since sowing) for a) all sample dates and b) summer (December to April) sample dates with fitted linear regression models for a) response protein %, slope -0.055 and constants for Rehab 1 (15.8) and Rehab 2 (16.8) significantly higher than the Control (11.0) and for Rehab 3 (12.5) not significantly different from the Control, overall model $P<0.001$. $R^2$ adjusted for the number of model parameters was 28.3, and for b) response *ln* protein%, slope -0.007 and constants for Rehab 1 (3.05) and

Rehab 2 (3.04) significantly higher than the Control (2.44) and for Rehab 3 (2.64) not significantly different from the Control, overall model $P$<0.001. $R^2$ adjusted for the number of model parameters was 37.1.

Figure 5. Pasture total standing dry matter (TSDM, kg/ha) for Rehab and Control paddocks between January 2014 and April 2018.

Figure 6 Mean pasture total standing dry matter (TSDM, kg/ha) over time for Rehab 3 and Control paddocks with linear regression trend lines, with one Control outlier point removed. Fitted model ($P$<0.001) equations were *ln*TSDM Control = -0.00041*date +70.6 *ln*TSDM Rehab 3 = -0.0002*date +38.1 and $R^2$ adjusted for the number of model parameters was 55.4.

Figure 7. Average daily growth (ADG, kg/head.day per grazing period) for cattle grazing the Rehab 1, Rehab 2, Rehab 3 and Control paddocks over time. Points include trial grazing periods (labelled) and rest grazing periods. The dashed line indicates cattle were retained over two years.

Figure 8. Trends in faecal NIRS indicators of a) dietary crude protein, b) dry matter digestibility, c) phosphorus percentage and d) the P:N ratio with increasing pasture age (months since sowing) in each trial paddock. Regression equations were a) CP% (Control) = -0.047*Pasture age+9.5, Rehab 1 constant = 12.5, Rehab 2 constant = 12.6, Rehab 3 constant = 10.1, b) DMD% (Control) = 0.11*age_mo+51.3, Rehab 1 constant = 45.1, Rehab 2 constant = 50.5, Rehab 3 constant = 51.6, c) lnP% (Control) = 0.008*age_mo-1.6, Rehab 1 constant = -1.5, Rehab 2 constant = -1.0, Rehab 3 constant = -1.2, d) lnP:N (Control) = 0.014*age_mo-1.98, Rehab 1 constant = -2.27, Rehab 2 constant = -1.80, Rehab 3 constant = -1.68. Note non-zero y-axis minimum value in b).

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**NAC Attachment 4 - Acland Pastures Report 1**

# OPTIMISING REHABILITATED GRAZING PASTURES FOR SUSTAINABLE AND ECONOMICALLY VIABLE BEEF PRODUCTION at NEW ACLAND MINING SITE

## Report on a)Pasture Assessments and Forage Budgets made on 14th & 15th January 2014, for the Purpose of Stocking Trial Paddocks, and b) initial pasture primary production data obtained from the Swiftsynd grazing exclosures on 17th February 2014

**Report by Col Paton, EcoRich Grazing Pty Ltd**

### Background

New Hope Coal is engaged in mining coal in the Surat basin region of Queensland. The New Acland mine is central to the operations of New Hope Coal in Southern Queensland. Mining is undertaken predominately through open cut techniques that require rehabilitation of land following mining to return the land to commercial production. The intention is to restore or improve the pre-mining land capability following mining through effective rehabilitation.

The focus of the Acland Pastoral Company (APC) farming area (10,000 ha) is on beef cattle production, although there are approximately 1,000 ha of land cropped each year. The pastoral business is managed by Acland Pastoral Company, a fully owned subsidiary of New Hope Coal. The basis for this project is that the project team, co-ordinated by Outcross Pty Ltd, is measuring the performance of rehabilitated land when compared with unmined land, based on commercial parameters. Given that the land is to be used predominately for beef cattle production, the team have chosen to compare the performance of a series of trial sites and control sites based on measuring commercially important key performance indicators (KPIs) for beef cattle production.

The area operated by APC is productive land based on mostly self-mulching black soil plains. As such it is considered that the most profitable land use is to run dry (non-lactating) cattle that are being grown out to sell, as opposed to running breeding cows that are being used for the purpose of producing a calf. The enterprise chosen for the project is growing out steers to feedlot entry weight. This is consistent with common commercial land use for the area in the absence of mining.

Key measures are being recorded from both rehabilitated mining land, at various ages since rehabilitation, and unmined land. These include:

- Soil depth, structure, fertility and water holding capacities
- Pasture growth, productivity and quality (in grazing exclosures referred to as Swiftsynds)

- Pasture presentation yields before cattle graze each paddock
- Pasture leaf quality at each grazing: %N; metabolisable energy(MJ/kg) and; digestibility(%)
- Cattle faecal samples for analysis by NIRS to determine diet quality
- Cattle weight gains, stocking rates and grazing days in each paddock

This document reports on the results of Pasture Yield Assessments made on 14th January 2014, which are then used in Forage Budgets, for the purpose of stocking trial paddocks with cattle, quality of green leaf samples plucked from paddocks before grazing commenced, and preliminary primary production data from grazing exclosures, referred to as Swiftsynd sites.

## Methods

**Trial Paddocks:** there are 4 paddocks sown to pasture over the last 7? years. Species sown include Rhodes grass, Gatton and green panics, Bambatsi panic, Queensland bluegrass, silk sorghum, purple pigeon grass, woolly pod vetch, lucerne and some medics. The paddocks include three rehabilitated sites previously mined and one unmined site:

- **Site 1** – oldest of the mined and Rehabilitated sites, returned to pasture in 2005/6 summer?
- **Site 2** – a second rehabilitated site, returned to pasture in the 2010/11 summer?
- **Site 3** – most recently rehabilitated area and returned to pasture in the summer of 2011/12
- **Site 4** – an unmined site, sown to a mix of pasture, with similar species and in the same year as Site 3, in the summer of 2011/12.

**Paddock Areas:** paddocks were only fenced in the week prior to cattle entering for the first grazing. Estimated areas are given in Table 1. A more accurate measurement, using a GPS, later revealed paddock areas were quite different.

**Cattle and grazing system**: young steers and heifers, approximately 300 to 400 kg average weight, will be concurrently grazed in each paddock for short periods of each of the four annual seasons. The grazing will mimic a rotational grazing system and will be informed by using forage budgets to determine stock numbers and the number of grazing days for each rotation, as described below.

**Pasture sampling method**: the Botanal Technique is used to assess pastures in all paddocks on a grid pattern. Information gathered includes:

- Pasture presentation yield, species composition, species frequency of occurrence
- Ground cover by the proportions of green pasture material, organic matter and rock; and
- Proportion of unpalatable pasture that stock are unlikely to consume when grazing

**Green leaf**: samples of leaf were collected from across each treatment paddock for analyses to determine % digestibility, protein and energy contents.

**Forage Budgets:** a set of spreadsheets were used to calculate the number of grazing days and number of stock required for the grazing period, to achieve an average pasture utilisation rate by grazing stock of 10% of the pasture on offer. Pasture average yields and proportions of unpalatable pasture were used to derive the number of grazing days and numbers of stock to graze each treatment paddock. As the first grazing was during the height of the pasture growing season, an estimated average rainfall figure for the grazing period (100mm) was used to project anticipated pasture growth during the 50-70 day period that paddocks would be grazed. Growth for the three rehabilitated paddocks was estimated (using the GRASP pasture growth model) to be 2,000 kg/ha and 1,500kg/ha for Site 4, the unmined Control, due to its poorer land condition (Table 1). The minimum number of stock to be grazed in any paddock was set at 20 for statistical purposes.

**Swiftsynds:** Ten metre by ten metre areas were fenced to exclude grazing stock so primary production and pasture quality could be determined. Grazing exclosures were located in areas considered representative of each paddock. Exclosures were subdivided into 4 sections and a single, 0.5m x 0.5m quadrat of pasture cut to ground level from each quarter, bagged and dried for 48 hours in a forced draught dehydrator oven set at 80°C before recording dry weights of pasture. Each bag of pasture was then sub-sampled and the sub-sample sent for chemical analysis to determine nutrient content. Another sub-sample from each quadrat was separated into green and dead to give proportions by weight of each component. The green component was then separated into leaf and stem with the leaf component later analysed for nutrient concentrations.

## Results

Pastures were assessed using the Botanal visual estimation technique on 14th January 2014. Table 1 shows the presentation yield of pastures in each paddock with Site 2 having the highest yield, 5,325 kg/ha of dry matter (DM) and Site 4 the lowest yield of pasture, 1,300 kg/ha DM.

| | Estimated Paddock Areas (ha) | PastureYield (kg/ha DM) | Anticipated Pasture Growth (kg/ha DM) | Number of Stock for Grazing Period | Calculated Number of Grazing Days |
|---|---|---|---|---|---|
| "Site 1 | 23 | 3,310 | 2,000 | 20 | 74 |
| "Site 2 | 33 | 5,325 | 2,000 | 40 | 68 |
| "Site 3 | 37 | 5,000 | 2,000 | 40 | 73 |
| "Site 4 | 25 | 1,300 | 1,500 | 20 | 49 |

**Tale 1.** Estimated paddock areas, average yields of pastures from the 4 grazed paddocks before entry by cattle, anticipated pasture growth during the grazing period, number of stock to graze in each paddock and number of days to graze each paddock to attain a pasture utilisation rate of 10%.

**Forage Budgets, Grazing period and Stock numbers:** The Rotational Forage Budget spreadsheets determined that a **grazing period of 49 days** by 20 head, average weights approximately 300 kg, would achieve a 10% level of pasture utilisation in the Site 4 paddock. Calculations using the forage budget spreadsheet also determined stock numbers required for the rehabilitated paddocks were 20, 40 and 40 head, for Sites 1, 2 and 3, respectively to achieve a similar amount (10%) of pasture utilisation by grazing stock for their respective grazing periods. The entry date to paddocks for stock was 24th January 2014 and exit dates were determined to be 13th March 2014 for Site 4, the unmined Control, and within the first week of April for the rehabilitated paddocks. The estimated paddock area for Site 3 paddock was 37 ha but it was later revealed that its area was 22 ha. The paddock was overgrazed during this grazing period as a consequence. Also, the forage budget included additional anticipated pasture growth for grazing period (Table 1) but no rain occurred on the rehabilitated paddocks, Sites 1, 2 and 3, during the first grazing. However, approximately 25mm of rain fell on Site

4 during the grazing period which allowed extra pasture growth during grazing and helped to lift diet quality of stock in that paddock.

**Leaf Samples from pastures prior to grazing:** Protein concentrations, energy content and digestibilities of leaf samples collected from each paddock prior to cattle entering paddocks are given in Table 2 below. They show that the potential diet quality of grazing stock is adequate for dry matter intakes of approximately 1.7% which would allow weight gains of approximately 0.5 kg/head/day (from Nutrition EDGE tables 2003, adapted from ARC Tables, 1980).

| | **Site 1** | **Site 2** | **Site 3** | **Site 4** |
|---|---|---|---|---|
| **Protein (%)** | 7.7 | 10.0 | 9.7 | 9.9 |
| **ME (MJ/kg)** | 8.1 | 8.4 | 8.4 | 8.5 |
| **Digestibility (%)** | 61.6 | 62.8 | 62.8 | 64.4 |

**Table 2**. Protein (%), metabolisable energy (MJ/kg DM) and Digestibility (%) of plucked leaf samples from the four treatment paddocks.

**Pasture Composition: Table 3** shows the species composition of paddocks, with Rhodes grass and the panics dominating all paddocks and Queensland bluegrass making a major contribution in Sites 1 and 2. Creeping bluegrass had a high Frequency of Occurrence in Sites 3 (55%) and 4 (59%), but was less frequent in Sites 1 and 2. A few plants of Vetch were recorded in Sites 1 and 2 but they made no significant contribution to composition. Lucerne and medics were recorded in Site 1 but made no significant contribution to composition. Pastures in all three rehabilitated paddocks appeared dense and in good condition despite a poor growing season, but Site 4 was in poor condition and recovering from overgrazing prior to the trial commencement as evidenced by the low yields.

| | | No. of Quadrats | Qld bluegrass | Rhodes | Bamabatsi | Creeping blue | Couch | Green panic | Gatton panic | Lucerne | Medics | Vetch |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a) Composition (% of Total Yield) | "Site 1 | 58 | 12 | 47 | 2 | 1 | 0 | 27 | 9 | 0 | 0 | 0 |
| | "Site 2 | 55 | 11 | 9 | 0 | 0 | 0 | 66 | 8 | 0 | 0 | 0 |
| | "Site 3 | 56 | 2 | 74 | 0 | 17 | 0 | 0 | 3 | 0 | 0 | 0 |
| | "Site 4 | 73 | 1 | 87 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | |
| b) Frequency (%) | "Site 1 | | 43 | 64 | 2 | 5 | 5 | 28 | 3 | 3 | 2 | 2 |
| | "Site 2 | | 24 | 15 | 0 | 0 | 13 | 51 | 5 | 0 | 0 | 2 |
| | "Site 3 | | 13 | 88 | 0 | 55 | 0 | 2 | 2 | 0 | 0 | 0 |
| | "Site 4 | | 1 | 99 | 0 | 59 | 5 | 0 | 0 | 0 | 0 | 0 |
| | | Site Totals | | | | | | | | | | |
| c) Yield (kg/ha DM) | "Site 1 | 3310 | 392 | 1567 | 54 | 29 | 5 | 883 | 314 | 6 | 1 | 4 |
| | "Site 2 | 5325 | 574 | 483 | 0 | 0 | 25 | 3492 | 431 | 0 | 0 | 2 |
| | "Site 3 | 5000 | 90 | 3714 | 0 | 859 | 0 | 17 | 155 | 0 | 0 | 0 |
| | "Site 4 | 1300 | 18 | 1126 | 0 | 142 | 4 | 0 | 0 | 7 | 0 | 0 |

**Table 3.** Species composition of pastures determined by Botanal: a) percent composition as a proportion of total average yield of paddocks; b) Frequency of Occurrence (%), a measure of abundance; c) Total Pasture Yields and Yields of each species.

Table 4 shows the amounts of ground cover partitioned into % Green, Total Ground Cover (% organic matter cover), % Cover by Rock. The proportion of green in pasture was highest in Site 4, the Control. Generally, having more than 30% green in pasture allows stock to select more than 80% green in the diet, which would afford the best possible diet selection and consequent good weight gains. Total ground cover was high in all paddocks, ensuring maximum infiltration of rainfall.

| | %Green | %Cover | %Rock |
|---|---|---|---|
| "Site 1 | 54.4 | 88.5 | 1.2 |
| "Site 2 | 49.7 | 95.2 | 0.3 |
| "Site 3 | 52.7 | 91.7 | 1.1 |
| "Site 4 | 66.3 | 86.2 | 0.6 |

**Table 4.** Proportions (%) of Green cover, Ground cover (organic matter), and Rock in the four treatment paddocks.

**Pasture Primary Production (Swiftsynds):** Table 5 shows pasture measurements in the absence of grazing for the beginning of 2013/14 season until 17$^{th}$ February 2014. This measurement is taken to give peak nitrogen yield of pastures but a lack of seasonal rainfall restricted growth to this point. Site 2 had approximately twice the pasture growth of Site 3, a younger pasture sown in the summer of 2010/11, and 3 times the amount of pasture grown in Site 4, the Control. The amount of nitrogen uptake by pasture in Site 2 is higher than other pasture treatments indicating that more nitrogen is cycling and available for pasture growth in this treatment paddock. Nitrogen uptake at this stage of the growing season was least in Site 4, the Control. This data can be used in simulations of pasture growth, using the GRASP model, over a number of years and a range of historical weather data to show how productivity might change over a longer time period than the trial will run.

| | Pasture Yield | Litter Yield | Proportions (%) | | Nitrogen Uptake |
|---|---|---|---|---|---|
| | (Kg/ha DM) | (Kg/ha DM) | Green | Dead | (Kg/ha) |
| **Site 1** | 3,110 | 6,890 | 43 | 57 | 28 |
| **Site 2** | 5,280 | 6,230 | 57 | 43 | 39 |
| **Site 3** | 2,200 | 2,750 | 31 | 69 | 15 |
| **Site 4** | 1,630 | 2,650 | 34 | 66 | 9 |

**Table 5:** Pasture yield (kg/ha DM), litter yield (kg/ha DM), proportions (%) of green and dead in pasture, and nitrogen uptake by pastures at sampling on 17$^{th}$ February 2014.

**Discussion of Results**

At this stage of the growing season, the data from the Botanals and Swiftsynd sites show that the rehabilitated pastures were more productive and of a similar quality, to the unmined treatment, Site 4. However, Site 2 appears to be much more productive than other treatments at this stage.

Due to the incorrect estimation of paddock areas, and a lack of seasonal rainfall, the rehabilitated paddocks were overgrazed and all stock were taken from the paddocks on 13$^{th}$ March, the same time as cattle were taken from Site 4, instead of the planned exit date of the first week in April. Site 3 in particular was heavily overgrazed and pasture condition in this paddock suffered most, affecting regrowth for the next grazing period (see Report 2).

**NAC Attachment 5 - Acland Pastures Report 2**

# OPTIMISING REHABILITATED GRAZING PASTURES FOR SUSTAINABLE AND ECONOMICALLY VIABLE BEEF PRODUCTION at NEW ACLAND MINING SITE

**Report on a) Pasture Assessments and Forage Budgets made on 15th & 16th April 2014, for the Purpose of re-Stocking Trial Paddocks, and b) pasture primary production data obtained from the Swiftsynd grazing exclosures on 6th May 2014.**

**Report by Col Paton, EcoRich Grazing Pty Ltd**

## Background

New Hope Coal is engaged in mining coal in the Surat basin region of Queensland. The New Acland mine is central to the operations of New Hope Coal in Southern Queensland. Mining is undertaken predominately through open cut techniques that require rehabilitation of land following mining to return the land to commercial production. The intention is to restore or improve the pre-mining land capability following mining through effective rehabilitation.

The focus of the Acland Pastoral Company (APC) farming area (10,000 ha) is on beef cattle production, although there are approximately 1,000 ha of land cropped each year. The pastoral business is managed by Acland Pastoral Company, a fully owned subsidiary of New Hope Coal. The basis for this project is that the project team, co-ordinated by Outcross Pty Ltd, is measuring the performance of rehabilitated land when compared with unmined land, based on commercial parameters. Given that the land is to be used predominately for beef cattle production, the team have chosen to compare the performance of a series of trial sites and control sites based on measuring commercially important key performance indicators (KPIs) for beef cattle production.

The area operated by APC is productive land based on mostly self-mulching black soil plains. As such it is considered that the most profitable land use is to run dry (non-lactating) cattle that are being grown out to sell, as opposed to running breeding cows that are being used for the purpose of producing a calf. The enterprise chosen for the project is growing out steers to feedlot entry weight. This is consistent with common commercial land use for the area in the absence of mining.

Key measures are being recorded from both rehabilitated mining land, at various ages since rehabilitation, and unmined land. These include:

- Soil depth, structure, fertility and water holding capacities
- Pasture growth, productivity and quality (in grazing exclosures referred to as Swiftsynds)

- Pasture presentation yields before cattle graze each paddock
- Pasture leaf quality at each grazing: %N; metabolisable energy(MJ/kg) and; digestibility(%)
- Cattle faecal samples for analysis by NIRS to determine diet quality
- Cattle weight gains, stocking rates and grazing days in each paddock

This document reports on the results of Pasture Yield Assessments made on 15th April 2014, which were then used in Forage Budgets, for the purpose of stocking trial paddocks with cattle. It also reports on the quality of green leaf samples plucked from paddocks before grazing commenced and pasture primary production data from grazing exclosures, referred to as Swiftsynd sites, for the first growing season of the trial.

## Methods

**Trial Paddocks:** there are 4 paddocks sown to pasture over the last 7? years. Species sown include Rhodes grass, Gatton and green panics, Bambatsi panic, Queensland bluegrass, silk sorghum, purple pigeon grass, woolly pod vetch, lucerne and some medics. The paddocks include three rehabilitated sites previously mined and one unmined site:

- **Site 1** – oldest of the mined and Rehabilitated sites, returned to pasture in 2005/6 summer?
- **Site 2** – a second rehabilitated site, returned to pasture in the 2010/11 summer?
- **Site 3** – most recently rehabilitated area and returned to pasture in the summer of 2011/12
- **Site 4** – an unmined site, sown to a mix of pasture, with similar species and in the same year as Site 3, in the summer of 2011/12

**Paddock areas** were initially estimated to be 23 ha, 33 ha, 37 ha, and 25 ha for Sites 1, 2, 3 and 4, respectively. A more accurate measurement, using GPS, later revealed paddock sizes were 22 ha, 32 ha, 22 ha and 21 ha respectively (Table 1). The latter paddock areas were used for stocking calculations for the second grazing period, as explained below.

**Cattle and grazing system**: young steers and heifers, 250 to 350 kg average starting weight, will be concurrently grazed in each paddock for short periods of each of the four annual seasons. The grazing will mimic a rotational grazing system and will be informed by using forage budgets to determine stock numbers and the number of grazing days for each rotation, as described below.

**Pasture sampling method**: the Botanal Technique is used to assess pastures in all paddocks on a grid pattern. Information gathered includes:

- Pasture presentation yield, species composition, species frequency of occurrence
- Ground cover by the proportions of green pasture material, organic matter and rock; and
- Proportion of unpalatable pasture that stock are unlikely to consume when grazing

**Forage Budgets:** a set of spreadsheets were used to calculate the number of grazing days and number of stock required for the grazing period, to achieve an average pasture utilisation rate by grazing stock of 10% of the pasture on offer. Pasture average yields and proportions of unpalatable pasture were used to derive the number of grazing days and numbers of stock to graze each treatment paddock. The first calculation entailed calculating the number of grazing days for the paddock with the lowest pasture yield, which was Site 3, yielding 3,620 kg/ha (Table 2). The minimum number of stock to be grazed in any paddock, for a reasonable statistical analysis, was set at 20 head, the stock number used to derive the number of grazing days for Site 3. A 'reverse' calculation was used with the same number of grazing days from Site 3 to derive the number of stock needed to achieve a utilisation rate of 10% of pasture on offer for remaining treatment paddocks.

**Green leaf**: samples of leaf were collected from across each treatment paddock immediately prior to grazing for analysis to determine % digestibility, protein and energy contents.

**Swiftsynds:** Ten metre by ten metre areas were fenced to exclude grazing stock so pasture primary production and quality could be determined. Grazing exclosures were located in areas considered representative of each paddock. Exclosures were subdivided into 4 sections and a single, 0.5m x 0.5m quadrat of pasture cut to ground level from each quarter, bagged and dried for 48 hours in a forced draught dehydrator oven set at 80$^{o}$C before recording dry weights of pasture. Each bag of pasture was then sub-sampled and a bulked sample for each exclosure sent for chemical analysis to determine Nitrogen concentration. Another sub-sample from each quadrat was separated into green and dead to give proportions by weight of each component and bulked for each exclosure/treatment. The green component was then separated into leaf and stem with the leaf component later analysed for macro nutrient (N, P, K and S) concentrations.

## Results

Pastures were assessed using the Botanal visual estimation technique on 15th April 2014. Table 1 shows the presentation yield of pastures in each paddock with Site 2 having the highest yield, 6,560 kg/ha of dry matter (DM). Site 3 had the lowest yield of pasture, 3,620 kg/ha DM, so this paddock was used in initial forage budgeting to determine the length of the grazing period.

| Paddock | Paddock Area (ha) | PastureYield (kg/ha DM) |
|---|---|---|
| | | |
| "Site 1 | 22 | 4,590 |
| "Site 2 | 32 | 6,560 |
| "Site 3 | 22 | 3,620 |
| "Site 4 | 21 | 4,630 |

**Tale 1.** Paddock areas and average yields of pastures from the 4 grazed paddocks before entry by cattle.

**Forage Budgets, Grazing period and Stock numbers:** The Rotational Forage Budget spreadsheet determined that a **grazing period of 41 days** by 20 head, average weights approximately 345 kg, would achieve a 10% level of pasture utilisation by stock of the Site 3 paddock. Inputting 41 days grazing for the other 3 paddocks determined Site 1 required 20 head, Site 2 required 40 head and Site 4 required 25 head to achieve a similar amount (10%) of pasture utilisation by grazing stock. The entry date to paddocks for stock was 17th April 2014 and the exit date was determined to be 28th May 2014.

**Green leaf of pasture in treatment paddocks:** Protein concentrations, energy content and digestibilities of leaf samples collected from paddocks are given in Table 2 below. They show that the potential diet quality of grazing stock is adequate for dry matter intakes of approximately 2% of lieveweights, which would give weight gains of approximately 1 kg/head/day or better. Site 2 leaf samples were slightly higher in quality than other paddocks.

| | **Site 1** | **Site 2** | **Site 3** | **Site 4** |
|---|---|---|---|---|
| **Protein (%)** | 15.7 | 19.9 | 15.4 | 14.9 |
| **ME (MJ/kg)** | 8.5 | 8.9 | 9.1 | 8.7 |
| **Digestibility (%)** | 62.8 | 64.0 | 66.4 | 62.9 |

**Table 2**. Protein (%), metabolisable energy (MJ/kg DM) and Digestibility (%) of plucked leaf samples from the four treatment paddocks.

**Pasture Composition:** Table 3 shows the species composition of paddocks, with Rhodes grass and the panics dominating all paddocks and Queensland bluegrass making a major contribution to pastures in Sites 1 and 2. Creeping bluegrass had a high Frequency of Occurrence in Sites 3 (67%) and 4 (49%), but was less frequent in Sites 1 and 2. A few seedlings of Vetch were observed but only recorded in 2 quadrats during sampling, so not widespread. Pastures in all paddocks appeared dense and in good condition despite a poor growing season, although, Site 3 was still recovering from overgrazing during the first grazing rotation and had patches with low yields.

| | | No.Qds | Qld bluegrass | Rhodes | Premier digit | Bamabatsi | Creeping blue | Couch | Green/ Gatton panics | Fleabanes | Maynes pest | Black rolly poly | Vetch |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a) Composition (% of total yield) | "Site 1 | 39 | 6.8 | 45.1 | 1.9 | 0 | 1.2 | 0.7 | 42.5 | 0.2 | 0.0 | 1.4 | 0.0 |
| | "Site 2 | 38 | 14.4 | 12.7 | 0.0 | 0 | 7.4 | 0.0 | 65.1 | 0.0 | 0.0 | 0.0 | 0.1 |
| | "Site 3 | 36 | 1.8 | 54.0 | 0.0 | 0 | 24.1 | 0.0 | 20.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| | "Site 4 | 39 | 0.9 | 86.5 | 0.0 | 0 | 11.4 | 0.9 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 |
| | | | | | | | | | | | | | |
| b) Frequency (%) | "Site 1 | | 23 | 74 | 3 | 0 | 3 | 5 | 46 | 3 | 0 | 3 | 3 |
| | "Site 2 | | 26 | 21 | 0 | 0 | 16 | 0 | 69 | 0 | 0 | 0 | 3 |
| | "Site 3 | | 11 | 86 | 0 | 0 | 67 | 0 | 25 | 0 | 0 | 0 | 0 |
| | "Site 4 | | 5 | 95 | 0 | 0 | 49 | 8 | 3 | 3 | 3 | 0 | 0 |
| | | Site Avge | | | | | | | | | | | |
| c) Yield (kg/ha DM) | "Site 1 | 4589 | 314 | 2068 | 86 | 0 | 53 | 33 | 1950 | 8 | 0 | 64 | 1 |
| | "Site 2 | 6562 | 947 | 830 | 0 | 0 | 484 | 0 | 4273 | 0 | 0 | 0 | 4 |
| | "Site 3 | 3619 | 66 | 1953 | 0 | 0 | 874 | 0 | 726 | 0 | 0 | 0 | 0 |
| | "Site 4 | 4632 | 42 | 4004 | 0 | 0 | 528 | 43 | 2 | 8 | 1 | 0 | 0 |

**Table 3.** Species composition of pastures determined by Botanal: a) percent composition as a proportion of total average yield of paddocks; b) Frequency of Occurrence (%), a measure of abundance; c) Total Pasture Yields and Yields of each species.

Table 4 shows the amounts of ground cover partitioned into % Green, Total Ground Cover (% organic matter cover), % Cover by Rock, and unpalatable pasture(% of total yield). The proportion of green in pasture was highest in Site 4, the Control. Total ground cover was high in all paddocks, ensuring maximum infiltration of rainfall. The amounts of unpalatable pasture were highest in Sites 1 and 2, which also had an effect on the forage budgets by reducing the amounts available for grazing.

| | %Green | %Cover | %Rock | %Unpalatable |
|---|---|---|---|---|
| "Site 1 | 58.1 | 93.3 | 0.3 | 35.5 |
| "Site 2 | 66.6 | 95.8 | 0.3 | 32.0 |
| "Site 3 | 67.7 | 91.8 | 1.6 | 19.6 |
| "Site 4 | 76.9 | 94.2 | 0.2 | 11.2 |

**Table 4.** Proportions (%) of Green cover, Ground cover (organic matter), Rock cover and Unpalatable pasture in the four treatment paddocks.

**Forage Budgets**

The calculated number of grazing days for Site 3 to achieve a 10% pasture utilisation rate, and numbers of stock for each paddock are given in Table 5

| **Number of Grazing Days** | **41** |
|---|---|
| **Paddock** | **Stock Numbers** |
| Site 1 | 20 |
| Site 2 | 40 |
| Site 3 | 20 |
| Site 4 | 25 |

**Table 5.** Grazing days and stock number required for each paddock to achieve a pasture utilisation rate of 10% of presentation yield.

**Pasture Primary Production (Swiftsynds):** Table 6 shows the pasture measurements in the absence of grazing for the 2013/14 season until 6th May 2014. Site 2 has approximately twice the pasture growth of other treatments. This data can be used in simulations of pasture growth, using the GRASP model, over a number of years and a range of historical weather data to show how productivity might change over a longer time period than the trial will run.

| | **Pasture Yield** | **Litter Yield** | **Proportions (%)** | | **Nitrogen Uptake** |
|---|---|---|---|---|---|
| | **(Kg/ha DM)** | **(Kg/ha DM)** | **Green** | **Dead** | **(Kg/ha)** |
| **Site 1** | 3,820 | 5,000 | 52 | 48 | |
| **Site 2** | 8,520 | 6,780 | 43 | 57 | |
| **Site 3** | 4,480 | 2,600 | 45 | 55 | |
| **Site 4** | 2,750 | 2,080 | 42 | 58 | |

**Table 6:** Pasture yield (kg/ha DM), litter yield (kg/ha DM), proportions (%) of green and dead in pasture, and nitrogen uptake at pasture sampling on 6th May 2014.

**Discussion of Results**

The data show that the rehabilitated pastures are as productive, and of a similar quality, as the unmined site, Site 4. However, Site 2 appears to be much more productive than other treatments at this stage. Site 2 was sown in the summer of 2010/11 and is not the youngest pasture, so this result is unexpected. An explanation may be that the surface soils of this paddock are more fertile than those of other paddocks, and the soil surveys will show whether that is the reason.

There is a discrepancy between pasture yields obtained from the Site 4 Swiftsynd and pasture yields taken across the Site 4 paddock using the Botanal technique. Observations confirmed that the Swiftsynd site appears to be located on a less productive area than the remainder of the paddock. Consideration should be given to relocating this Swiftsynd site to a more representative part of the paddock for the next growing season in 2014/15.

It could be reasonably expected that the productivity of all these pastures will decline with time, due to the process known as 'pasture rundown', which occurs as pastures age after sowing. Total nitrogen might not alter but the amount cycling annually and available for uptake by pastures declines as more of the nitrogen becomes 'tied up' in organic matter. We may not witness any discernible evidence of a decline in productivity in the five years of this project as variations in annual climate tend to mask the changes.

However, using this data in a modelling exercise, with the GRASP model, would reveal how productivity might change with time and this would be invaluable for projecting the ongoing viability of rehabilitated mining land.

**NAC Attachment 6 - OUTCROSS - New Hope Cattle Grazing Trial**

# New Hope Cattle Grazing Trial Executive Summary

This report includes the results of the first 6 months work for stage 2 of the Cattle Grazing Trials. The project has been undertaken by a project group of industry experts and academics. The group includes the following:

Table 1: Project Management Team

| CONSULTANT | ROLE | PRIMARY CONTACT |
|---|---|---|
| Outcross Pty Ltd | Project management and Livestock | Tom Newsome |
| University of Southern Queensland | Soil science | Dr John Bennett |
| Ecorich Grazing | Agronomy | Colin Paton |
| Dr John Armstrong | Veterinarian | |
| Dr Peter O'Rourke | Statistician | |

The project has been designed to compare rehabilitated mining land with unmined land to measure the success of the rehabilitation program at the New Acland mine. The project focus is on measuring the economic viability and sustainability of beef production from previously mined land.

The project has been ongoing since October, 2011. Work to date includes a pilot trial run from October, 2011 to May, 2012. Stage 2 began in January, 2013 with the tender process to identify and engage the expertise of the project team. Stage 2 of the grazing trial began in January, 2014.

Four sites are being monitored during stage 2 including three mined sites rehabilitated in 2007 (site 1), 2010 (site 2) and 2012 (site 3). The rehabilitated sites are being compared to an unmined site (site 4) that was sown down to improved pastures at the same time as site 3, with a similar sub-tropical pasture mix.

**Soil Analysis**

The University of Southern Queensland (USQ) has completed initial soil testing from 18 benchmark sites in the area surrounding the New Acland mine. USQ have concluded that the control site is comparable to the benchmark sites and typical of soils in the surrounding area. Therefore the control site is deemed to be suitable for comparison with the rehabilitated sites. The rehabilitated sites were considered to be similar to benchmark sites for potentially mineralisable nitrogen, root exploration and depth of top soil. Darkening of the colour of top soil has been observed, indicating significant breakdown of organic matter. With the exception of elevated plant available phosphorous in site 1 and 2, initial results suggest little difference in benefits or constraints to pasture production between sites.

**Pasture observations**

Pastures were assessed prior to the first grazing event using the Botanal process. The Agronomist assessed pasture composition and estimated dry matter yield of pasture (KgDM/ha), the percentage of unpalatable and dead feed, along a minimum of 5 transects across each site. Samples are taken in each site to allow calibration of estimates of available feed for accuracy.

Pasture composition prior to G1 and G2 indicated that Rhodes grass was the dominant pasture in sites 1,3 and 4, whereas site 2 had mostly green panic. The results of the Botanal and Swiftsynd measurements indicated that the rehabilitated sites were comparable to the control site for pasture productivity when considering yield and quality measurements. Site 2 was considered to be the most productive site.

Figure 1 shows the performance of pastures following significant rainfall (126 – 140mm) between grazing 1 and 2. Protein, digestibility and metabolisable energy increased in grazing 2, leading to improved cattle performance.

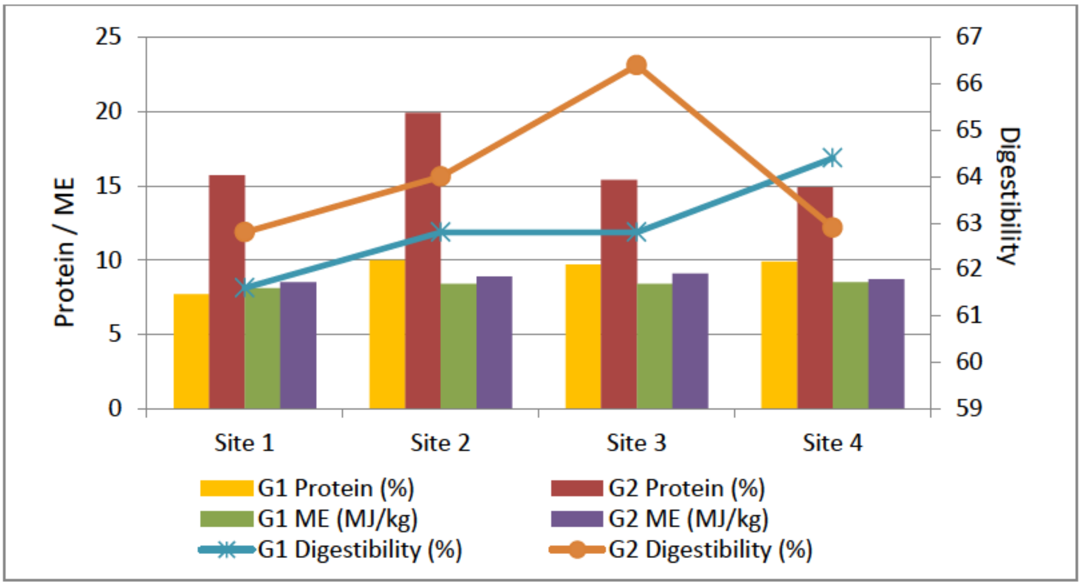


**Figure 1: Pasture Chemical Analysis before grazing**

Pasture samples are taken for calculation of yield and chemical analysis for quality measurements including protein, metabolisable energy and digestibility. Chemical analysis prior to G1 indicated that the animal performance would be restricted by pasture quality as intake would be limited to approximately 1.7% of body weight.

**Cattle performance**

One hundred and eighty head of 2012 drop Angus cattle were sourced in one consignment from a single vendor. The cattle comprised 90 steers and 90 heifers. All cattle were weighed prior to induction into the project. The outliers from both the heavier and lighter end were eliminated from the project. Only cattle weighing between 250 – 350Kg were used in the grazing trial. Through this process, we have been able to eliminate sources of variation that may confound the results of the project.

The key performance indicators (KPIs) for the livestock analysis were average daily weight gain (ADG) and gross beef production per hectare (KGBeef/Ha). The stocking rate was calculated based on consumption of 10% of available feed in each grazing event with a minimum of 20 head grazing each site.

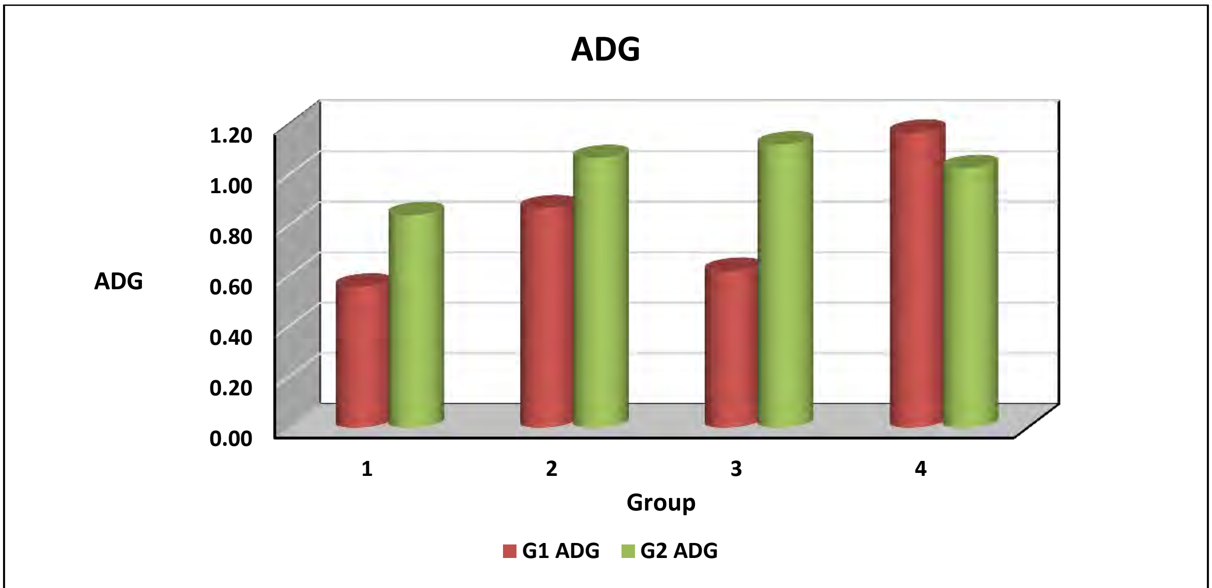


**Figure 2: Average Daily gain by Group**

The first grazing event (G1) occurred between 23 January and 13 March, 2014. The control site achieved a significantly higher ADG than the rehabilitated sites (Figure 2).

The second grazing event (G2) occurred between 16 April and 28 May, 2014. The performance of livestock during G2 was reversed, with the rehabilitated sites 2 and 3 exceeding the performance for ADG of that achieved by the control. Site 2 also had the highest gross beef production for G2 (Figure 3).

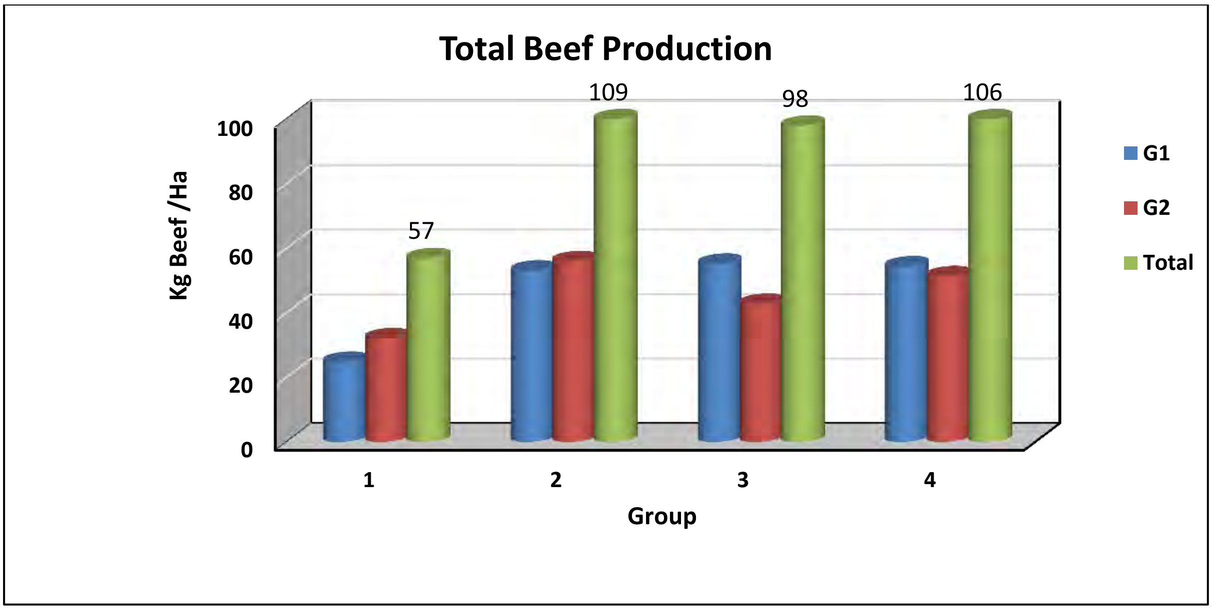


**Figure 3: Total Beef production per grazing by Group**

Site 1 has consistently been the worst performing site. The project agronomist, Colin Paton suggests that this could be associated with a common scenario in Queensland sub-tropical pastures where pasture quality and quality reduces over time, mostly due to nitrogen becoming increasingly unavailable as it is tied up in organic matter. While site 1 has had the lowest performance to date, weight gains on site 1 are above industry benchmark expectations. This indicates that animal performance may plateau at a level that remains competitive with industry expectations over the long term. Potential modelling and ongoing results will assist in measuring the sustainability of pasture and animal performance into the future.

Early results indicate that the beef production from cattle grazed on rehabilitated mining land is comparable to that achieved from unmined land. We will be able to make more informed comparisons when a full statistical analysis is able to be completed at the end of the first year of stage 2. This will enable us to quantify the effect of seasonal conditions on livestock and pasture performance.

**NAC Attachment 7 - USQ - Assessing soil properties of rehabilitated coal mine soils for sustainable and economically viable beef cattle operations, Progress Report**

UNIVERSITY OF SOUTHERN QUEENSLAND

# Assessing soil properties of rehabilitated coal mine soils for sustainable and economically viable beef cattle operations

## Progress Report May 2014

Bennett, J.McL.
Melland, A.R.
Eberhard, J.E.


NCEA
National Centre for Engineering in Agriculture

NCEA Publication 1005XXX/14/1
National Centre for Engineering in Agriculture
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# Contents

# Executive Summary

Acland Pastoral Company (APC), as a subsidiary of, and in conjunction with, New Hope Group, are undertaking progressive rehabilitation of open cut coal mining land to return to grazing pasture. As such, APC seek commercially relevant research outcomes to enable them to quantify the performance of the rehabilitated pastures in terms of productivity and sustainability.

This report provides a progress summary of the NCEA portion of work that aims to assess the soil chemical properties, associated with fertility and structural integrity, and basic soil water properties of rehabilitated land and compare these to unmined land. These qualitative and quantitative objective data, and their interpretations, will help inform APC as to the potential success, or otherwise, of their rehabilitated soils for supporting cattle production.

Soil pit analyses, time sensitive soil sampling, preliminary soil moisture analysis and soil nutrient analysis have been undertaken by the NCEA for 18 benchmark sites, the control and sites representing three rehabilitation ages (with the exception of pit analysis). The benchmark sites are predominantly Dermosols (9/18) and Vertosols (7/18) with one Chromosol identified and one benchmark site still to be assessed.

The control site was identified as a Brown Dermosol with root growth depth and soil depth at the higher end of the benchmark range. Considering gravimetric soil moisture content, the control exhibited soil moisture within the benchmark range, but toward the lower end (note this will also be compared volumetrically when bulk density data are available). Preliminary analysis suggests that the control site is not unusual compared with surrounding grazed land in terms of soil type, depth and moisture characteristics.

The rehabilitated sites are classified as Spolic Anthroposols, meaning 'man-made' from mine spoil. Plant available soil nitrogen is highly transient and dependant on soil moisture and temperature conditions whereas plant-available soil phosphorus is more stable over time.  In December 2013 the rehabilited sites showed no significant benefit or constraint for pasture production in terms of available nitrogen and available P was high in the two oldest rehabilitated sites. Soil moisture analysis indicate that these soil profiles tend to contain less water at depth than the control and benchmark sites, which is consistent with lower clay contents measured in the field?. From the limited pit analyses in the rehabilitation to date, qualitative data suggests that root depth extends well into the interburden (40 to 50 cm depth) at 0.9 m, but is below the benchmark average root depth of 1.12 m. The A Horizon shows encouraging signs of soil evolution, with darkening of the soil layer consistent with significant organic matter breakdown, as well as weak structural development to 0.35 m.

This work is ongoing.

# Introduction

New Hope Coal is engaged in mining coal in the Surat basin region of Queensland. The New Acland mine is central to the operations of New Hope Coal in Southern Queensland. Mining is undertaken predominately through open cut techniques that require rehabilitation of land following mining to return the land to commercial production. The intention is to restore or improve the pre-mining land capability following mining through effective rehabilitation.

The focus of the Acland Pastoral Company (APC) farming area (10,000 ha) is on beef cattle production, although there are approximately 1,000 ha of land cropped each year. Cropping includes farming of cereal crops (Wheat, Barley) in winter in rotation with legume based crops (Chick peas and Faba Beans) and summer cropping of Sorghum. The pastoral business is managed by APC, a fully owned subsidiary of New Hope Coal.

The aim of the project is to provide the APC with commercially relevant research outcomes to enable them to quantify the performance of the rehabilitation program in terms of productivity and sustainability.

Outcross Pty Ltd, as the project leader, have engaged the NCEA to assess the soil chemical and basic soil water properties responsible for structural stability and fertility for rehabilitated and comparable unmined land. This assessment will be combined with plant productivity data supplied by EcoRich Grazing and cattle production assessment conducted by Outcross to provide basic insight into land productivity.

The aim of the NCEA portion of work is to assess the soil chemical properties that are indicators of fertility and structural integrity, as well as basic soil water properties of rehabilitated land, and compare these to unmined land in order to provide qualitative and quantitative objective data, and their interpretations, will help inform APC as to the potential success, or otherwise, of their rehabilitated soils for supporting cattle production.

This report is a report on progress to date, including soil pit analyses and preliminary chemical analyses.

# Progress

## Soil pit analyses

Soil pit analyses were undertaken to characterise the soil profile and classify the soil type at 17 benchmark sites, the experimental control (3 pits) and one pit on Rehab 2. Benchmark site numbers are detailed in Figure 1.

Palaris Australia Pty Ltd (Palaris) were engaged by the NCEA to provide quality assurance (QA) of pit classification under the recent Certified Professional Soil Scientist (CPSS) amended guidelines that require a CPSS Level 3 qualified pedologist to provide QA for Environmental Impact Statement preparation. Hence, to avoid external party scrutiny of rigour, QA was undertaken. Mr Bob Reid (CPSS 3) provided this service.

Mr Bob Reid, Dr John Bennett (CPSS 2) and Dr Anne Schneider (Palaris) undertook 16 pit analyses as part of the QA process, while Dr John Bennett completed the remaining pit analyses. Sites 13 and 15 were flooded, with half the profile characterised at Site 15 and no characterisation at Site 13. These sites will be revisited when the remaining rehabilitation sites are opened and analysed. NCEA soil pit reports are contained in Appendix A, while the Palaris report is attached as Appendix B.

In summary, from the 17 assessed benchmark sites 16 of these were mapped as strategic cropping land (SCL) under the QLD Government guidelines. However, Sites 1, 2 and 8, all mapped SCL, were considered too shallow and, in one case, likely having too much surface stone to be considered SCL from the single pit analysis. On the other hand, Site 4 was not mapped as SCL, but fits the SCL criteria. The benchmark sites are predominantly Dermosols (9/17) and Vertosols (7/17) with one Chromosol identified (Table 1). For the benchmark soils the average rooting depth was 1.12 m with a range of 0.80–1.40 m, while the soil depth averaged 1.13 m with a range 0.25–1.5 m (measured as depth to BC or C horizon). Site 8 was removed for this basic analysis as the soil depth was 0.15 with a rooting depth of the same; this site was considered an outlier from the other benchmark sites.

*Table 1. Benchmark sites by number and Australian Soil Classification (Isbell 1996)*

| Site # | Australian Soil Classification | Site # | Australian Soil Classification |
|---|---|---|---|
| 1 | Red Dermosol | 10 | Brown Chromosol |
| 2 | Black Dermosol | 11 | Red Dermosol |
| 3 | Black Vertosol | 12 | Brown Dermosol |
| 4 | Black Vertosol | 13 | N/A |
| 5 | Black Vertosol | 14 | Black Vertosol |
| 6 | Red Dermosol | 15 | Black Vertosol |
| 7 | Red Dermosol | 16 | Black Vertosol |
| 8 | Red Dermosol | 17 | Red Dermosol |
| 9 | Black Vertosol | 18 | Brown Dermosol |

There was a significant correlation between rooting depth and soil depth, as was expected ($r^2$=0.832). However, with the exception of Site 8, where the depth to a BC or C horizon was very shallow, the rooting depth was often well into the saprolitic (weathered parent) material.

Three pits within the control site were analysed with the same soil classification observed for all three: Brown Dermosol. The average rooting depth was 1.33 m and the average soil depth was 1.4 m. This is situated toward the high end of the benchmark data. The control soil is mapped as SCL and is considered to meet these requirements. Data to date suggests that the control site is representative of soil in surrounding used for grazing cattle and is therefore suitable for use as a comparison against the rehabilated soils in this trial.

From the one rehabilitated site (Rehab 2 Swiftsynd) it was observed that the soil depth was 0.35 m. However, roots were observed well into the interburden at 0.9 m. This rooting depth is below the benchmark average in the lower quartile, but is within the observed benchmark range. The interburden is considered structureless, much like naturally occurring saprolitic horizons, but is apparently being utilised to satisfy plant demands. This might be comparable to plants growing on shallow soils such as Sites 1 and 2, but the rehabilitated soil characteristics should still be compared to the benchmark average. Darkening of the A1 horizon suggests that there is a significant level of organic matter breakdown. Subsequent observation within a 10 m proximity to the pit revealed that a large amount of litter was remaining on site and that there was evidence of organic matter breakdown, especially at the base of grass tussocks. While there have not been enough rehabilitated soil pits analysed to be definitive, the current qualitative data are encouraging in terms of rehabilitated soil evolution.

## Time sensitive soil core sampling

Soil cores have been collected thus far at two time periods, and soil pits were opened and analysed as per Table 2. Of note, T0 was an opportunistic sampling to collect some data on Rehab and Control sites to inform the starting conditions of these sites; due to time limitations and the fact this was additional data it was not feasible to undertake full sampling.

*Table 2. Year one with sampling times and activities identified.*

| Year | Activity | Date period | Comment | |
|---|---|---|---|---|
| Y1 | Soil pit | 01 Oct 2013 – 30 Sep 2014 | 17 x BMK | 2 pits to open |
| | | | 3 x Control | 0 pits to open |
| | | | 1 x Rehab | 7 pits to open, 1 pit to analyse |
| T0 | Soil coring | 28 Nov 2013 - 18 Dec 2013 | Opportunistic sampling of trial sites to capture time zero soil nutrient characteristics | |
| T1 | Soil coring | 14 Feb 2014 – 13 Mar 2014 | Full sampling across trial and benchmark sites | |

The analyses that have been conducted on these are only in preliminary form with samples currently prepared and waiting for laboratory analysis. Detail of progress here is supplied in Table 3.

*Table 3. Physical and chemical analysis completed to date*

| | T0 | T1 | Data summary |
|---|---|---|---|
| Roots presence or absence | Yes<br>(to 60 cm) | Yes<br>(to depth) | See Melland et al. 2014 and soil pit analyses |
| Subsoil depth | yes | yes | See Melland et al. 2014 and soil pit analyses |
| Soil plant available P and N[1] | yes | no | See Melland et al. 2014 |
| Soil gravimetric moisture content | yes | yes | See Figures 1 and 2 |

[1] Colwell P, Potentially mineralisable N, nitrate-N, ammonium-N

## Soil moisture

Soil moisture has been assessed gravimetrically (% weight/weight) for 0–10, 10 –20 and 40–60 cm depth interval (Figures 2 and 3). These data will be converted to volumetric (% volume/volume) once bulk density has been determined and used primarily to identify moisture trends and as a covariate to explain nutrient chemistry variation within sites and over time (rather than inter-site comparisons).

In contrast to normal seasonal expectations, the soil moisture was higher during the T0 (Dec 2013) sampling at all depths compared with the T1 sampling (Feb 2014) (Figure 2). Variation between treatments during T0 will be due to rain that fell within the sampling period (140 mm, New Hope Acland weather station), as well as due to soil and plant characteristics. Differences in soil moisture content between locations during T1 will be largely due to soil and plant characteristics because only 3mm of rainfall fell during the sampling period, so inter-site comparisons were also possible for this sampling.


*Figure 1. Benchmark site location by site ID relative to the Acland mine. Rehabilitated sites are approximately 2 km NW of Site 17, while the Control is approximately 0.75 km E of Site 17.*

Soil moisture at the benchmark sites are presented against the Rehab and Control sites for T1 in Figure 3. Importantly, all samples for T1 were taken prior to the >100 mm rainfall event in March 2014. Soil water content in the rehabilitated and control sites tended to be within the range measured in the upper depths (0-20cm) of the benchmark sites, and at the lower end of the range measured at depth (40-60 cm). Inferences regarding soil water availability to plants will be made once the soil moisture characteristic curves (relationship between soil water content and soil water potential energy that governs availability of water to plant roots) are analysed for these soils.

Whilst it is not fair to statistically compare between soil profiles without volumetric data, differences within soil profiles and trends between these should be noted from the gravimetric data. There is a consistent trend for rehabilitated soils in the 40–60 cm zone to have gravimetric water content similar to, or lower than, the 0–10 and 10–20 cm depths. For the control and benchmark soil range there is a clear trend for soil moisture to increase with depth. From the soil pit analyses it can be determined that this is due to the general increase in clay content (increasing soil texture) with depth. In the rehabilitated sites, the increase in soil moisture at depth at T1 is less pronounced and is likely due to lower clay contents in the interburden as compared to the 'topsoil' horizons, consistent with observations from the single rehabilitated pit.

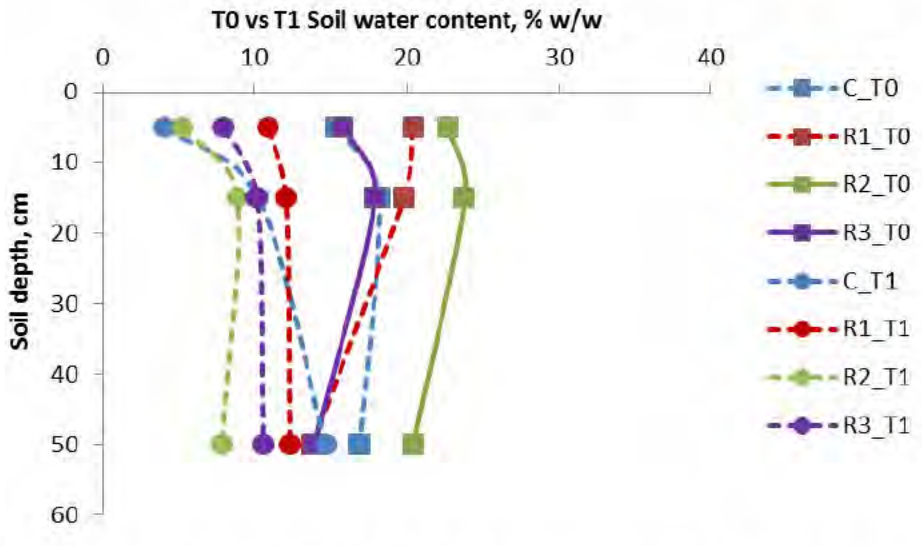



*Figure 2. Soil water content (% w/w) at 0-10, 10-20 and 40-60 cm depth intervals measured at T0 (square symbols) and T1 (circular symbols) in rehabilitated and control pasture treatments.*

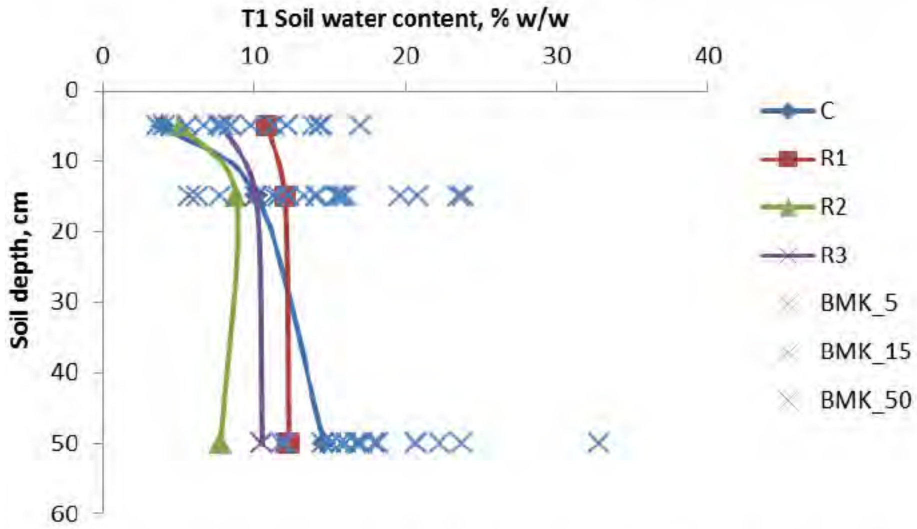



*Figure 3. Soil water content (% w/w) at 0-10, 10-20 and 40-60 cm depth intervals measured at T1 in the rehabilitated and control pasture treatments (coloured lines and symbols) and in the 18 benchmark sites (blue crosses).*

## Soil nutrient status

Some preliminary analysis on soil nutrient status, along with soil structural and pasture biomass, has been presented as a conference paper submission to the Soil Science Australia conference in Melbourne, December 2014 (Appendix C). The major conclusion of this nutrient data synthesis is that there was little difference between control and rehabilitated sites, excepting two rehabilitated soil sites with higher plant-available P, with regard to benefits or constraints to pasture production.

# Appendices

## APPENDIX A: NCEA soil pit analysis report

# NCEA pit analyses

## *Sites Described*

### Site 00B - Control Mid-slope (First site visited 18 April 2014)

**Location:** ~200 m NNW from S 27 17 7.913, E 151 44 45.731

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Walloon Coal Measures – Shale, siltstone, sandstone, coal, mudstone, limestone |
| Land Management Field Manual | 6a – Gently undulating rises and plains on Walloon Sandstone (Brigalow uplands), Grey brown cracking clays (Vertosols), Brigalow, belah, wilga open woodland |
| Strategic Cropping Land Trigger Mapping | Strategic cropping land |

**Landform:** Mid slope in gently undulating rises (similar to Control Swiftsynd, but lower down the slope)

**Slope %:** 2 to 2.5 to NW

**Surface coarse fragments:** 20% rounded ironstone and fragmented basalt, 5 to 10 mm

**Surface condition:** Surface crust

**Root distribution:** 1 to 2 mm roots common in A1 horizon, decreasing to 1.2 m

**Land use:** Sown grazed pasture, previously cropped

**Adjacent natural vegetation:** Brigalow (*Acacia harpophylla*) 200 m to W

**Australian Soil Classification:** Brown Dermosol

**Profile morphology:**

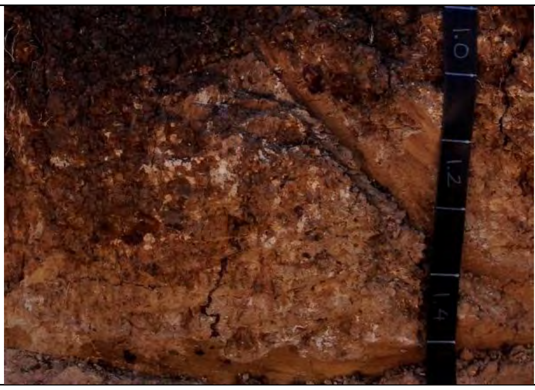
| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.15 m | Very dark brown (7YR2.5/2) light clay, 2-5% transported ironstone to 10 mm, granular to weak 2-5 mm angular blocky, moist weak, <2% soft calcareous segregations to 6 mm, field pH 8.0, clear boundary to: |
| B1 | 0.15 – 0.4 m | Dark brown (7.5YR3/4) medium clay, 2-5% transported ironstone to 6 mm with 2% angular ironstone to 10 mm, moderate 5 to 10 mm angular blocky, few <5 mm cracks, moist firm, 1% ferromanganiferous 1 to 2 mm concretions, 2-10% soft calcareous segregations 6 to 20 mm, field pH 8.5, gradual wavy boundary to: |
| B21 | 0.4 – 0.9 m | Very dark greyish brown (10YR3/2) medium heavy clay, <2% transported ironstone to 6 mm with 2% angular ironstone to 10 mm, strong lenticular > 50 mm breaking to angular block 5-10 mm, dry very strong, 1% ferromanganiferous 1 to 2 mm concretions, 20-50% soft calcareous segregations 6-20 mm, field pH 9.0 gradual boundary to: |

| Horizon | Depth | Description |
|---|---|---|
| B22 | 0.9 – 1.2 m | Light yellowish brown 10YR6/4 medium heavy clay, 5 to 40 mm angular blocky, dry very firm, 5% ferromanganiferous 2 to 5 mm concretions, 20-50% soft calcareous segregations > 60 mm, field pH 9.0, gradual boundary to: |
| C | 1.2 – >1.4 m | Very pale brown (10YR8/2) clay loam, weak granular to weathered rock |

The boundary observed between B21 and B22 is gradual, although may appear irregular in the profile picture. In this picture A and B1 horizon material has adhered to the *in situ* horizon creating the irregular boundary appearance. Whilst below 1.2 m there is clear loss of structure and indication of a saprolitic layer, there is also evidence of cracking containing darker veins of illuvial deposits most likely from the A and B1 horizons and consitant with the vertic properties in the B21 horizon; lenticular peds were not obviously eveident in the B22 layer.

**Control Mid-slope profile showing profile described above**

**Control Mid-slope view toward Control Lower-slope**



**Evidence of and upper horizon illuvial deposit and cracking to 1.4 m**

**Surface stone at Control Mid-slope**

## Site 00C - Control Lower-slope (Second site visited 18 April 2014)

**Location:** ~400 m NW from S 27 17 7.913, E 151 44 45.731

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Walloon Coal Measures – Shale, siltstone, sandstone, coal, mudstone, limestone |
| Land Management Field Manual | 6a – Gently undulating rises and plains on Walloon Sandstone (Brigalow uplands), Grey brown cracking clays (Vertosols), Brigalow, belah, wilga open woodland |
| Strategic Cropping Land Trigger Mapping | Strategic cropping land |

**Landform:** Lower slope in gently undulating rises

**Slope %:** 2 to NE

**Surface coarse fragments:** 10 to 20% transported ironstone, 2 to 5 mm

**Surface condition:** Surface crust

**Root distribution:** 1 to 2 mm roots common in A1 horizon, decreasing to 1.5 m

**Land use:** Sown grazed pasture, previously cropped

**Adjacent natural vegetation:** Brigalow (*Acacia harpophylla*) 80 m to W

**Australian Soil Classification:** Brown Dermosol

**Profile morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.1 m | Dark brown (10YR3/3) sandy light clay, <2% 5 to 20 mm transported ironstone fragments, moderate <2 mm granular to 10 mm depth then moderate 2 to 5 mm angular blocky, moist weak,<2% calcareous soft segregations, field pH 7.0, clear wavy boundary to: |
| B1 | 0.1 – 0.6 m | Very dark greyish brown (10YR3/2) medium heavy clay, strong angular blocky 10-20 mm breaking to <10 mm angular blocky, few <5 mm cracks, moist firm, ,<2% calcareous soft segregations, field pH 8.0, gradual boundary to: |
| B2 | 0.6 – 0.5 m | Yellowish brown (10YR5/6) medium heavy clay, strong lenticular >50 mm breaking to angular block 5-10 mm, dry very strong, field pH 8.5, 20-40% calcareous soft segregations, gradual boundary to: |
| B3 | >1.5 m | Brownish yellow (10YR6/8) light medium clay, weak 2-5 mm angular blocky integrading to structureless, moist firm, field pH 8.5 |

As observed in the surface picture the cracking is not evident to the surface, nor throughout the A1 horizon, precluding this from the Vertosol classification and more suited to the Dermosol classification. This site and the previous control sites meet the strategic cropping land classification they are mapped as

| | |
|---|---|
|  |  |
| **Control Lower-slope profile showing profile described above** | **??? vegetation 80 m west, down-slope of Control-Lower-slope** |

| | |
|---|---|
|  |  |
| **Starting depth of carbonate in Control-Lower-slope profile** | **Surface stone at Control-Lower-slope** |

## Site 12 - Storey's (Third site visited 18 April 2014)

**Location:** S 27.328985, E 151.685627

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Walloon subgroup: Walloon Coal Measures – Shale, siltstone, sandstone, coal, mudstone, limestone |
| Land Management Field Manual | 8a: Undulating rises and low hills on Walloon sandstone (Poplar box Walloons); Self-mulching, black cracking clays (Vertosols); Poplar box open woodland |
| Strategic Cropping Land Trigger Mapping | Strategic cropping land |

**Landform:** Mid to lower slope in gently undulating plains

**Slope %:** 0.5 to SWW

**Surface coarse fragments:** None evident

**Surface condition:** some cracking slightly > 5 mm (Cracking), tendency to be hard setting

**Root distribution:** 1 to 2 mm roots common in A1 horizon, decreasing to 1.4 m

**Land use:** Grazed pasture, mix including Qld Bluegrass

**Adjacent natural vegetation:** Scattered poplar box (*Eucalyptus populnea*) within 150 m

**Australian Soil Classification:** Brown Dermosol

**Profile morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.1 m | Black (7.5YR2.5/1) medium heavy clay, 5% polished ironstone to 2.5 mm, moderate 2.5 mm angular blocky, moist weak and moving to firm within 20 mm, <1% calcareous soft segregations, field pH 6.5, gradual boundary to: |
| B21 | 0.1 – 0.45 m | Dark brown (7.5YR3/4) medium heavy clay, 5% polished ironstone to 2.5 mm, moderate 5 to 10 mm angular blocky, moist firm, field pH 7.5, gradual boundary to: |
| B22 | 0.45 – 0.1 m | Dark yellowish brown (10YR4/6) heavy clay, 5% polished ironstone to 2.5 mm and <2% 10-25 mm transported ironstone, strong lenticular 10-50 mm breaking to <10 mm angular blocky, moist strong, 10-20% calcareous soft segregations 20 to 30 mm, field pH 8.5, gradual boundary to: |
| B23 | 1.0->1.4 m | Yellowish brown (10YR5/6) heavy clay, angular blocky 5 to 10 mm, dry strong, 40-50% calcareous soft segregations >50 mm, field pH 9.0 |

There appears to be some linear gilgai microrelief synonymous with soil having vertic properties (Vertosols) within the area. However, cracks were not evident to the surface and, while there was some lenticular structure, frictional planes and cracking within the B horizontal were minimal. Cracking visualised in pictures below did not extend deeper than ~5 mm with surface between cracks hard setting.

| | |
|---|---|
|  |  |
| **Storey’s profile showing profile described above** | **Storey’s view toward North and ??? vegetation** |

| | |
|---|---|
|  |  |
| **Surface near vegetation at Storey’s** | **Surface cracking typical at Storey’s** |

## Site 14 - Larry's (Fourth site visited 18 April 2014)

**Location:** S 27.353883, E 151.694652

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Main Range Volcanics (Basalt, agglomerate, shale, dolomite) |
| Land Management Field Manual | 8a: Undulating rises and low hills on Walloon sandstone (Poplar box Walloons); Self-mulching, black cracking clays (Vertosols); Poplar box open woodland |
| Strategic Cropping Land Trigger Mapping | Strategic cropping land |

**Landform:** Mid slope in gently undulating plains

**Slope %:** 1 to 1.5 to E

**Surface coarse fragments:** None evident

**Surface condition:** Self mulching

**Root distribution:** 1 to 2 mm roots common in A1 horizon, decreasing to >1.2 m

**Land use:** Sown Qld Bluegrass grazed pasture, previously cropped

**Adjacent natural vegetation:** (Unknown)

**Australian Soil Classification:** Black Vertosol

**Profile morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.2 m | Black (2.5YR2.5/1) medium clay, <2% 1 to 5 mm transported ironstone fragments, strong <2.5 mm angular blocky, moderate cracks >5 mm, moist firm, field pH 6.5, gradual boundary to: |
| B21 | 0.2 – 0.4 m | Black (2.5YR2.5/1) medium heavy clay, <2% 1 to 5 mm transported ironstone fragments, strong 5 to 10 mm angular blocky, moderate cracks >5 mm, moist firm, <2% calcareous soft segregations 2.5 to 5 mm, field pH 7.0, gradual boundary to: |
| B22 | 0.4 – 1.0 m | Black (2.5YR2.5/1) heavy clay, <2% 1 to 5 mm transported ironstone fragments,20 to 50 mm strong lenticular breaking to 5 to 10 mm angular blocky, moist strong, <2% calcareous soft segregations 2.5 to 10 mm field pH 8.5, clear irregular boundary to: |
| B23 | 1.0 – >1.2 m | Olive brown (2.5YR4/3) heavy clay, <2% 1 to 5 mm transported ironstone fragments, strong 5 to 20 mm angular blocky, moist very firm, 2 to 5% calcareous soft segregations 10 to 25 mm, field pH 9.0 |

|  |  |
|---|---|
| **Larry’s profile showing profile described above** | **Strong vertical cracking with slickensides evident at 0.45 m** |

|  |  |
|---|---|
| **Illuvial deposits in vertical cracks (dark veins) at Larry’s (~1.0 m)** | **Self-mulching and cracking surface at Larry’s** |

## Site 15 - Hoile's Upper (Fifth site visited 18 April 2014)

**Location:** S 27357778, E 151.696818

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Main Range Volcanics (Basalt, agglomerate, shale, dolomite) |
| Land Management Field Manual | 8a: Undulating rises and low hills on Walloon sandstone (Poplar box Walloons); Self-mulching, black cracking clays (Vertosols); Poplar box open woodland |
| Strategic Cropping Land Trigger Mapping | Strategic cropping land |

**Landform:** Mid slope in level to gently undulating plains (500 m upslope to the west from Hoile's Low)

**Slope %:** 1 to 1.5% to E

**Surface coarse fragments:** <2% weathered basalt, 50 to 150 mm, 10 to 20% transported ironstone fragments, 5 to 25 mm

**Surface condition:** Soft crust to 5 mm with fine sand separation on surface, cracking

**Root distribution:** 1 to 2 mm roots common in A1 horizon, decreasing to >0.5 m

**Land use:** Natural grassland pasture, previously cropped

**Adjacent natural vegetation:** Unknown

**Australian Soil Classification:** Black Vertosol

**Profile morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.2 m | Black (2.5YR2.5/1) medium heavy clay, 2 to 5% 2.5 to 5 mm transported ironstone fragments, strong <5 mm angular blocky, few cracks >5 mm, moist firm, field pH 6.0, gradual boundary to: |
| B21 | 0.2 – 0.4 m | Black (2.5YR2.5/1) heavy clay2 to 5% 2.5 to 5 mm transported ironstone fragments, strong 5 to 25 mm angular blocky, moderate cracks >5 mm, moist strong, <2% calcareous soft segregations 2.5 to 5 mm, field pH 7.0, gradual boundary to: |

Hoile's Upper is considered to be very similar to Hoile's Low, but without evidence of gilgai. This site was also comparable to Larry's and situated SE approximately 600 m, although self mulching surface was not evident. Pit description could only be completed to 0.4 m due to flooding of bit below ~0.5 m.

| | |
|---|---|
|  |  |
| **Hoiles Upper 0–0.4 m profile unaffected by flooding** | **Hoiles Upper view toward Hoiles Lower** |

| | |
|---|---|
|  |  |
| **Surface cracking and stone at Hoiles Upper** | **Surface cracking and stone at Hoiles Upper** |

# APPENDIX B: Palaris pit analysis report

# Report

## Technical Soils Advice

| | |
|---|---|
| **Company** | University of Southern Queensland |
| **Site** | New Acland Mine Area |
| **Date** | May 2014 |
| **Doc No.** | USQ2011-01 |

palaris

| | | | |
|---|---|---|---|
| Report To | | | |
| Project No. | | | |
| Doc No. | USQ2011-01 | | |
| **Document History** | **Name** | **Date** | **Version** |
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| Final Issued To | | | |



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- capability and availability of management and employees
- workplace health and safety issues
- availability of funding to the operation
- availability and reliability of supporting infrastructure and services
- efficiency considerations
- variations in cost elements
- market conditions and global demand
- industry development
- regulatory and policy changes

# Contents



# Figures

# 1 Introduction

Fifteen soil pits on land surrounding the New Acland coal mine north of Oakey were described to gain an improved understanding of the soils and landscapes surrounding the mine and how the landscapes provide a basis for establishing objectives and assessing progress with mine rehabilitation.

The descriptions were undertaken along the lines set out in the *Australian Soil and Land Survey Field Handbook* (National Committee on Soil and Terrain, 2009). The profiles directly opposite the leg of the T of the excavated pits were described. A significant feature was considerable short-range variability at a number of pits.

One pit on rehabilitated land was described.

The sites were considered in relation to regional mapping of geology (Whitaker and Green, 1980), land resource areas (Harris, Biggs, and Coutts, 1999), and Strategic Cropping Land Trigger Mapping (based on *Trigger map for strategic cropping land in Queensland v2.0* obtained from Department of Natural Resources and Mines, 2012). It is important to understand that the survey intensity and map scale of these reference investigations is such that they give only an approximate guide to conditions at any given location.

This report sets out profile descriptions, presents photographs of the pits and surrounding landscapes, and discusses the soils in relation to the regional mapping and the surrounding landscapes. Locations of the pits described are shown on Google Earth imagery in Figure 1.1.

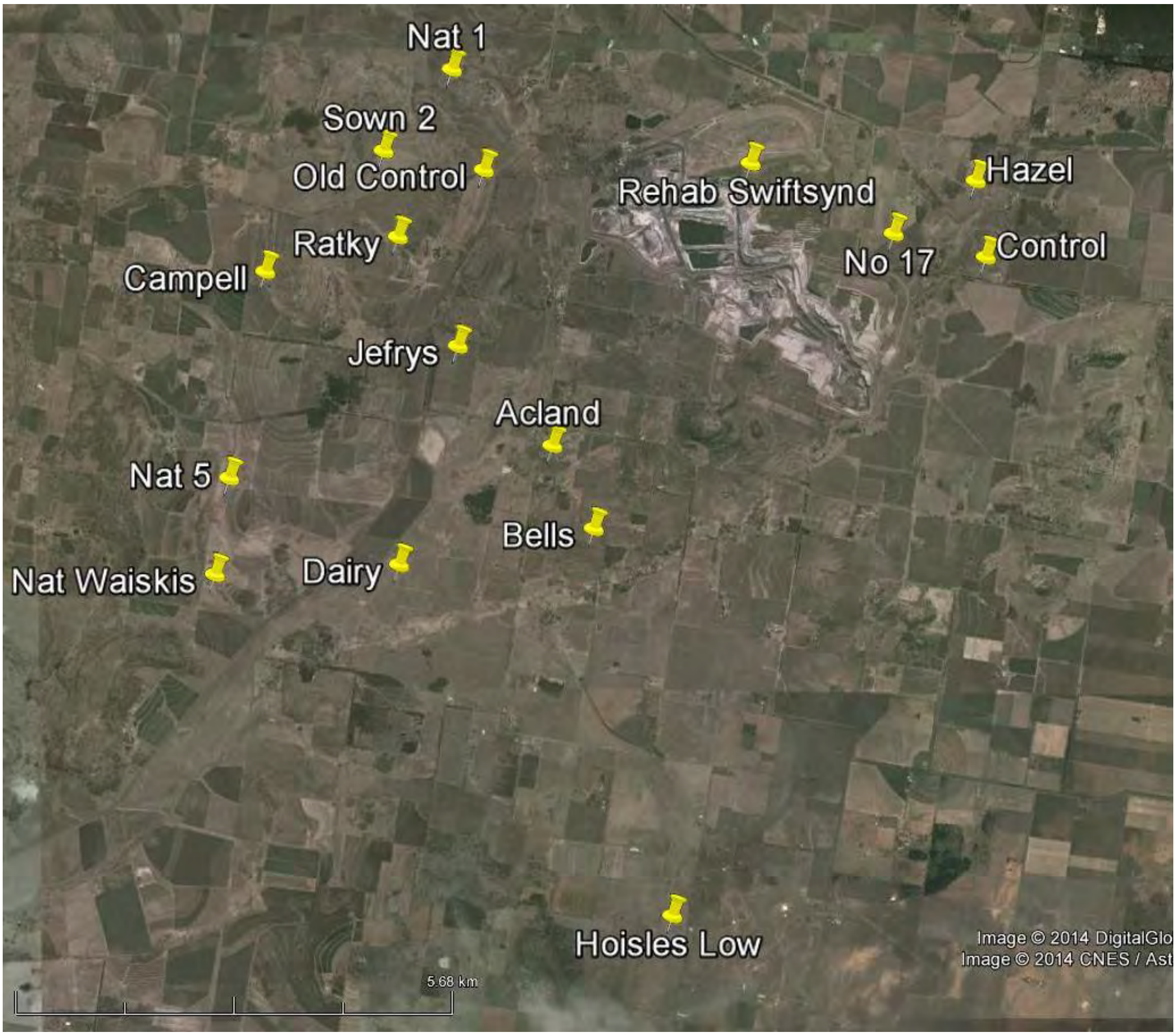



**Figure 1.1 Locations of the pits described around the New Acland mine on16 and 17 April 2014 (Image from Google Earth)**

# 2 Sites Described

## 2.1 Site 1 - Nat 1 (First site visited 16 April 2014)

**Location:** S 27 15 48.917 E 151 40 33.251

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Main Range Volcanics – Basalt, agglomerate, shale, dolomite |
| Land Management Field Manual | 7a – Undulating rises and rolling low hills on basaltic uplands, Black to dark brown clays or brown clay loams (Vertosols, Dermosols), Mountain coolibah open woodland |
| Strategic Cropping Land Trigger Mapping | Strategic cropping land |

**Landform:** Gentle crest on low rise mid height in undulating low hills

**Slope %:** 1.5 to 2 to NE

**Surface coarse fragments:** 40 to 60% basalt, 50 to 200 mm

**Surface condition:** Self-mulching

**Root distribution:** 1 to 2 mm roots common in A1 horizon, decreasing to absent below 0.9 m

**Land use:** Grazing, previously cropped

**Adjacent natural vegetation:** Mountain coolibah (*Eucalyptus orgadophila*) 80 m N

**Australian Soil Classification:** Red Dermosol (may crack when dry but no slickensides or lenticular peds were observed so is not a Vertosol)

**Profile morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.15 m | Very dark brown (7.5YR2.5/2) light medium clay, 10% 5 to 20 mm basalt fragments, strong <2 mm granular to 10 mm depth then strong 3 to 10 mm angular blocky, <2% ferromanganiferous 1 to 2 mm concretions, moist firm, field pH 6.0, clear boundary to: |
| B21 | 0.15 – 0.3 m | Dark brown (7.5YR3/3) medium heavy clay, moderate 20 to 40 mm prismatic breaking to 10 mm angular blocky, few <5 mm cracks, <2% ferromanganiferous 1 to 2 mm concretions, moist firm, field pH 7.5, gradual boundary to: |
| B22 | 0.3 – 0.55 m | Dark reddish brown (5YR3/3) light clay, 10 to 15% mealy weathered basalt, moderate 10 mm angular blocky, dry very firm, field pH 7.8, clear irregular boundary to: |
| BC | 0.55 – 0.7 m | 7.5YR3/4 (dark brown) clay loam, mealy weathered basalt with 20 to 60 % hard rock to 400 mm, ghost rock structure, dry very firm, field pH 7.5, clear wavy boundary to: |
| C | 0.7 – >0.85 m | 20% mealy weathered basalt, 80% 50 to 400 mm little-weathered basalt, field pH 7.5 |

The Nat 1 site described sits on a low ridge running north-east from a low basalt-capped hill to the south-west. There are broad drainage depressions on each side and there appears to be more surface stone along the low ridge than in the adjacent depressions. One interpretation of the landscape is that the low ridge represents an area of basalt more resistant to weathering, resulting in the low ridge with shallower soils than may occur in the depressions to the north-west and south-east. There is a change in slope beyond the clump of mountain coolibah north-east of the site and deeper soils are likely beyond this as well.

The pit shows considerable variability and the profile described is deeper to hard or weathered rock than much of the rest of the pit.

The described site fits within the mapped geological and land resource area units but the soil is too shallow to be classed as strategic cropping land (SCL). Also, there may be too much surface stone.


**Nat 1 pit showing variability in depth to hard and weathered rock and described profile**

**Mountain coolibah adjacent to Nat 1 pit**

**Surface stone at Nat 1 pit**

## 2.2 Site 2 - Sown 2 (Second site visited 16 April 2014)

**Location:** S 27 16 23.675 E 151 40 1.691

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Main Range Volcanics – Basalt, agglomerate, shale, dolomite |
| Land Management Field Manual | 7a – Undulating rises and rolling low hills on basaltic uplands, Black to dark brown clays or brown clay loams (Vertosols, Dermosols), Mountain coolibah open woodland |
| Strategic Cropping Land Trigger Mapping | Strategic cropping land |

**Landform:** Mid to upper slope in undulating low hills

**Slope %:** 2 to 2.5 to NW

**Surface coarse fragments:** 5 to 10% basalt up to 150 mm

**Surface condition:** Weak crust

**Root distribution:** Many 1 to 2 mm roots in A1 and B2 horizons, decreasing to 0.8 m (exposure depth)

**Land use:** Grazing, previously cropped

**Adjacent natural vegetation:** Mountain coolibah (*Eucalyptus orgadophila*) 200 m S

**Australian Soil Classification:** Black Dermosol

**Profile morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.1 m | Very dusky red (2.5YR2.5/2) light clay, 10% angular basalt fragments to 100 mm, strong 5 mm angular blocky below crust, 1% ferromanganiferous 1 to 2 mm concretions, dry very firm, field pH 6.0, clear boundary to: |
| B2 | 0.1 – 0.25 m | Very dusky red (2.5YR2.5/2) medium clay, 10% angular basalt to 100 mm, strong 10 mm angular blocky, clay skins, <2% ferromanganiferous 1 to 2 mm concretions, dry very firm, field pH 6.5, gradual wavy boundary to: |
| BC | 0.25 – 0.5 m | 40% dark brown (7.5YR3/4) light medium clay, 40% mealy weathered basalt, 20% hard weathered basalt, 10 ferromanganiferous soft segregations on soil and weathered rock faces, field pH 7.0, clear wavy boundary to: |
| C | 0.5 – >0.8 m | Mealy and hard weathered basalt |

The Sown 2 site sits in the centre of north-west facing slope approximately 400 m long. There is no evidence to suggest that the described soil is not representative of that in the surrounding area.

As with the Nat 1 site, there is some short-range variability within the pit

The site fits within the mapped geological and land resource area units but the soil is too shallow to be classed as SCL.


**Described profile in the Sown 2 pit**


**Slightly deeper profile in the Sown 2 pit – BC horizon at approximately 0.55 m**

**View NE from Sown 2 pit**

**View NW from Sown 2 pit**

## 2.3 Site 4 - Nat Walskis (Third site visited 16 April 2014)

**Location:** S 27 19 21.161 E 151 38 41.345

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Colluvium – Pliocene Pleistocene pediment remnants |
| Land Management Field Manual | 7b – Level to gently undulating plains on basaltic uplands, Reddish brown to brown clays or clay loams (Ferrosols, Dermosols), Poplar box open woodland |
| Strategic Cropping Land Trigger Mapping | Not strategic cropping land |

**Landform:** Mid to upper slope in gently undulating alluvial plains**Slope %:** 1 to 1.5 to S

**Surface coarse fragments:** None

**Surface condition:** Surface crust to 10 mm (soft) with fine sand separation on top; cracking

**Root distribution:** Many 1 to 2 mm roots in A1 and upper B21 horizons (to 0.25 m), decreasing to 0.9 m

**Land use:** Grazing, previously cropped

**Adjacent natural vegetation:** Poplar box (*Eucalyptus populnea*) and *Acacia* spp. on foot slope 80 m N and on road reserve 100 m W

**Australian Soil Classification:** Black Vertosol

**Profile morphology:**

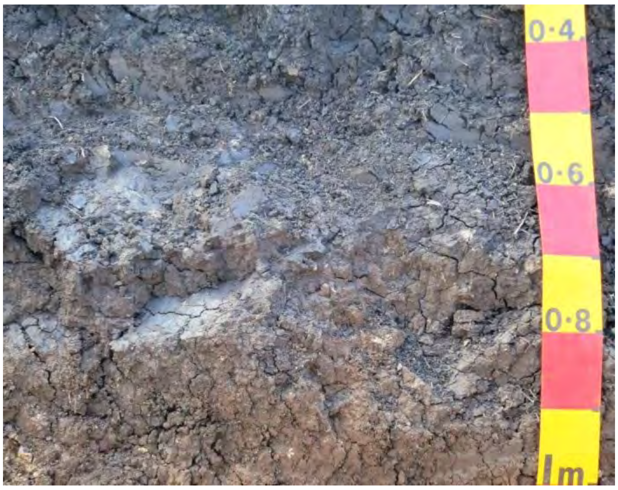
| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.1 m | Black (7.5YR2.5/1) heavy clay, strong 2 to 10 mm angular blocky below crust, dry very firm, 1% carbonate nodules, field pH 7.5, clear boundary to: |
| B21 | 0.1 – 0.45 m | Black (7.5YR2.5/1) heavy clay, moderate 10 to 30 mm angular blocky with occasional lenticular in lower parts, dry very firm, 5% carbonate nodules and soft segregations, field pH 8.8, gradual wavy boundary to: |
| B22 | 0.45 – 1.0 m | Black (7.5YR2.5/1) heavy clay, <1% weathered basalt fragments to 25 mm, strong 50 to 150 mm lenticular breaking to angular blocky, dry very firm, 5% carbonate nodules and soft segregations, field pH 8.8, clear wavy boundary to: |
| B23 | 1.0 – >1.15 m | Brown (7.5YR4/4) medium heavy clay, lenticular and angular blocky structure, <10% mangans, 5% carbonate nodules and soft segregations, field pH 8.8 |

The Nat Walski site sits on the northern margin of the alluvial plain of an un-named drainage line that flows south, then east in the vicinity of Cookes Road. The drainage line is a tributary of Lagoon Creek. The alluvial plain is approximately 400 m wide at the site and the site appears to be representative of soil on the plain. It is likely that the source materials for the alluvium are both basalt and sediments of the Walloon Coal Measures.

Geology mapping shows the area as Pliocene – Pleistocene pediment remnants though it would be better placed within the Qa – Flood plains, river terraces unit to the east.

Land Resource area mapping places the area in unit 7b which can be summarised as part of the Basaltic Uplands and red or brown Ferrosols or Dermosols with poplar box open woodland. Though there is poplar box in the vicinity of the site, the pit and surrounding alluvial plain areas to the south and west do not fit within this unit .

The area is shown as not strategic cropping land though the site meets the eight criteria to qualify as SCL.

| | |
|---|---|
|   |   |
| **Described profile in the Nat Walskis pit** | **Slickensides in the Nat Walskis pit** |
|  |  |
| **Acacias and poplar box along the foot of the rise adjacent to the alluvial plain NE of the Nat Walski pit** | **View SW from the Nat Walski pit across the alluvial plain** |

## 2.4 Site 5 - Nat 5 (Fourth site visited 16 April 2014)

**Location:** S 27 18 40.32 E 151 38 48.113

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Colluvium – Pliocene Pleistocene pediment remnants |
| Land Management Field Manual | 7b – Level to gently undulating plains on basaltic uplands, Reddish brown to brown clays or clay loams (Ferrosols, Dermosols), Poplar box open woodland |
| Strategic Cropping Land Trigger Mapping | Strategic cropping land |

**Landform:** Mid slope in gently undulating rises

**Slope %:** 2 to W

**Surface coarse fragments:** <2% silicified wood and polished ironstone fragments to 20 mm

**Surface condition:** Surface crust to 10 mm with fine sand separation on top, cracking, little surface expression but imagery shows linear gilgai

**Root distribution:** Many 1 to 2 mm roots in A1 and upper B21 horizons (to 0.25 m), decreasing to 0.9 m then occasional roots on slickenside faces, decomposed tree or shrub roots to 1 m

**Land use:** Grazing, previously cropped

**Adjacent natural vegetation:** Poplar box (*Eucalyptus populnea*) on road reserve 100 m W

**Australian Soil Classification:** Black Vertosol

**Profile morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.1 m | Dark brown (7.5YR3/2) medium clay, <1% ironstone 3 to 5 mm (non-magnetic), strong 5 to 10 mm angular blocky below crust, dry very firm, <1% carbonate nodules, field pH 8.2, clear boundary to: |
| B21 | 0.1 – 0.35 m | Dark brown (7.5YR3/2) medium heavy clay, <1% ironstone 3 to 5 mm (non-magnetic), moderate 20 to 40 mm angular blocky, dry very firm, <1% carbonate nodules, field pH 8.8, gradual wavy boundary to: |
| B22ca | 0.35 – 0.6 m | Brown (7.5YR4/4) medium heavy clay, <1% ironstone 3 to 5 mm (non-magnetic), strong 50 to 100 mm lenticular breaking to angular blocky, dry very firm, 5% carbonate nodules, soft segregations and veins, field pH 8.8, clear wavy boundary to: |
| B23ca | 0.6 – 0.9 m | Brown (7.5YR5/4) medium heavy clay, <1% ironstone 3 to 5 mm (non-magnetic), strong 100 to 200 mm lenticular breaking to angular blocky, dry very firm, 5% carbonate nodules, soft segregations and veins, field pH 8.8, clear wavy boundary to: |
| C | 0.9 – >1.2 m | Light brown weathered mudstone with clayey layer, dominantly ghost rock structure with occasional clay-coated slickensides, field pH 7.0 |

The Nat 5 site sits in the centre of west-facing slope approximately 400 m long that runs to the upper reaches of the drainage line near the Nat Walski site. There is no evidence to suggest that this site is not representative of the surrounding area.

There is some short-range variability within the pit, particularly in depth to C horizon. The area is gilgaied so this may have been caused by differential soil movement though the pit face is parallel with direction of gilgai.

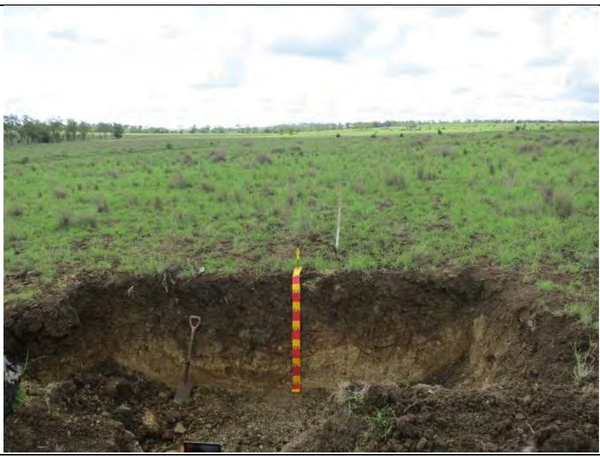
Geology mapping shows the area as Pliocene – Pleistocene pediment remnants though it would be better placed within the Jw – Walloon Coal Measures unit. Nevertheless, there may be a basalt cap on the ridge to the east.

Land Resource area mapping places the area in unit 7b which can be summarised as part of the Basaltic Uplands and red or brown Ferrosols or Dermosols with poplar box open woodland. The soil is on sandstone and the landscape indicates that all or most of the slope it is on is likely to be on sandstone as well. There is poplar box in the vicinity of the site and the soil is a Vertosol so that the area might be better placed within unit 8a in the Poplar Box Walloons.

The area is shown as SCL and the site meets the criteria.


Described profile in the Nat 5 pit


Clay-coated slickenside in th C horizon at the Nat 5 pit



Nat 5 pit showing variability in pit and landscape to N

Landscape to SW of the Nat 5 site

## 2.5 Site 10 - Dairy (Fifth site visited 16 April 2014)

**Location:** S 27 19 17.027 E 151 40 8.321

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Walloon Coal Measures – Shale, siltstone, sandstone, coal, mudstone, limestone |
| Land Management Field Manual | 8a – Undulating rises and low hills on Walloon Sandstone (Poplar box Walloons), Self-mulching black cracking clays (Vertosols), Poplar box open woodland |
| Strategic Cropping Land Trigger Mapping | Strategic cropping land |

**Landform:** Mid to lower slope in gently undulating plains

**Slope %:** 1.5 to W

**Surface coarse fragments:** <1% basalt fragments to 100 mm, <2% ferruginous fragments to 50 mm

**Erosion:** Minor sheet erosion

**Surface condition:** Hard setting, apparent slight undulations approximately 15 m wavelength may indicate gilgai, possibly a gilgai depression site

**Root distribution:** Common 1 to 2 mm roots in A1 and upper B21 horizons (to 0.4 m), decreasing to 1 m

**Land use:** Grazing, pasture appears run down from past overgrazing, previously cropped

**Adjacent natural vegetation:** Scattered poplar box (*Eucalyptus populnea*) within 200 m

**Australian Soil Classification:** Brown Chromosol

**Profile morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.1 m | Dark brown (7.5YR3/2) clay loam sandy, 1% ironstone to 10 mm (non-magnetic), massive to weak 20 to 40 mm angular blocky, dry firm, field pH 6.5, abrupt boundary to: |
| B21 | 0.1 – 0.4 m | Brown (7.5YR4/3) medium heavy clay, 2% ironstone to 20 mm (non-magnetic), strong 20 to 50 mm prismatic breaking to angular blocky, dry very firm, field pH 8.5, clear boundary to: |
| B22ca | 0.4 – 0.55 m | Brown (7.5YR4/4) medium heavy clay, 5% ironstone 60 mm (non-magnetic), strong 50 to 100 mm lenticular breaking to angular blocky, dry very firm, 5% carbonate nodules, soft segregations and veins, field pH 8.8, clear wavy boundary to: |
| B23ca | 0.55 – 1 m | Brown (7.5YR5/4) medium heavy clay, 2% ironstone to 60 mm (non-magnetic), moderate 100 to 200 mm lenticular breaking to angular blocky, dry very firm, 5 to 10% carbonate soft segregations and veins, field pH 9.0, gradual boundary to: |
| B24ca | 1 – 1.3 m | Reddish yellow (7.5YR6/6) medium clay, 2% ironstone to 20 mm (non-magnetic) and <2% sandstone fragments to 20 mm, moderate 100 to 200 mm lenticular breaking to angular blocky, dry very firm, 5 to 10% carbonate soft segregations and veins, field pH 9.0, clear boundary to: |
| C | >1.3 m | Pale weathered sandstone with dominantly ghost rock structure and bedding evident |

The Dairy site sits in the centre of west-facing slope, approximately 300 m long that runs to an un-named tributary of Lagoon Creek. There is no evidence to suggest that this site is not representative of the surrounding area though, if the site is in a gilgai depression, mound sites may have a heavier surface texture.

As with other sites where the soil is apparently formed *in situ*, or with little down-slope movement of material, there is some short-range variability within the pit, particularly in depth to C horizon. The prismatic structure in the upper B horizon may indicate some sodicity in the upper B horizon but the material is unlikely to be strongly sodic.

Geology mapping shows the area as Walloon Coal Measures and the underlying sandstone would fit within this unit.

Land Resource area mapping places the area in unit 6a, part of the Brigalow Uplands but it would better fit within one of the units with texture contrast soils and poplar box on Waloon Coal Measures.

The area is shown as SCL and the site meets the criteria.

Described profile in the Dairy pit


Detail of sandstone at the base of the Dairy pit


Landscape W of the Dairy pit


Landscape NE of the Dairy pit

## 2.6 Site 16 - Hoisles Low (Sixth site visited 16 April 2014)

**Location:** S 27 21 44.171 E 151 42 17.345

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Walloon Coal Measures – Shale, siltstone, sandstone, coal, mudstone, limestone |
| Land Management Field Manual | 8a – Undulating rises and low hills on Walloon Sandstone (Poplar box Walloons), Self-mulching black cracking clays (Vertosols), Poplar box open woodland |
| Strategic Cropping Land Trigger Mapping | Strategic cropping land |

**Landform:** Mid slope in level to gently undulating plains

**Slope %:** 0.5 to 1 to E

**Surface coarse fragments:** <1% carbonate nodules to 5 mm

**Surface condition:** Soft crust to 10 mm with fine sand separation on surface, cracking; patterns in imagery, colour mix from 0.9 to 1.1 m, and wavy boundary at 0.9 m indicate gilgai

**Root distribution:** Common 1 to 2 mm roots in A1 and upper B21 horizons (to 0.5 m), decreasing to 1.2 m

**Land use:** Grazing, previously cropped

**Adjacent natural vegetation:** Unknown

**Australian Soil Classification:** Black Vertosol

**Profile morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.1 m | Very dark grey (5YR3/1) medium heavy clay, strong 2 mm granular under crust then moderate 5 to 10 mm angular blocky, dry very firm, 1% carbonate nodules, field pH 8.0, abrupt boundary to: |
| B21 | 0.1 – 0.5 m | Very dark grey (7.5YR3/1) medium clay (+), strong 20 to 50 mm angular blocky, dry very firm, 2% carbonate nodules, field pH 8.5, clear boundary to: |
| B22ca | 0.5 – 0.9 m | Dark grey (7.5YR4/1) medium clay (+), strong 50 to 500 mm lenticular breaking to angular blocky, dry very firm, 5% carbonate nodules and soft segregations, field pH 8.5, clear wavy boundary to: |
| B23ca | 0.9 – 1.1 m | Brown (7.5YR4/4) with 10% 7.5YR4/1 (mix, not mottle) medium clay, moderate 50 to 200 mm lenticular breaking to angular blocky, dry very firm, 5% carbonate nodules and soft segregations, field pH 8.5, clear boundary to: |
| B24ca | 1 – 1.3 m | Strong brown (7.5YR5/6) with some dark mix medium clay, moderate 10 to 30 mm angular blocky, well developed clay skins, dry very firm, 5% carbonate nodules and soft segregations, trace ferromanganiferous soft segregations on ped faces, field pH 8.5, clear boundary to: |
| D | 1.3 - >1.4 m | Reddish yellow (7.5YR6/6) with 10YR4/1 mix light medium clay, massive |

The Hoisles low site sits in a gently undulating plain draining to the east. Surface soil features of surrounding areas of the plain are similar to those at the site so it appears representative ot a larger area.

Geology mapping shows the area as Walloon Coal Measures but the material underlying the profile is similar to that often found underlying soils formed on clayey alluvium so it may better fit with the Qa – Flood plains, river terraces unit to the east.

Land Resource area mapping places the area in unit 8a, poplar box Walloons but it would fit better with the adjacent unit 2a, Older Alluvial Plains with black self-mulching cracking clays.

The area is shown as SCL and the site meets the criteria.

<table>
<tr><td>
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<tr><td>Described profile in the Hoisles Low pit</td><td>Slickensides in the Hoisles Low pit</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Landscape E of the Hoisles Low pit</td><td>Landscape SW of the Hoisles Low pit</td></tr>
</table>

## 2.7 Site 18 - Hazels (Seventh site visited 16 April 2014)

**Location:** S 27 16 36.264 E 151 44 40.632

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Walloon Coal Measures – Shale, siltstone, sandstone, coal, mudstone, limestone |
| Land Management Field Manual | 6a – Gently undulating rises and plains on Walloon Sandstone (Brigalow uplands), Grey brown cracking clays (Vertosols), Brigalow, belah, wilga open woodland |
| Strategic Cropping Land Trigger Mapping | Strategic cropping land |

**Landform:** Mid slope in undulating rises

**Slope %:** 1 to E

**Surface coarse fragments:** None evident

**Surface condition:** Hard setting

**Root distribution:** Common 1 to 2 mm roots in A1 and B21 horizons, decreasing to 1.2 m

**Land use:** Grazing, good Rhodes grass (*Chloris gayana*) cover, previously cropped

**Adjacent natural vegetation:** Brigalow (*Acacia harpophylla*)

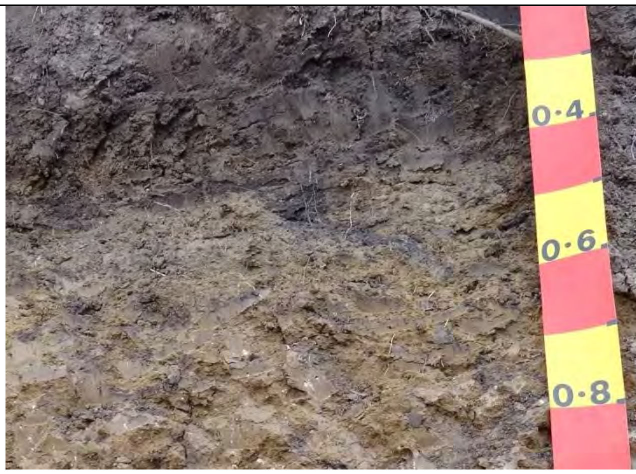
**Australian Soil Classification:** Brown Dermosol

**Profile morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.2 m | Dark brown (7.5YR3/2) sandy clay, massive with some weak 10 mm angular blocky in lower 0.1 m, moist firm, 2% ferromanganiferous concretions, field pH 6.0, clear boundary to: |
| B21 | 0.2 – 0.4 m | Brown (7.5YR4/3) light medium clay, moderate 5 to 20 mm angular blocky, moist firm, 2% ferromanganiferous concretions and soft segregations, field pH 7.4, clear boundary with some toungs protruding into: |
| B22 | 0.4 – 0.7 m | Brown (7.5YR4/4) with 20% yellow mottle medium clay, moderate 5 to 25 mm angular blocky, dry very firm, 2% ferromanganiferous concretions and soft segregations with trace ferromanganiferous soft segregations on ped faces, field pH 8.5, clear wavy boundary to: |
| B23ca | 0.7 – 1.2 m | Brown (7.5YR5/4) medium heavy clay, moderate 50 to 100 mm lenticular breaking to angular blocky, dry very firm, 10% carbonate nodules and soft segregations, field pH 9.0, clear boundary to: |
| B24ca | 1.2 – >1.5 m | Brown (7.5YR5/4) medium heavy clay, moderate 10 to 30 mm angular blocky, well developed clay skins, dry very firm, 5% carbonate nodules and soft segregations, 5% ferromanganiferous concretions and soft segregations, field pH 9.0 |

Though the pit at the Hazel site did not encounter underlying rock, the situation suggests it is on the Walloon Coal measures as mapped. The soil is a Brown Dermosol and is within the range that would support brigalow (the adjacent vegetation) and the site meets the SCL criteria, as mapped.

Described profile in the Hazels pit




Grey tongue, probably a former root channel, into brown B21 horizon

Landscape with brigalow W of the Hazels site

Landscape to the NE of the Hazels site

## 2.8 Site 17 (Eighth site visited 16 April 2014)

**Location:** S 27 16 58.307 E 151 44 1.883

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Walloon Coal Measures – Shale, siltstone, sandstone, coal, mudstone, limestone |
| Land Management Field Manual | 6a – Gently undulating rises and plains on Walloon Sandstone (Brigalow uplands), Grey brown cracking clays (Vertosols), Brigalow, belah, wilga open woodland |
| Strategic Cropping Land Trigger Mapping | Strategic cropping land |

**Landform:** Mid slope in gently undulating rises

**Slope %:** 2.5 to 3 to SE

**Surface coarse fragments:** None evident

**Erosion:** Now stable but evidence of sheet erosion and rilling in the paddock

**Surface condition:** Hard setting

**Root distribution:** Common 1 to 2 mm roots in A1, B21 and B22 horizons, decreasing slightly to 1.2 m (on ped faces in B24 horizon)

**Land use:** Rhodes grass (*Chloris gayana*) cover, previously cropped

**Adjacent natural vegetation:** Brigalow (*Acacia harpophylla*) and belah (*Casuarina cristata*) 200 m to SW

**Australian Soil Classification:** Red Dermosol

**Profile morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.1 m | Dark reddish brown (2.5YR3/3) light clay (+), massive with some weak 10 mm angular blocky, moist firm, field pH 7.0, clear boundary to: |
| B21 | 0.1 – 0.4 m | Dark reddish brown (2.5YR3/3) light medium clay, 1% polished ironstone to 15 mm, weak 20 to 50 mm prismatic, dry very firm, field pH 7.5, clear boundary to: |
| B22 | 0.4 – 0.6 m | Yellowish red (5YR4/6) light medium clay, 1% polished ironstone to 15 mm, weak 10 to 20 mm angular blocky, dry very firm, field pH 8.0, gradual boundary to: |
| B23 | 0.6 – 0.8 m | Yellowish red (5YR5/6) with 20% distinct red mottle light medium clay, weak 10 to 20 mm angular blocky, dry very firm, 5% ferromanganiferous nodules and soft segregations, field pH 8.5, gradual boundary to: |
| B24 | 0.8 – >1.3 m | Yellowish red (5YR5/6) with 20% distinct red mottle medium clay, moderate 10 to 30 mm angular blocky with some extensive crack faces, dry very firm, 5% ferromanganiferous concretions and soft segregations some on ped faces, field pH 8.5 |

One corner of the pit had 5% carbonate concretions and soft carbonate in the B24 horizon and there were occasional sandstone fragments in the profile in some parts of the pit. The sandsrone fragments indicate the site is on Walloon Coal Measures as mapped. The soil is a Red Dermosol and is within the range that would support brigalow and belah (the adjacent vegetation) and the site meets the SCL criteria, as mapped.

Described profile at site 17 pit


Landscape to S of site 17 pit including rehabilitated land


Landscape to N of site 17 pit


Landscape to NE of site 17 pit

## 2.9 Control Swiftsynd (First site visited 17 April 2014)

**Location:** S 27 17 7.913 E 151 44 45.731

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Walloon Coal Measures – Shale, siltstone, sandstone, coal, mudstone, limestone |
| Land Management Field Manual | 6a – Gently undulating rises and plains on Walloon Sandstone (Brigalow uplands), Grey brown cracking clays (Vertosols), Brigalow, belah, wilga open woodland |
| Strategic Cropping Land Trigger Mapping | Strategic cropping land |

**Landform:** Mid slope in gently undulating rises

**Slope %:** 2 to NW

**Surface coarse fragments:** None evident

**Erosion:** None evident

**Surface condition:** Hard setting

**Root distribution:** Common 1 to 2 mm roots in A1, A2 and upper B21 horizonsto 0.4 m, decreasing to 1.3 m

**Land use:** Rhodes grass (*Chloris gayana*) cover, previously cropped

**Adjacent natural vegetation:** Brigalow (*Acacia harpophylla*) 80 m to S

**Australian Soil Classification:** Brown Dermosol (probably Bleached, Hypocalcic Brown Dermosol)

**Profile morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.2 m | Dark brown (7.5YR3/2) light medium clay, massive with some weak 5 to 10 mm angular blocky, moist firm, field pH 7.3, clear boundary to: |
| A2cb | 0.2 – 0.25 m | Conspicuously bleached pinkish grey (7.5YR7/2 dry, 7.5YR5/2 moist) light clay, 1% ironstone to 10 mm, massive, moist soft, 1% ferromanganiferous concretions to 1 mm, field pH 8.2, clear wavy boundary to: |
| B21 | 0.25 – 0.7 m | Dark yellowish brown (10YR4/6) medium clay (+), 1% rounded ironstone to 5 mm, strong 5 to 25 mm angular blocky, dry very firm, field pH 8.8, clear boundary to: |
| B22ca | 0.7 – 1.1 m | Strong brown (7.5YR4/6) medium heavy clay, 1% rounded ironstone to 5 mm, strong 100 to 200 mm lenticular breaking to angular blocky, dry very firm, <1% ferromanganiferous nodules and soft segregations, 5% carbonate soft segregations, field pH 9.0, gradual boundary to: |
| B23ca | 1.1 – >1.5 m | Strong brown (7.5YR4/6) with 10% fine dark mottle, medium heavy clay, 1% rounded ironstone to 5 mm, strong 100 to 200 mm lenticular breaking to angular blocky, dry very firm, <1% ferromanganiferous nodules and soft segregations, 5% carbonate soft segregations, field pH 9.0 |

This soil is unusual in that the A1 and A2 horizons are clays yet it has a bleached A2 horizon. Bleached clays occur in some parts of the dry tropics of northern Queensland but they are unusual in southern Queensland.


Described profile at Control Swiftsynd pit


Pale bleach in profile at Control Swiftsynd pit

Landscape to NE of Control Swiftsynd site

Brigalow in road reserve SW of Control Swiftsynd site

## 2.10 Rehab 2 Swiftsynd (Second site visited 17 April 2014)

**Location:** S 27 16 28.967 E 151 42 54.557

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | NA – Waste rock dump |
| Land Management Field Manual | NA |
| Strategic Cropping Land Trigger Mapping | NA |

**Landform:** Mid slope in undulating low hills (made land)

**Slope %:** 5 to S

**Surface coarse fragments:** 2% coal and sandstone to 70 mm

**Erosion:** None evident

**Surface condition:** Hard setting

**Root distribution:** Common 1 to 2 mm roots in A1 and B2 horizons then decreasing to 0.9 m

**Land use:** Good cover of mixed grass species – established four to six years ago

**Adjacent natural vegetation:** NA

**Australian Soil Classification:** Spoilic Anthroposol

**Profile morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.2 m | Dark brown (7.5YR3/2) medium heavy clay, 5% coal and sandstone fragments to 100 mm, massive with 20% weak 5 to 10 mm angular blocky, moist firm, field pH 8.8, clear boundary to: |
| B2 | 0.2 – 0.35 m | Red (2.5YR4/6) with 10% 7.5YR3/2 (mix not mottle) medium clay, 5% coal and sandstone fragments to 100 mm, massive with 20% weak 5 to 10 mm angular blocky, moist firm, 2% carbonate soft segregations in som parts, field pH 8.8, abrupt boundary to: |
| D1 | 0.35 – 0.6 m | Pale grey gravelly light clay, 60% sandstone fragments to 300 mm and 5% coal fragments, dry very firm, field pH 8.8, clear boundary to: |
| D2 | 0.6 – 1.1 m | Pale grey gravelly light clay, 40% sandstone fragments to 100 mm and 5% coal fragments, dry very firm, field pH 8.8, clear boundary to: |
| D3 | 1.1 – >1.6 m | Dark grey gravelly light clay, 80% sandstone, shale and coal fragments to >300 mm, field pH 7.5 |

It is understood that the topsoil used for rehabilitation at this site was a mix of an entire soil profile to a specified depth and was subsequently placed as a single layer. If this is the case, the dark colours in the top 0.2 m suggest that there has been an appreciable accumulation of organic matter since the grass pasture was established.


Described profile at Rehab 2 pit showing thin soil layer over waste rock


Surface horizons showing darkening in the top 0.2 m, apparently as a result of organic matter accumulation

Rehabilitated landscape NW of the Rehab 2 site

Rehabilitated landscape E of the Rehab 2 site

## 2.11 Site 7 - Old Control (Third site visited 17 April 2014)

**Location:** S 27 16 31.59 E 151 40 48.91

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Main Range Volcanics – Basalt, agglomerate, shale, dolomite |
| Land Management Field Manual | 7a – Undulating rises and rolling low hills on basaltic uplands, Black to dark brown clays or brown clay loams (Vertosols, Dermosols), Mountain coolibah open woodland |
| Strategic Cropping Land Trigger Mapping | Strategic cropping land |

**Landform:** Mid slope in gently undulating rises

**Slope %:** 2 to E

**Surface coarse fragments:** <1% basalt to 15 mm

**Erosion:** None evident but past erosion likely

**Surface condition:** Hard setting, weak crust

**Root distribution:** Common 1 to 2 mm roots in A1 and upper B21 horizons to 0.35 m, decreasing to 1.4 m

**Land use:** Rhodes grass (*Chloris gayana*) cover, previously cropped

**Adjacent natural vegetation:** Mountain coolibah (*Eucalyptus orgadophila*) 200 m W and E

**Australian Soil Classification:** Red Dermosol

**Profile morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.25 m | Dusky red (2.5YR3/2) medium clay, moderate 20 to 50 mm angular blocky breaking to 5 to 10 mm angular blocky, moist firm, field pH 7.0, clear wavy boundary to: |
| B21 | 0.25 – 0.55 m | Dark reddish brown (2.5YR3/3) light medium clay, strong 5 to 15 mm angular blocky, moist firm, field pH 7.5, clear boundary to: |
| B22 | 055 – 1.0 m | Dark reddish brown (5YR3/3) medium clay, <1% weathered basaltic fragments (possibly tuff), strong 5 to 15 mm angular blocky with occasional slickenside to 30 mm, moist firm, field pH 8.5, gradual boundary to: |
| B23ca | 1.0 – 1.3 m | Reddish brown (5YR4/3) medium heavy clay, <2% weathered basaltic fragments (possibly tuff), strong 100 to 200 mm lenticular breaking to lenticular to 20 mm, dry very firm, 2% ferromanganiferous soft segregations, 5% carbonate soft segregations and nodules, field pH 8.5 |
| C | >1.3 m | Grey mealy weathered basalt grading to dark hard weathered basalt, field pH 8.0 |

There may be some evidence of layering in the B21 horizon. This may relate to thin beds in tuff material, which are known to occur locally though are not recognised in the geological mapping, but no other evidence of tuff was observed

| | |
|---|---|
|  |  |
| Old control pit on 26 March 2014 | Described profile at Old Control pit |
|  |  |
| Landscape SE of Old Control site | Landscape W of Old Control site showing basalt cap on the ridge |

## 2.12 Site 8 - Ratky (Fourth site visited 17 April 2014)

**Location:** S 27 16 59.286 E 151 40 8.009

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Main Range Volcanics – Basalt, agglomerate, shale, dolomite |
| Land Management Field Manual | 7a – Undulating rises and rolling low hills on basaltic uplands, Black to dark brown clays or brown clay loams (Vertosols, Dermosols), Mountain coolibah open woodland |
| Strategic Cropping Land Trigger Mapping | Strategic cropping land |

**Landform:** Mid slope in undulating low hills

**Slope %:** 3 to NE

**Surface coarse fragments:** 2% basalt to 150 mm

**Erosion:** None evident

**Surface condition:** Soft, weak crust

**Root distribution:** Few 1 to 2 mm roots in A1 and upper B21 horizons to 0.15 m,

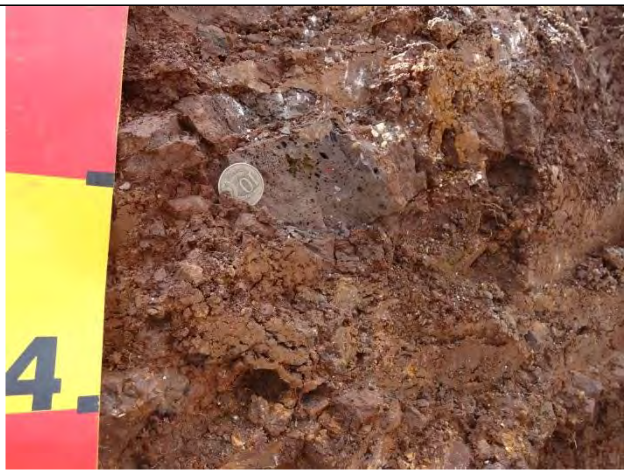
**Land use:** Blue grass cover, may have been previously cropped

**Adjacent natural vegetation:** Mountain coolibah (*Eucalyptus orgadophila*) 150 m S

**Australian Soil Classification:** Red Dermosol

**Profile morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.05 m | Dusky red (2.5YR3/2) light medium clay, moderate 5 to 10 mm angular blocky, dry very firm, field pH 7.0, clear wavy boundary to: |
| B21 | 0.05 – 0.15 m | Dark reddish brown (2.5YR3/3) medium clay, 5% hard weathered basalt fragments to 50 mm, strong 5 to 30 mm angular blocky, dry very firm, field pH 7.5, clear boundary to: |
| BC | 015 – 0.35 m | Dark reddish brown (5YR3/3) medium clay, 70% hard weathered basalt fragments, moderate 5 to 15 mm angular blocky, dry very firm, gradual boundary to: |
| C1 | 0.35 – 0.5 m | Thin veins of brown clay between fractured hard weathered basalt, clear wavy boundary to |
| C2 | 0.5 – 0.65 m | Dark reddish brown (2,5YR3/3) medium clay, 30% hard weathered basalt fragments to 100 mm, moderate 50 mm angular blocky, clear wavy boundary to: |
| C3 | 0.65 – 0.75 | Reddish yellow saponititic material, 40% hard weathered basalt fragments, clear wavy boundary to: |
| C4 | 0.75 - >1 m | Purplish mottled basaltic material, possibly tuff or scoriaceous basalt at flow contact; zeolite infills in vesicles |

| | |
|---|---|
|  |  |
| Described profile at Ratky pit | Vesicular basalt, possibly protected from weathering by an iron layer as a result of deposition in tuff |
|  |  |
| Dark brown clay layer and light brown saponite at about 0.7 m in Ratky pit | Dark brown clay layer, light brown saponite and hard weathered basalt in Ratky pit |
|  |  |
| Landscape to S and ridge crest from Ratky site | Landscape to NE and drainage line from Ratky site |

## 2.13 Site 6 - Jeffrey (Fifth site visited 17 April 2014)

**Location:** S 27 17 45.293 E 151 36.017 8.009

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Walloon Coal Measures – Shale, siltstone, sandstone, coal, mudstone, limestone |
| Land Management Field Manual | 7a – Undulating rises and rolling low hills on basaltic uplands, Black to dark brown clays or brown clay loams (Vertosols, Dermosols), Mountain coolibah open woodland |
| Strategic Cropping Land Trigger Mapping | Strategic cropping land |

**Landform:** Mid slope in gently undulating landscape

**Slope %:** 2.5 to S

**Surface coarse fragments:** 2% polished ironstone to 15 mm

**Erosion:** None evident

**Surface condition:** Hard setting with patches of weak crust, fine sand separation on surface,

**Root distribution:** Common 1 to 2 mm roots in A1 upper B21 horizons to 0.35 m, decreasing to 1.2 m

**Land use:** Grazing, moderate grass cover, previously cropped

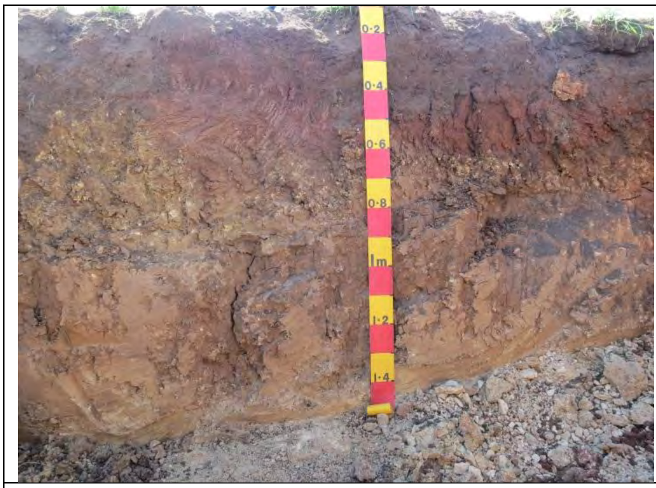
**Adjacent natural vegetation:** Poplar box (*Eucalyptus populnea*) 200 m to W

**Australian Soil Classification:** Red Dermosol

**Profile morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.2 m | Dusky red (2.5YR3/2) light medium clay (+), 2% polished ironstone to 5 mm, weak 5 to 15 mm angular blocky, moist firm, field pH 8.5, clear boundary to: |
| B21 | 0.2 – 0.6 m | Dark reddish brown (2.5YR3/4) medium clay, moderate 5 to 15 mm angular blocky, moist firm, field pH 8.5, clear wavy (0.45 to 0.6 m) boundary to: |
| B22ca | 0.6 – 0.9 m | Strong brown (7.5YR4/6) medium heavy clay, strong 50 to 150 m lenticular breaking to angular blocky, dry very firm, 10% carbonate soft segregations and nodules, field pH 9.0, gradual boundary to: |
| B23 | 0.9 –1.45 m | Strong brown (7.5YR4/6) medium heavy clay, strong 100 to 200 m lenticular breaking to angular blocky, dry very firm, 5% carbonate soft segregations and nodules, 2% manganiferous soft segregations, dry very strong, field pH 9.0, gradual boundary to: |
| C | >1.45 m | Pale weathered sandstone |

**Note:** 300 mm limestone band on 45 degree angle below 0.7 m in eastern end of pit



Described profile at Jeffrey pit

Limestone band in Jeffery pit

Landscape to W from Jeffery site

Landscape to S from Jeffery pit

## 2.14 Site 3 - Campbell West (Sixth site visited 17 April 2014)

**Location:** S 27 17 14.357 E 151 39 5.423

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Main Range Volcanics – Basalt, agglomerate, shale, dolomite |
| Land Management Field Manual | 7a – Undulating rises and rolling low hills on basaltic uplands, Black to dark brown clays or brown clay loams (Vertosols, Dermosols), Mountain coolibah open woodland |
| Strategic Cropping Land Trigger Mapping | Strategic cropping land |

**Landform:** Mid slope in undulating low hills

**Slope %:** 4.5 to W

**Surface coarse fragments:** 1% vesicular basalt to 100 mm

**Erosion:** None evident

**Surface condition:** Moderately self mulching, cracking, linear gilgai

**Root distribution:** Common 1 to 2 mm roots to 0.6 m, decreasing to 1.2 m

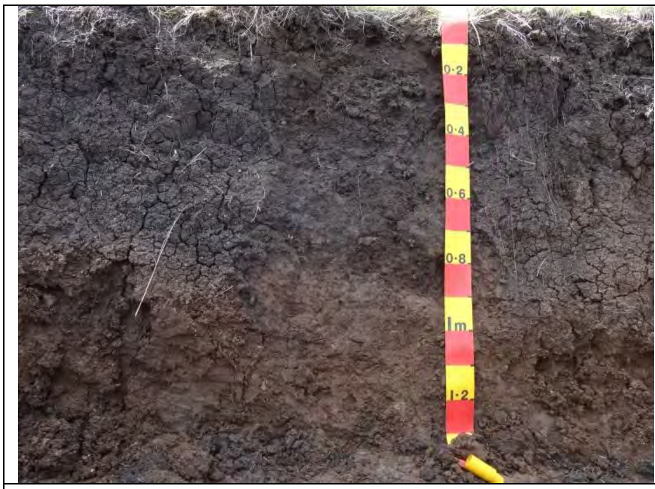
**Land use:** Grazing, good grass cover, previously cropped

**Adjacent natural vegetation:** Mountain coolibah (*Eucalyptus orgadophila*) 150 m to NE

**Australian Soil Classification:** Black Vertosol

**Profile morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.15 m | Reddish black (2.5YR2.5/1) medium clay (+), <1% rounded quartz to 5 mm, strong 1 to 3 mm granular grading to moderate 5 to 15 mm angular blocky, dry firm, 2% carbonate nodules, <1% manganiferous concretions, field pH 8.5, clear boundary to: |
| B21 | 0.15 – 0.3 m | Very dark grey (5YR3/1) medium heavy clay, <1% rounded quartz to 5 mm, strong 10 to 15 mm angular blocky, dry very firm, 2 to 5% carbonate soft segregations with occasional nodules, <1% manganiferous concretions, field pH 8.5, gradual boundary to: |
| B22 | 0.3 – 0.8 m | Dark reddish brown (5YR3/2) medium heavy clay, <1% rounded quartz to 5 mm, strong 10 to 15 mm angular blocky, dry very firm, 2 to 5% carbonate soft segregations with occasional nodules, <1% manganiferous concretions, field pH 8.8, clear boundary to: |
| B23 | 0.8 –1.2 m | Reddish brown (5YR4/3) medium heavy clay, <1% rounded quartz to 5 mm, strong 100 to 200 m lenticular breaking to 20 mm lenticular, dry very firm, 5% carbonate soft segregations and nodules, 2% manganiferous soft segregations, dry very strong, field pH 9.0, gradual boundary to: |
| BC | 1.2 - >1.4 m | Wet clay |

| | |
|---|---|
|  |  |
| Described profile in Campbell West pit | Surface on profile in Campbell West pit showing small carbonbate nodules between 0.1 and 0.2 m |
|  |  |
| Landscape to SW from Campbell West site | Landscape to N from Campbell West site |

## 2.15 Site 9 - Acland (Seventh site visited 17 April 2014)

**Location:** S 27 18 27.023 E 151 41 20.211

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Walloon Coal Measures – Shale, siltstone, sandstone, coal, mudstone, limestone |
| Land Management Field Manual | 6a – Gently undulating rises and plains on Walloon Sandstone (Brigalow uplands), Grey brown cracking clays (Vertosols), Brigalow, belah, wilga open woodland |
| Strategic Cropping Land Trigger Mapping | Strategic cropping land |

**Landform:** Mid slope in gently undulating rises

**Slope %:** 1 to S

**Surface coarse fragments:** <1% ironstone to 50 mm

**Erosion:** None evident

**Surface condition:** Crusting with fine sand separation on surface, cracking

**Root distribution:** Common 1 to 2 mm roots to 0.1 m, decreasing to 1.1 m

**Land use:** Grazing, poor grass cover, previously cropped

**Adjacent natural vegetation:** Poplar box (*Eucalyptus populnea*) on road 200 m SW, brigalow and belah (*Casuarina cristata*) in drainage line 300 m S

**Australian Soil Classification:** Black Vertosol

**Profile morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.1 m | Very dark greyish brown (10YR3/2) light medium clay, 1 to 2% rounded ironstone to 10 mm, weak 5 to 10 mm angular blocky, dry firm, field pH 8.5, clear wavy boundary to: |
| B21 | 0.1 – 0.55 m | Very dark grey (10YR3/1) medium clay, 1 to 2% rounded ironstone to 10 mm, strong 5 to 15 mm angular blocky, dry very firm, field pH 7.5, gradual boundary to: |
| B22 | 0.55 – 0.8 m | Very dark grey (10YR3/1) medium heavy clay, 1 to 2% rounded ironstone to 10 mm, strong 100 to 150 mm lenticular breaking to angular blocky, dry very firm, 10% carbonate soft segregations with occasional nodules, field pH 8.8, gradual boundary to: |
| B23 | 0.8 –1.3 m | Yellowish brown (10YR5/4) medium clay, 1 to 2% rounded ironstone to 10 mm, strong 10 to 30 mm angular blocky with occasional slickensides with dark clay faces, dry very firm, 5% carbonate soft segregations and nodules, 2% manganiferous nodules, dry very strong, field pH 8.8, gradual boundary to: |
| C | >1.3 m | Weathered sedimentary rock – hard ferruginised sandstone in W half of pit and softer pale sandstone in E end |

Notes: Ironstone appears to be a band in the rock, not a pan formed by more recent weathering and pedogenetic processes

| | |
|---|---|
|  |  |
| Described profile in Acland pit | Ironstone layer in base of Acland pit |
|  |  |
| Landscape to NE of Acland site | Landscape to S of Acland site showing brigalow |

## 2.16 Site 11 - Bells (Eighth site visited 17 April 2014)

**Location:** S 27 19 1.985 E 151 40.381

**Currently mapped as:**

| Mapping | Unit and Description |
|---|---|
| Geology | Walloon Coal Measures – Shale, siltstone, sandstone, coal, mudstone, limestone |
| Land Management Field Manual | 6a – Gently undulating rises and plains on Walloon Sandstone (Brigalow uplands), Grey brown cracking clays (Vertosols), Brigalow, belah, wilga open woodland |
| Strategic Cropping Land Trigger Mapping | Strategic cropping land |

**Landform:** Mid slope in gently undulating rises

**Slope %:** 2 to S

**Surface coarse fragments:** <1% polished ironstone to 5 mm and ironstone fragments to 50 mm

**Erosion:** Apparently sheet eroded but stable at present

**Surface condition:** Hard setting with sand wash on surface

**Root distribution:** Common 1 to 2 mm roots to 0.15 m, decreasing to 1.2 m

**Land use:** Grazing, poor cover of grasses and medics, previously cropped

**Adjacent natural vegetation:** Softwood scrub species and occasional poplar box 50 m N and S, brigalow 150 m to E

**Australian Soil Classification:** Red Dermosol

**Profile morphology:**

| Horizon | Depth | Description |
|---|---|---|
| A1 | 0 – 0.1 m | Reddish brown (5YR4/3) sandy clay, 2% rounded polished ironstone to 10 mm, massive, dry firm, field pH 6.0, clear boundary to: |
| B21 | 0.1 – 0.4 m | Red (2.5YR4/6) medium clay, 2% rounded polished ironstone to 10 mm, strong 30 to 50 mm prismatic breaking to angular blocky, dry strong, field pH 8.0, clear boundary to: |
| B22 | 0.4 – 1.0 m | Yellowish red (5YR4/6) with 20% distinct yellow mottle on ped faces, medium clay, 2% rounded polished ironstone to 10 mm, strong 30 to 50 mm prismatic breaking to angular blocky, dry strong, 1% carbonate nodules, faunal infills, field pH 8.0, clear wavy (0.9 to 1.1 m) boundary to: |
| BC | 1.0 –1.4 m | Very pale brown (10YR7/4) with 30% red mottle, light medium clay, 10% sandstone fragments to 500 mm, massive, dry very firm, 2% Ferromanganiferous soft segregations, field pH 8.0, clear boundary to: |
| C | >1.4 m | Pale platy weathered sandstone |

Landscape and soil surface features suggest that there is an appreciable area of this, or similar soils, to the south and west of the site.

| | |
|---|---|
|   |   |
| Described profile in Bells pit | Sandstone rich part of BC horizon in Bells pit profile |
|   |  |
| Detail of prismatic and lenticular structure in Bells pit profile | Faunal channel in Bells pit profile |
|  |  |
| Landscape E from Bells site to brigalow | Landscape S of Bells site with wilga |

# 3 References

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# APPENDIX C: Paper submitted to Soil Science Australia conference

"The potential for a rehabilitated coal mine soil to support livestock grazing in south-east Queensland"

# The potential for a rehabilitated coal mine soil to support livestock grazing in south-east Queensland

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## Abstract
Land that is disturbed by mining activities is required to be suitably rehabilitated. A trial was initiated to compare the performance of livestock grazing pasture sown on land that was rehabilitated after coal mining activity with that of livestock grazing pasture on unmined land. Pasture biomass, and soil structural, nutritional and hydrological properties important for pasture production and sustainability were intensively monitored on three sites rehabilitated at different stages over the last 10 years, and one unmined Control site. A further 18 unmined grazing sites were monitored for benchmarking purposes. Preliminary results for soil ammonium, nitrate and potentially mineralisable nitrogen suggest little difference in terms of benefits or constraints to pasture production between the rehabilitated and Control sites. Plant-available phosphorus was sufficiently high in the two oldest rehabilitated sites that a fertiliser response would not be expected. Subsoil and rooting depth of the rehabilitated sites was within the range observed across the benchmark sites and shallower than in the Control site. Higher pasture biomass in the rehabilitated sites compared with the Control at the initiation of the trial was attributed more-so to differences in grazing history than differences in soil attributes. Analysis of year one monitoring data is ongoing.

## Introduction
Land that is disturbed by mining activities is required to be suitably rehabilitated. The New Acland coal mine in south-east Queensland is undertaking a program of continuous improvement of processes used to rehabilitate disturbed land to minimise the environmental and social footprint of its coal mining operations and to comply with legal requirements for future relinquishment of rehabilitated land (SKM, 2013). At the mine, most of the disturbed land is being rehabilitated for cattle grazing and some areas will be rehabilitated to water storages. To rehabilitate land, the mine uses best industry practice to remove, stockpile and subsequently reform the subsoil, and spread the topsoil before sowing pasture species. Topsoil is defined by the mine as the O and A horizons, and subsoil is defined as the B horizon and/or „the first flitch of material traditionally removed by an excavator in shot ground" (New Hope Group, 2012). The target dimensions for topsoil stockpiles are 3 m height, 14 m width and 35 m apart. Before topsoil is spread, the subsoil between rows is deep ripped. Topsoil is then spread to a target depth of 300 mm. Pasture species sown can include the exotics Katambora Rhodes grass (*Chloris gayana*) and both green and Gatton Panic (*Panicum maximum*) grasses as well as native Queensland Bluegrass (*Dicanthium sericeum*). Once established and stable, the rehabilitated land is grazed with cattle. Soil conditions monitored after the wet season in 2013 were found to be generally favourable for plant growth and good soil aggregate stability was observed (SKM, 2013).

The mine is conducting a five-year trial to compare the livestock production performance of rehabilitated land with that from unmined land. The trial includes livestock, pasture and soil monitoring over five years. The soil monitoring component of the study compares soil fertility and structure of the rehabilitated soils with an unmined soil recently sown to similar pasture species (the Control site) and analyses the relative benefits and constraints to pasture production. The study also compares soil characteristics between the Control site and 18 nearby grazed soils (Benchmark sites) to identify how indicative the Control site is of surrounding land. A range of soil structural (e.g. sodicity, soil stability and particle size analysis), nutritional (e.g. cation exchange capacity) and hydrological (e.g. soil moisture characteristics) properties important for pasture production and sustainability were analysed. Preliminary data on plant-available soil phosphorus (P) and nitrogen (N), depth to subsoil and rooting depth from the first year of soil sampling are presented here. The complete first year of soil analysis will be presented at the conference.

## Methods
The mine is located in south-east Queensland which has summer-dominant rainfall of between 500-700 mm annually on average. Four trial site paddocks were fenced for cattle grazing. The sites represent pasture rehabilitated seven to ten years ago (R1, 22 ha), five years ago (R2, 32 ha) and three years ago (R3, 22 ha)

and a Control site which had not been disturbed and was sown with the same pasture mix three years ago (C, 21 ha). Benchmark sites were chosen to represent the main soil types used for grazing within a surrounding unmined area of approximately 10000 ha. In November-December 2013 (time zero, T0), composite samples from at least five soil cores were collected from depths of 0-10 cm, 10-20 cm and 40-60 cm in each trial site to obtain an indication of the soil nitrogen (N) and phosphorus (P) status at the beginning of the growing season and before cattle started grazing the sites. Pasture yields were visually assessed just prior to T0 and assessed using the Botanal technique (Tothill JC, Hargreaves JNG *et al.* 1992) prior to the introduction of cattle in January 2014. Colwell P (Method 9B), KCl-extractable nitrate-N and ammonium-N (Method 7C2) and hot KCl-extractable potentially mineralisable N (Method 7D1) were measured using methods from Rayment and Lyons (2011) on samples that were dried at 40°C and sieved to 2mm. All P and N analyses were conducted by staff at the Agricultural Chemistry Ltd laboratory in Ipswich, Queensland. During February-March 2014 (T1), five soil cores were collected along transects within five subsample areas in each trial site. Subsample areas were stratified to represent the major topographic and vegetative (measured by NDVI survey in October 2013) variation in the landscape. Sampling was avoided in atypical parts of the landscape. Three cores were also collected during T1 at each Benchmark site. Depth to subsoil and presence or absence of root growth to 60cm was measured by direct observation in the field for each soil core.

**Results**

AT T0, pasture yields were estimated to be up to 15,000 kg/ha of Dry Matter (DM) in the R2 and R3 sites, consisting of old growth accumulated from recent years of above average rainfall and a small proportion of new growth from the current season. To make green pasture more readily accessible for grazing stock, R1, R2 and R3 paddocks were slashed to a height of approximately 30 cm at T0. The Control site had been "crash" grazed and at T0 had very low pasture yields (< 300 kg/ha DM) and low ground coverage by pasture. In January 2014, the rehabilitated sites R1, R2 and R3 yielded 3300, 5300, 5000 and kg /ha DM, respectively, and the Control site yielded 1300 kg/ha DM.

Time zero analysis of plant-available N (Figure 1a, b, & c) suggests similar levels of ammonium-N across all sites and depths, variable nitrate-N availability with some accumulation at depth in the mid-aged rehabilitated site, similar amounts of potentially mineralisable N in the control and R3 sites, which were sown to pasture at the same time, and higher potentially mineralisable N particularly at 40-60cm depth in the two older rehabilitated sites (R2 and R3). There was more plant-available P (Figure 1d) in the two older rehabilitated soils compared with the more recently sown rehabilitated (R3) and control (C) sites. Colwell P levels (0-10 cm) in the oldest (R1) and mid-aged (R2) rehabilitated sites indicated that pasture was not likely to respond to P fertiliser.

Soil layers classed as „topsoil" by visual assessment in the field tended to include components of B horizon material in the control and benchmark sites where there was a gradational change in texture , and in the rehabilitated soils, where pre-existing O, A and B horizon material had been mixed to varying extents during the stripping and stockpile process. At T1, the mean (± standard error of the mean) depth to the subsoil horizon in the Control site (85 ± 24.3 cm ) was within the variability exhibited by the 18 benchmark sites (63 ± 28.6 cm) and deeper than the upper layer depths measured in the rehabilitated sites (Figure 2). Variation (expressed as the standard error or the mean) in depth of upper layers across the rehabilitated sites was fairly uniform (40 ± 21.4 cm, 50 ± 21.5 cm and 44 ± 21.3 cm at sites R1, R2 and R3 respectively). There was a similar rate of presence or absence of roots to 60 cm across the benchmark (78%) and rehab (80%, 63% and 77% at R1, R2 and R3 respectively) sites and a higher rate of 100% at the control site.

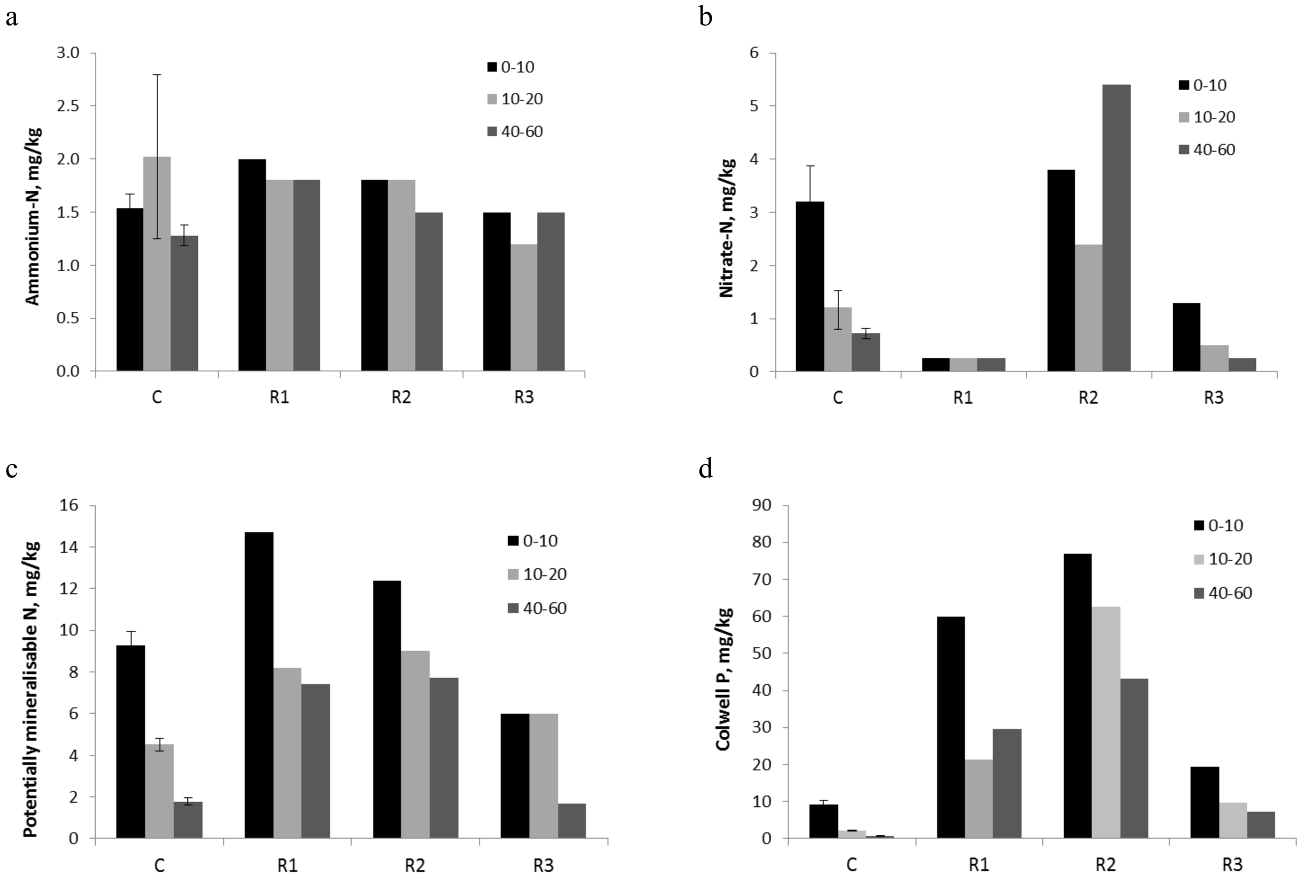


**Figure 1. Soil (a) ammonium-N, (b) nitrate-N, (c) potentially mineralisable N and (d) Colwell P (mg/kg) in the 0-10, 10-20 and 40-60 cm depth increments of samples collected in November and December 2013 that represent the rehabilitated (R1, R2, & R3) and Control (C) sites. Standard error of the mean presented as error bars for the control site. Data for the rehabilitated sites represented composite multi-core samples from a single subarea per site.**

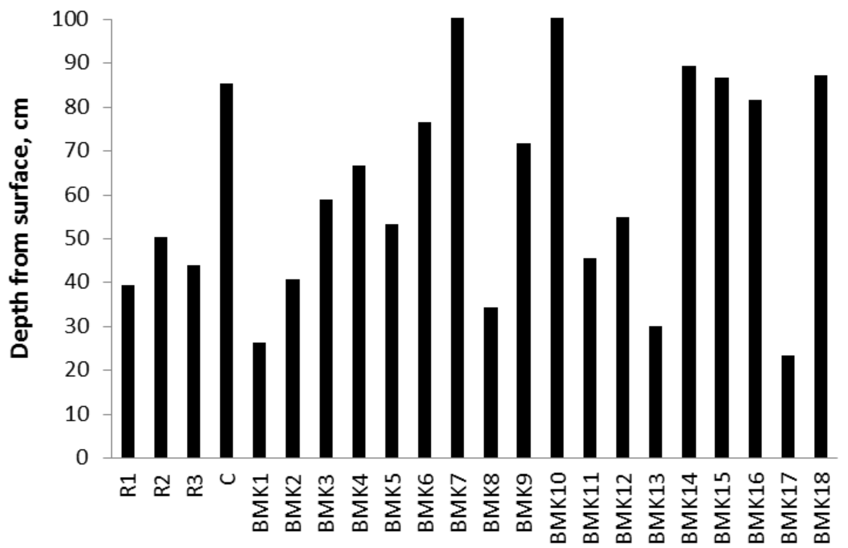


**Figure 2. Depth to subsoil horizon in the rehabilitated sites (R1, R2, R3), the control site (C) and at nearby benchmark grazing sites (BMK1-18).**

## Discussion

The similar amounts of potentially mineralisable nitrogen, and evidence for root exploration to at least 60 cm across all the sites suggests that grazing management was likely to have been more important in determining the large variation in biomass between the rehabilitated and Control sites at T0 than enhanced root exploration or enhanced mineralisation of soil organic N in the disturbed rehabilitated soils. However high plant-available P in R1 and R2 may have played a role in supporting production in these sites, as would enhanced root access and vigour in the more recently disturbed topsoil in the rehabilitated sites. Quantification of root vigour deserves further investigation in terms of the sustainability of soil conditions favourable for root exploration in these soils.

The mean depth to subsoil in all rehabilitated sites (40-50 cm) exceeded the target depth of 30 cm. Forty percent of the sampled cores displayed shallower topsoil profiles in the oldest rehabilitated site (R1) and only 12% and 16% of observed topsoil depths were shallower than 30 cm in the more recently rehabilitated sites (R2 and R3, respectively). The latter rate of shallow topsoil occurrence was similar to the rate of shallow topsoils occurring across the benchmark sites (15%). The presence of the mine spoil subsoil layer in the top 60 cm of the soil in the rehabilitated sites did not appear to present any more of a physical barrier to root exploration than was observed across the benchmark sites. Soil pit analysis will be used to observe variation in root activity and investigate relationships between root depth and vigour and associated nutrient and water availability. The large variation in depth to subsoil across the benchmark sites indicated that the control site was representative of surrounding un-mined grazed land. Analysis of soil classification features will further refine the estimates of depth to subsoil.

## Conclusion

Preliminary results suggest little difference, with the exception of higher plant-available P in two rehabilitated sites, in terms of benefits or constraints to pasture production between the rehabilitated and Control sites. To support these findings, differences in structural and nutrient supply and hydrological properties require analysis, including over time and between seasons. Furthermore, soil properties need to be investigated in relation to pasture composition, nutritional quality and biomass. These properties will be measured and issues addressed within the ongoing investigation.

## Acknowledgments

Our thanks are extended to Ben Muirhead and colleagues at the Acland Pastoral Company, and Ashlee Austin and Tom Newsome (Outcross Pty Ltd) for project funding and management, to Jeff Clewett (Agroclim Australia) for collaboration, to Ian Grant (Agricultural Chemistry Ltd) and Diogenes Antille (USQ) for technical advice and discussions, and to Tom Sheppard (New Hope Coal) for provision of background commercial in confidence information.

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**NAC Attachment 8 - OUTCROSS - Optimising Rehabilitated Grazing Pastures For Sustainable and Economically Viable Beef Production**

*Optimising Rehabilitated Grazing Pastures For Sustainable and Economically Viable Beef Production*

## Stage 2

## Report 1: Grazing Period 1 and 2

**Background**

The project is designed to measure the economic viability and sustainability of beef production on previously mined land at the New Acland coal mine.

Outcross Pty Ltd has been engaged by the New Hope Group through its wholly owned subsidiary, Acland Pastoral Company (APC). The role of Outcross is as the third party Project Manager. Expert consultants to the project have been engaged by Outcross to provide specialist advice relating to the project design, methodology, analysis, reporting and dissemination of information. The research group includes nationally recognised experts in their field.

**Table 1: Project Management Team**

| **Entity** | **Role** | **Contacts** |
|---|---|---|
| **Outcross Pty Ltd** | Project Management / Cattle | Tom Newsome |
| | Project Co-ordination | Ashlee Austin |
| **University of Southern Queensland** | Client Manager | Dr Craig Baillie |
| | Soil Scientist | Dr John Bennett |
| | Soil Scientist | Dr Alice Melland |
| | Technical Officer | Jochen Eberhard |
| **EcoRich Grazing** | Agronomy | Colin Paton |
| **Dr John Armstrong** | Veterinarian | |
| **Dr Peter O'Rourke** | Statistician | |

## Introduction

The Aim for the project is measuring the performance of rehabilitated land when compared to unmined land, based on commercial parameters for soil, pasture and beef cattle production. Given that the land is to be used predominately for beef cattle production, the project aims to compare the performance of a series of rehabilitated trial sites (n=3) and control sites (n=1), based on measuring commercially important key performance indicators (KPIs).

In addition the project will compare the performance of the rehabilitated sites with industry benchmarks and commercial production data collected by Acland Pastoral Company (APC) and industry.

This report addresses the cattle performance to date. The report should be read in conjunction with the following attached reports:

- Paton, Col: Optimizing rehabilitated grazing pastures for sustainable and economically viable beef production at New Acland mining site, Report 1
- Paton, Col: Optimizing rehabilitated grazing pastures for sustainable and economically viable beef production at New Acland mining site, Report 2
- Bennett, J *et al.* Assessing soil properties of rehabilitated coal mine soils for sustainable and economically viable beef production
- O'Rourke, P: New Hope grazing trial: cattle weight during first and second grazings

**Cattle Enterprise**

The enterprise chosen for the project is backgrounding steers and heifers to feedlot entry weight. This is consistent with common commercial land use for the area in the absence of mining.

This report details the methods and results of the first grazing period of the trial sites conducted from 23 January to 13 March, 2014 (G1) and the second grazing period from 17 April to 28 May, 2014 (G2).

**Trial Sites**

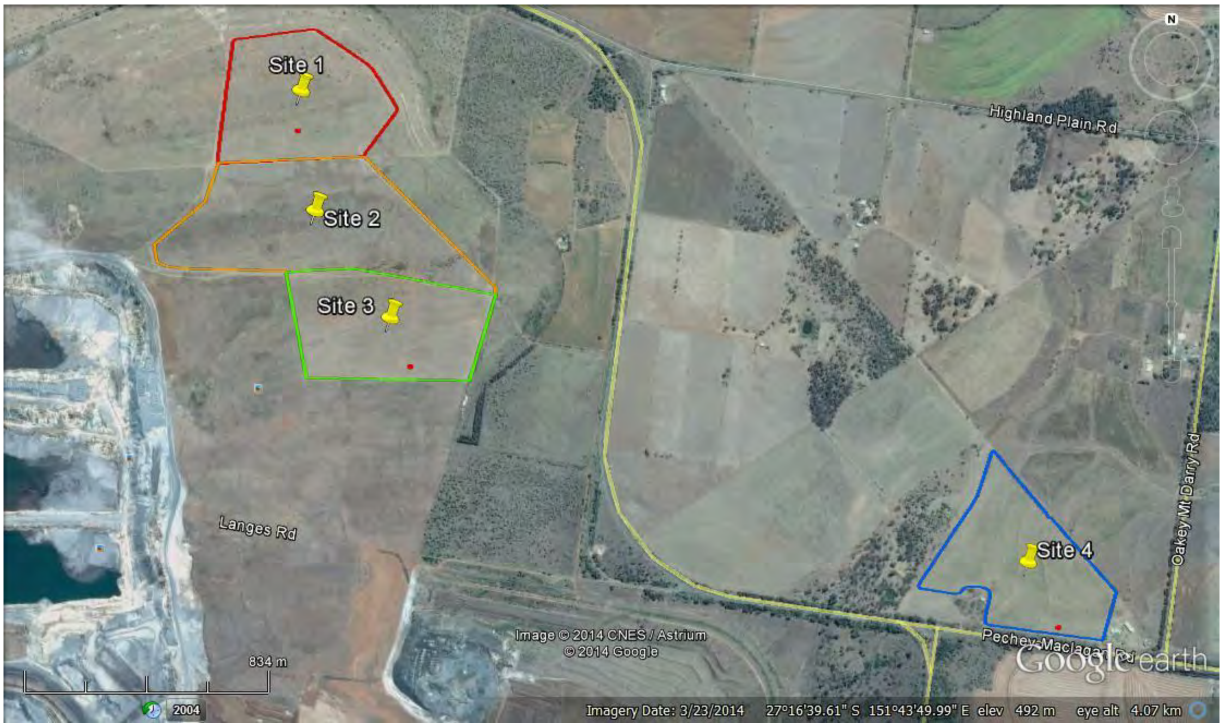



***Image 1: Project trials sites relative to mine***

Four sites were selected to be used in the grazing trial. Three of the sites were previously mined and subsequently rehabilitated and sown to sub-tropical pastures. Each rehabilitated site represents a different age of rehabilitation and pasture. Site 4 is unmined land selected to be used as the control site.

**Table 2: Description of sites**

| Site Name | Description |
|---|---|
| Site 1 | Site 1 is approximately 22ha in size and had been previously mined prior to being rehabilitated in 2007. Site 1 is the oldest of the rehabilitated sites and is located at (27°16’10.91”, 151°43’10.78”E). |
| Site 2 | Site 2 is approximately 32ha in size and had been previously mined prior to being rehabilitated in 2010. Site 2 is located at (27°16’24.31”S, 151°43’12.75”E) and is south of site 1, sharing the southern boundary fence of site 1. |
| Site 3 | Site 3 is approximately 22ha in size and had been previously mind prior to rehabilitation in 2012. Site 3 is the youngest of the rehabilitated sites and is located at (27°16’36.14”S, 151°43’22.19” and is south of site 2, sharing the southern boundary fence of site 2 |
| Site 4 | Site 4 is approximately 21ha and has not previously been mined, making it the control site of the trial. Site 4 is located at (27°17’2.98”S, 151°44’41.11”E). The pasture was sown in 2012, at the same time as site 3. |

**Rehabilitation Process**

The rehabilitation process was as follows:

1. Inter and over burden are dumped on the rehabilitation site until they reach a defined level
2. Topsoil that was removed from various locations was stockpiled on top of the dump site
3. Bulldozers are used to rip between topsoil stockpiles
4. Topsoil is spread by large bulldozers and levelled using small bulldozers, stick rakes, blades, rips, offsets, harrows and level bars to provide an even soil surface layer
5. Sub-tropical pastures are planted

**Pre Trial Land Preparation**

Prior to the first grazing period (December, 2013), sites 1, 2 and 3 were slashed to remove dead and unpalatable feed. Site 4 had been grazed heavily then given the same rest period as sites 1, 2 and 3 to allow adequate pasture growth and availability prior to cattle entering the sites.

## Selection of Cattle

The 180 cattle (90 steers, 90 heifers) in the grazing trial were selected on the basis that they were the same breed and bloodline; were a single year drop and were sourced from a single vendor.

On arrival to Acland Pastoral, the animals were grazed as a single cohort group on previously unmined land for 6 months and had the same treatment protocols.

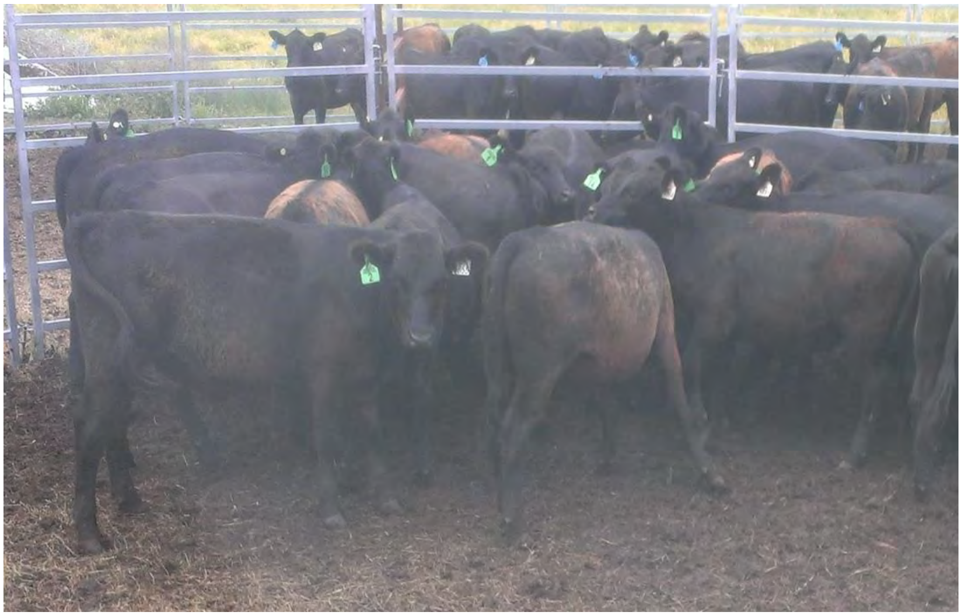


**Photo 1: Site 1 cattle at induction, 23 January, 2014**

We have described the important variables in table 3 below.

**Table 3: Description of variables**

| | |
|---|---|
| Breed | 100% Angus |
| Bloodline | Nindooinbah |
| Number steers | 90 |
| Number heifers | 90 |
| Total number | 180 |
| Year drop | 2013 |
| Trial start date | 23/01/2014 |

**Cattle Management Protocols**

**Treatment**

All cattle received the same treatment protocols, with the exception of animals affected by infectious bovine kerato-conjunctivitis (pink eye), which were treated individually where required.

We have listed the treatment protocols for all trial cattle in table 4 below:

**Table 4: Animal Health treatments (G1 and G2)**

| Date | Treatment | Issue Controlled | Dosage |
|---|---|---|---|
| 9/01/2014 | 5 in 1 Vaccine | Clostridium bacteria causing clostrial diseases tetanus, malignant oedema, enterotoxaemia, black disease and blackleg) | 2ml |
| 9/01/2014 | Anthelmentic Drench | Parasitic worms | |
| 17/04/2014 | Coopers Easy Dose | Buffallo Fly affecting performance through external irritation | 10ml /100kg |
| 17/04/2014 | Terramycin spray | Broad spectrum antibiotic for control of pink eye | Spray directly at eye for 2 seconds |

**Stocking Rate**

The stocking rate was determined by the following process.

1. The minimum number of head per site was set at 20 to be statistically significant.
2. The average body weight was calculated to be 288kg.
3. The number of adult equivalents (450Kg non lactating animal) was calculated to be 13 (20head *288kg/450kg)
4. The dry matter yield (DMY) per hectare was estimated using the Botanal process.
5. The total available dry matter was calculated by multiplying the DMY by the area of each site.
6. The percentage of unpalatable feed was estimated for each site.
7. The expected daily feed consumption, measured in kilograms dry matter per head (KgDM/head) was calculated on the expectation that an animal will consume 2.2% of its body weight per day. This equates to 10KgDM consumed daily per adult equivalent.
8. The available feed was calculated on the basis that 10% of available feed was to be consumed and that we assumed pasture growth of 2,000 and 1,500 KgDM during the grazing period for the rehabilitated and control sites respectively.
9. The number of grazing days was calculated by dividing the available feed by the daily

consumption.

10. The stocking rate was calculated by dividing the number of grazing days by the grazing length (49 days).
11. The stocking rate was calculated for sites 1,2,3,4 as 20, 40, 40, and 20 head respectively.

**Curfew**

All animals were weighed on a 2.5 hour dry curfew (no water available) period between mustering and start of weighing. The typical weighing time was between 2.5 and 3 hours.

Cattle were co-mingled between groups during weighing.

The scales were calibrated down to a 3kg variance for G1 and a 0.5 Kg variance for G2.

Scales were tared every 10 animals and the scale check weight was taken every 25 animals weighed.

**Allocation to treatment group**

We colour coded each group and also had sequential Visual ID for each tag in addition to the NLIS ID. The numbering system is shown in Table 5 below:

**Table 5: Tag Colour and Visual Identification Number by Group**

| Group | Tag Colour | VID (Steers) | VID (Heifers) |
|---|---|---|---|
| 1 | Green | 1 to 10 | 11 to 20 |
| 2 | Yellow | 151 to 170 | 171 to 190 |
| 3 | Red | 301 to 320 | 321 to 340 |
| 4 | Blue | 451 to 460 | 461 to 470 |

New Hope provided weights for the group showing a weight range of 230kg within the group. The maximum weight was 430kg and the minimum weight was 200kg. In order to eliminate outliers, we used a weight range for cattle to enter the trial of 250-350kg.

We used random allocation of animals to each treatment group within the specified weight range. As animals were weighed, we allocated them sequentially to each group in order from group 1 to group 4. As groups 2 and 3 had 40 head to be allocated and groups 1 and 4 had only 20 head to be allocated, we allocated the cattle in the following sequence:

1. Group 1
2. Group 2

3. Group 2
4. Group 3
5. Group 3
6. Group 4

In addition we had the added complication that we had a mix of steers and heifers to be allocated. We used the numbering sequence in table 4 to distinguish steers and heifers in each group.

Cattle that were outside the acceptable weight range were defined as ‘filler’ cattle. This group are grazed on the rest paddock and are added into trial groups when there is a need to increase the stocking rate to attain the benchmark 10% pasture utilisation.

**Induction and weighing**

Data collected on individual animals has been recorded using the *BeefLink* software provided by Outcross Pty Ltd. Weighing was completed on a full weight basis less curfew as described. The following data was recorded on each animal.

**Table 6: Cattle information recorded**

| Grazing Induction | | Grazing Exit |
|---|---|---|
| NLIS number | | Shrink adjusted weight |
| Visual ID | | G1 average daily weight gain |
| Breed | | Body condition score |
| Weight | | Operator |
| Sex | | Processing date |
| Tag Colour | | Time of weighing |
| Body condition score | | Paddock from |
| Treatment Group (Site) | | Paddock to |
| Paddock from | | |
| Paddock to | | |
| Fate | | |
| Operator | | |
| Processing date | | |
| Processing time | | |

**Key Performance Indicators (KPIs)**

We identified the following key performance indicators for cattle in the trial.

1. Average Daily Weight Gain (ADG): ADG is commonly used in the beef industry to measure the performance of individual cattle and to compare the performance of pasture sites.
2. Kilograms of beef produced per hectare: KgBeef/Ha is particularly useful for calculating the annual beef production from a site.

**Faecal Near Infrared Reflectance Spectroscopy (NIRS)**

Faecal NIRS is a process which estimates the quality of feed being consumed, from faecal samples taken from animals. The use of NIRS enables us to further inform the cattle performance results by showing the quality of what is actually consumed. This differs from the potential diet quality that is measured by the quality of the green leaf component of the pasture samples taken.

Faecal samples for G1 were taken directly from animals during the exit process. During G2 we modified our methodology to take NIRS samples in the middle of the grazing period to ensure samples were taken when feed was not limited. faecal NIRS samples were analysed by Symbio Alliance laboratory.

**Results and Discussion**

**Average Daily Gain**

Average daily gain from G1 and G2 is shown in table 7 below.

**Table 7: Average Daily gain by Stocking rate**

| Group | Area (Hectares) | No. Head | Stocking Rate / Ha | ADG G1 | No. Head | Stocking Rate / Ha | ADG G2 |
|---|---|---|---|---|---|---|---|
| 1 | 22 | 20 | 0.91 | 0.56 | 20 | 0.91 | 0.84 |
| 2 | 32 | 40 | 1.25 | 0.87 | 40 | 1.25 | 1.07 |
| 3 | 22 | 40 | 1.82 | 0.62 | 20 | 0.91 | 1.12 |
| 4 | 21 | 20 | 0.95 | 1.17 | 25 | 1.19 | 1.03 |
| **Total** | **97** | 120 | 1.24 | 0.78 | 105 | 1.08 | 1.02 |

**Grazing 1**

In grazing 1, O'Rourke found that graze site group was significant ($P<0.05$) for average daily gain. The control (Group 4) had the highest average daily gain. This was consistent between sex with both steers and heifers having significantly higher average daily gain than cattle grazing on the rehabilitation sites (groups 1,2,3).

Overall steers gained 7% more weight than heifers. The interaction of sex and grazing group was not significant, as expected.

There was a significant issue with respect to the stocking rate for Group 3. The size of the area was incorrectly estimated prior to allocation of animals. We have estimated that the subsequent utilisation rate was double site 4 at approximately 20%. As a result we cannot comment accurately with respect to the comparison of performance of site 3 and site 4 for G1.

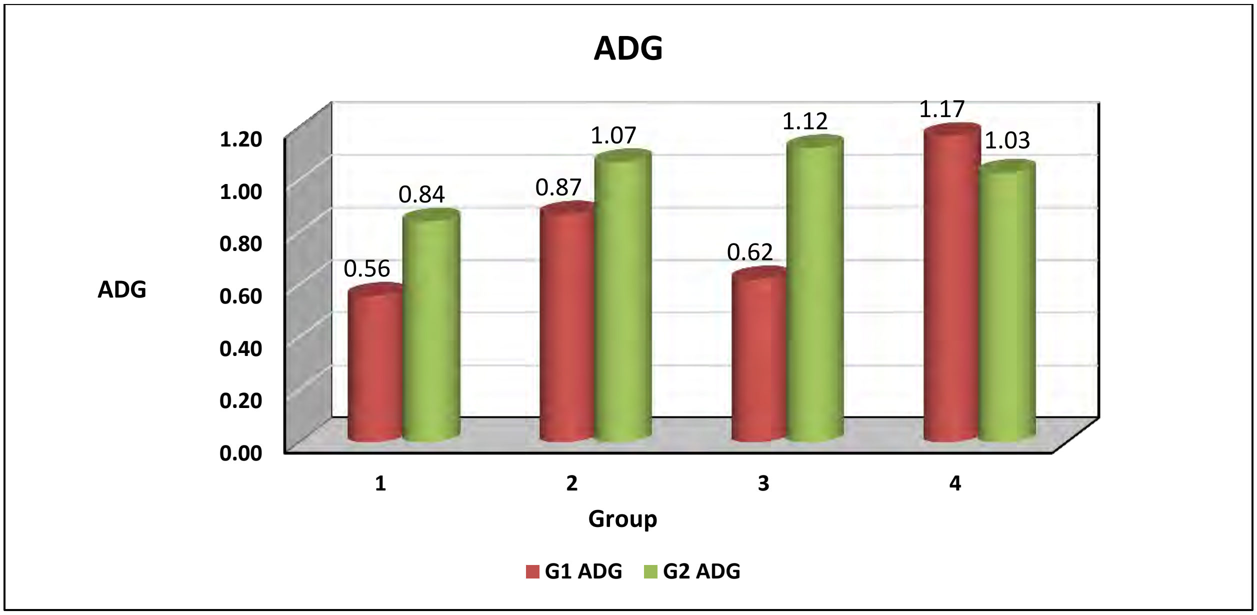



**Figure 1: Average daily weight gain by group- Grazing 1 and 2.**

**Grazing 2**

The performance of cattle on all rehabilitated sites improved in grazing 2. This was expected given good rainfall (126-140mm) during the rest period between grazings.

Site 1 improved by 50% in terms of ADG between grazings but remains the poorest performing site. This is expected as site 1 was the oldest site and pasture productivity is expected to deteriorate over time according to Paton's report of 16 April, 2014.

Site 2 has shown to be relatively productive in terms of both ADG (highest in G2) and gross beef production as shown in figure 2 below.

ADG on site 3 improved by 81% between G1 and G2. The large improvement can be attributed to adjustment made in stocking rate to correct the overgrazing that occurred in grazing 1. It is unlikely that there was significant compensatory gain as the cattle had been grazed in the rest paddock for 4 weeks between G1 and G2.

Site 4 was the only site to have a lower ADG in G2 than G1. This is most likely to be attributable to lower feed quality in G2 as the stage of pasture growth progressed from Phase 1 during G1, with young fresh leafy shoots, to Phases 2 and 3 in G2, with aging leaf, stem elongation and seed set. Site 4 dropped to 3rd highest ADG in G2.

**Kilograms Beef Produced**

The kilograms of beef produced will not be significantly affected by the overgrazing of site 3 in G1, as the increased number of head compensates for the lower average daily gain. However, in achieving the highest KgBeef/Ha, the cattle in site 3 have consumed more than 10% of available feed, which is considered optimal for both weight gain of grazing stock and subsequent pasture recovery when using a rotational grazing system for sub-tropical pastures.

We expected that the future results for site 3 would be relatively low compared to the result achieved in G1, due to lower stocking rates. Figure 2 shows that whilst the average daily gain in site 3 improved dramatically in grazing 2, the overall beef production fell by 28% from grazing 1 to 43 Kg Beef /Ha. Reduced pasture yield in site 3 restricted stocking rates and total beef production.

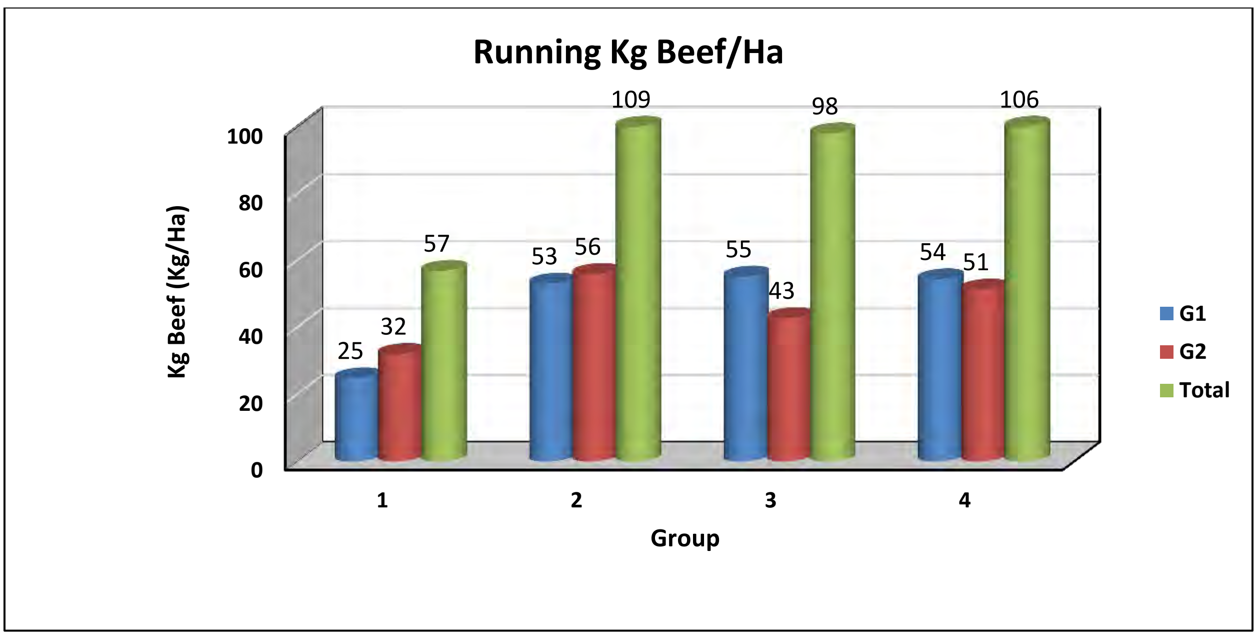



**Figure 2: Total beef production (KgBeef/Ha)**

## Interaction between Cattle, Pasture and NIRS Variables for G1

### Comparison between Cattle and Pasture KPIs

### Grazing 1

Table 8 displays the results for cattle and pasture quality for each site for grazing 1.

**Table 8: Cattle and Pasture KPIs- G1**

| | CATTLE | | | PASTURE | | | |
|---|---|---|---|---|---|---|---|
| **Site** | **Stocking Rate (Head / ha)** | **ADG (Kg/Day)** | **Kg Beef/Ha (Kg/Ha)** | **Yield (KgDM/Ha)** | **Protein (%)** | **ME (MJ/Kg )** | **Digestibility (%)** |
| **1** | 0.91 | 0.56 | 11 | 3310 | 7.7 | 8.1 | 61.6 |
| **2** | 1.25 | 0.87 | 25 | 5325 | 10 | 8.4 | 62.8 |
| **3** | 1.82 | 0.62 | 29 | 5000 | 9.7 | 8.4 | 62.8 |
| **4** | 0.95 | 1.17 | 26 | 1300 | 9.9 | 8.5 | 64.4 |

Site 1 recorded the lowest Average Daily Gain (ADG) of 0.56kg/day and the lowest kilograms of beef produced per hectare of 25kg. Whilst these results were the lowest of all the sites, site 1 also exhibited the lowest pasture quality results of all the sites with 7.7% protein, 8.1 MJ/Kg of metabolisable energy and 61.6% digestibility. Hence the cattle performed as expected due to the lower quality of the pasture available in site 1 which reflects the age of pasture since sowing.

Site 3 recorded the second lowest ADG of 0.62kg/day however, site 3 also recorded the second highest kilograms of beef produced per hectare of 29kg/ha. The pasture quality results were slightly higher in site 3 than site 1 with 9.7% Protein, 8.4 MJ/Kg of metabolisable energy and 62.8% digestibility. Given the higher quality of pasture available in site 3 the cattle did not perform as expected in regards to ADG. The lower weight gains observed in site 3 can be explained due to the inaccurate paddock area that was used to calculate the stocking rate for site 3. This inaccuracy resulted in site 3 being overstocked (1.82 head/Ha) which increased the amount of pasture utilised and reduced diet quality. This overstocking also explains the higher kilograms of beef produced per hectare observed in site 3, as there were a greater number of head per hectare than the other sites.

Site 2 recorded the second highest ADG of 0.87kg/day and comparable beef production per hectare to the control site of 25kg/ha. Site 2 also observed similar pasture quality results to site 3 with 8.4 MJ/Kg of metabolisable energy and 62.8% digestibility.

Site 4 (control) had the best performance for G1 with an ADG of 1.17 kg / day. This is reflected in underlying pasture quality with relatively high protein, metabolisable energy and digestibility.

### Grazing 2

Table 9 shows a summary of cattle performance relative to pasture quality in G2.

**Table 9: Cattle and Pasture KPIs- G2**

| | CATTLE | | | PASTURE | | | |
|---|---|---|---|---|---|---|---|
| **Site** | **Stocking Rate (Head / Ha)** | **ADG (Kg/Day)** | **Kg Beef/Ha (Kg/Ha)** | **Yield (KgDM/Ha)** | **Protein (% )** | **ME (MJ/Kg)** | **Digestibility (% )** |
| **1** | 0.91 | 0.84 | 32 | 4589 | 15.7 | 8.5 | 62.8 |
| **2** | 1.25 | 1.07 | 56 | 6562 | 19.9 | 8.9 | 64 |
| **3** | 0.91 | 1.12 | 43 | 3619 | 15.4 | 9.1 | 66.4 |
| **4** | 1.19 | 1.03 | 51 | 4632 | 14.9 | 8.7 | 62.9 |

The overall performance of livestock grazing rehabilitated sites in G2 was significantly higher than in G1. Site 4 (control) did not continue its high ranking performance from G1, being ranked 3$^{rd}$ for ADG and 2$^{nd}$ for beef production in G2. Site 4 was the only site to have a lower ADG in G2 than G1. This is reflective of reduced digestibility in site 4 although protein and metabolisable energy increased.

The relative performance of cattle grazing groups was significantly different in grazing 2. The sites were ranked in order for average daily gain (3,2,4,1) and for beef production (2,4,3,1).

Site 3 had the highest ADG. An accurate estimate of paddock area, which affected stocking rate calculations for G2, allowed a fair comparison of weight gains. However, the lower stocking rate due to lower pasture yields also affected the beef production in site 3. The ranking of site 3 for beef production fell from 1$^{st}$ to 3$^{rd}$ in G2. This result highlights the importance of considering both average daily gain and total beef production when considering the performance of each site.

Site 2 performed the best overall in G2, with the 2$^{nd}$ highest ADG and highest beef production. This reflects the underlying productivity of the pasture in site 2. Site 2 has the highest pasture yield and protein with relatively high metabolisable energy and digestibility. Therefore the cattle grazing site 2 have achieved a high level of individual performance while maintaining the highest stocking rate.

### Comparison between Cattle and NIRS KPIs

The NIRS results for G2 are summarised in Table 10 below. Sites 2 and 4 were the highest performing sites in G1 for average daily gain. This is reflected in the NIRS results for diet quality with sites 2 and 4 also having the highest crude protein, digestibility and metabolisable energy intake. The elevated crude protein levels of the best performing sites is reflected in lower dry matter digestibility to crude protein ratio (DMD:CP). NIRS Results for G2 are not yet available.

**Table 10 Faecal NIRS Results (G1)**

| | **Faecal NIRS** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Site** | **Forage crude protein %** | **Forage Digestibility** | **Faecal Nitrogen %** | **ME intake MJ/100kg LWT** | **ASH % Faeces** | **Diet Non grass %** | **P mg/kg by wet chem** | **DMD/ CP ratio** | **P/N Ratio** |
| **1** | 6.93 | 57.12 | 1.57 | 15.28 | 17.19 | 6.32 | 4981 | 8.24 | 0.45 |
| **2** | 8.29 | 59.20 | 1.71 | 17.28 | 16.03 | 8.28 | 1898 | 7.14 | 0.14 |
| **3** | 6.81 | 56.27 | 1.54 | 15.58 | 17.18 | 8.35 | 2411 | 8.26 | 0.22 |
| **4** | 8.22 | 58.75 | 1.54 | 17.05 | 18.31 | 0 | 2468 | 7.15 | 0.19 |

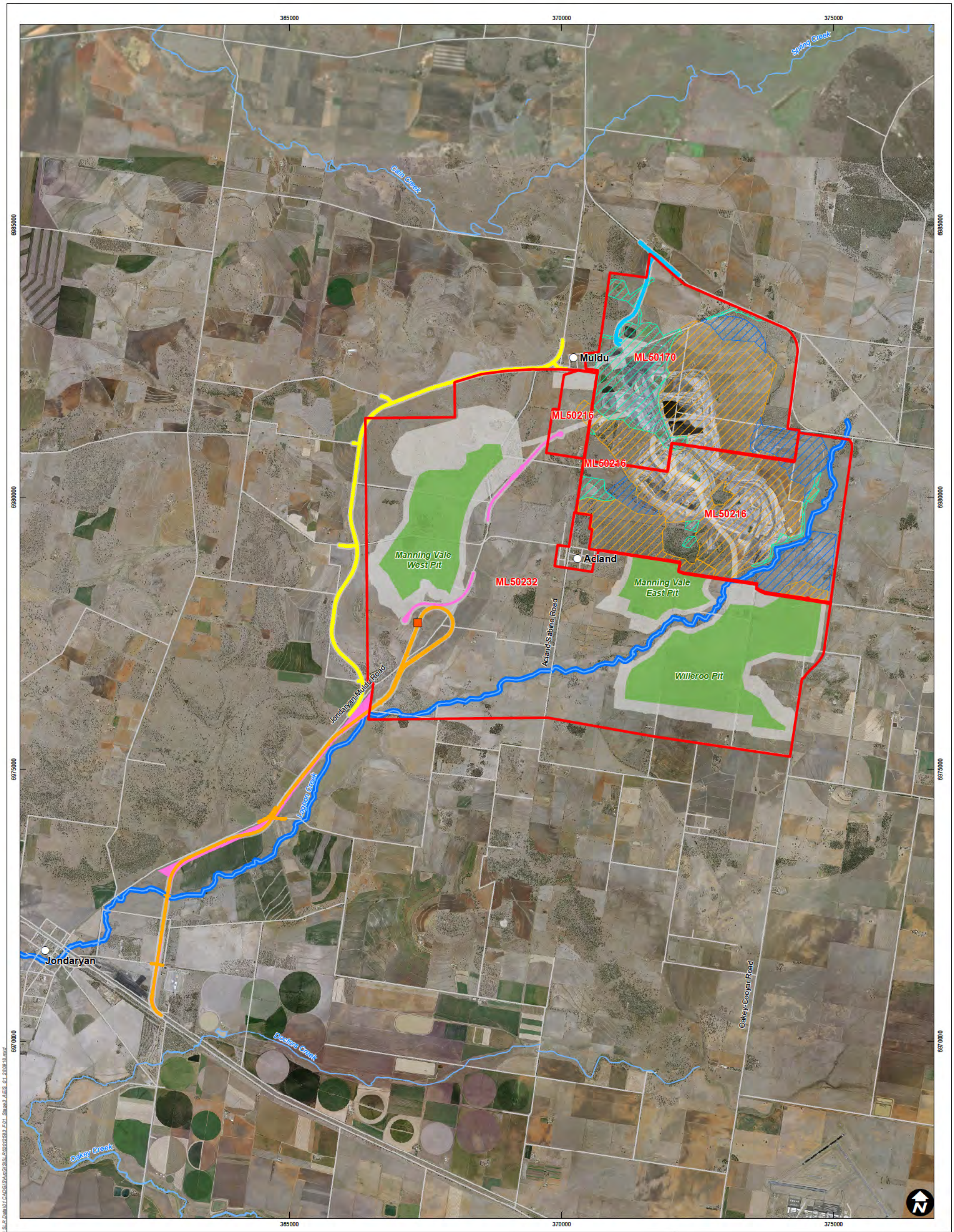
## Conclusion

Initial results indicate that the performance of livestock grazing sub-tropical pastures on rehabilitated land can be comparable to grazing equivalent pastures on unmined land.

Sites 3 and 4 are directly comparable in relation to pasture age since sowing, Site 3 being rehabilitated mined country and Site 4, unmined land. However, the comparison was initially compromised due to an error in estimating the area of Site 3. The area was overestimated for G1 which resulted in a higher utilisation rate of pastures, suppressed cattle weight gains per head and reduced condition and vigour of pastures. However, cattle weight gains in G2, and pasture quality from Site 3 just prior to G2, were higher than those from Site 4 (Table 7) indicating that rehabilitated land can be as productive as unmined land. Pastures in Site 3 were still recovering from overgrazing by G2 with reduced yields which affected cattle weight gains per hectare. A more fair comparison between these two paddocks should eventuate as Site 3 pasture recovers to better condition.

The performance of livestock on all sites has been good compared to industry benchmarks of 0.6kg per day. However, we need to consider that the grazing data to date has been collected during the growing season. While the initial results are positive for livestock performance, we will need to collect data through winter and spring before we are able to calculate annual beef production and ADG by site.

**NAC Attachment 9 - Figure showing MLA50232 and MLA700002**




LEGEND

- Towns and Localities
- Train Loadout Facility

Revised Rail & Road Infrastructure

- Internal Haulage Road
- Revised Access to Mine
- Revised Jondaryan-Muldu Road Diversion
- Revised Rail Spur and Balloon Loop Alignment
- Roads
- Creeks
- Mining Tenements
- Disturbance Footprint
- Stage 3 Pit Areas
- Infrastructure Mining Lease
- Watercourse Buffer

Disturbance Area - Stage 2

- Mining Areas
- Other Surface Infrastructure Areas
- Out of Pit Dumping Areas

NEW HOPE GROUP

**NEW ACLAND COAL MINE STAGE 3 PROJECT**

**Figure 1 - Revised Project Overview Indicative Only**

Scale: 1:65,000
Projection: AGD 1984 AMG Zone 56

**NAC Attachment 10 - Environmental Authority for the Project**

## Department of Environment and Science

# Permit[1]

***Environmental Protection Act 1994***

## Environmental authority EPML00335713 New Acland Coal Mine

*This environmental authority is issued by the administering authority under Chapter 5 of the Environmental Protection Act 1994.*

## Permit[1] number: EPML00335713

**Environmental authority takes effect upon grant of ML50232 and ML700002**

Anniversary Day: **27 May**

**Environmental authority holder(s)**

| Name | Registered address |
|---|---|
| New Acland Coal Pty Ltd | 3/22 Magnolia Drive<br>BROOKWATER QLD 4300 |

## Environmentally relevant activity and location details

| Environmentally relevant activity(ies) | Location(s) |
|---|---|
| ***Environmental Protection Regulation 2008 — Schedule 2***<br>ERA 31(2)(b) Mineral processing - processing, in a year, the following quantities of mineral products, other than coke - more than 100,000t<br>ERA 8(3) Chemical Storage — storing more than 500m$^3$ of chemicals of class C1 or C2 combustible liquids under AS 1940 or dangerous goods class 3 under subsection (1)(c)<br>ERA 60(1)(a) operating a facility for disposing of, in a year, the following quantity of waste mentioned in subsection (1)(a)(i) - less than 50,000t<br>ERA 63(1)(b) Sewage treatment — operating sewage treatment works, other than no-release works, with a total daily peak design capacity of - more than 100 but not more than 1500EP<br>***Environmental Protection Regulation 2008 — Schedule 2A***<br>ERA 13 Mining black coal | ML50170<br>ML50216<br>ML700002<br>ML50232 |

[1] Permit includes licences, approvals, permits, authorisations, certificates, sanctions or equivalent/similar as required by legislation

**Additional information for applicants**

<u>Environmentally relevant activities</u>

The description of any environmentally relevant activity (ERA) for which an environmental authority is issued is a restatement of the ERA as defined by legislation at the time the approval is issued. Where there is any inconsistency between that description of an ERA and the conditions stated by an environmental authority as to the scale, intensity or manner of carrying out an ERA, then the conditions prevail to the extent of the inconsistency.

An environmental authority authorises the carrying out of an ERA and does not authorise any environmental harm unless a condition stated by the authority specifically authorises environmental harm.

A person carrying out an ERA must also be a registered suitable operator under the *Environmental Protection Act 1994 (*EP Act).

<u>Contaminated land</u>

It is a requirement of the EP Act that if an owner or occupier of land becomes aware a notifiable activity (as defined in Schedule 3 and Schedule 4) is being carried out on the land, or that the land has been, or is being, contaminated by a hazardous contaminant, the owner or occupier must, within 22 business days after becoming so aware, give written notice to the chief executive.

| | |
|---|---|
| | 12 March 2019 |
| Signature | Date |

Wayne Boyd
Department of Environment and Science
Delegate of the administering authority
*Environmental Protection Act 1994*

**Enquiries:**
Business Centre (Coal)
Department of Environment and Science
PO Box 3028
EMERALD QLD 4720
Phone: (07) 4987 9320
Email: CRMining@des.qld.gov.au

**Obligations under the *Environmental Protection Act 1994***

In addition to the requirements found in the conditions of this environmental authority, the holder must also meet their obligations under the EP Act, and the regulations made under the EP Act. For example, the holder must comply with the following provisions of the EP Act:

- general environmental duty (section 319);
- duty to notify environmental harm (section 320-320G);
- offence of causing serious or material environmental harm (sections 437-439);
- offence of causing environmental nuisance (section 440);
- offence of depositing prescribed water contaminants in waters and related matters (section 440ZG); and
- offence to place contaminant where environmental harm or nuisance may be caused (section 443).

**Location:** New Acland Coal Mine

Muldu Road, ACLAND QLD 4401

**Schedules:**

Agency interest A General

Agency interest B Air

Agency interest C Water

Agency interest D Groundwater

Agency interest E Waste

Agency interest F Noise

Agency interest G Sewage Treatment

Agency interest H Land and Rehabilitation

Agency interest I Biodiversity

Agency interest J Regulated Structures

Agency interest K Rail Infrastructure

Agency interest L Light

Agency interest M Community

Agency interest Figures

**Conditions of environmental authority**

| Agency interest: General | |
|---|---|
| **Condition number** | **Condition** |
| **A1** | This environmental authority authorises environmental harm referred to in the conditions. Where there is no condition or this environmental authority is silent on a matter, the lack of a condition or silence does not authorise environmental harm. |
| **A2** | In carrying out the mining activity authorised by this environmental authority, the holder of this environmental authority must comply with **Figure 1 (Revised Project Overview — Mine Area)**. |
| **A3** | The holder of the environmental authority must implement the Environmental Management Plan New Acland Coal Mine Stage 3 project dated June 2015. This document should be made available to the administering authority upon request. |
| **A4** | **Maintenance of measures, plant and equipment**<br>The holder of this environmental authority must:<br>a) install all measures, plant and equipment necessary to ensure compliance with the conditions of this environmental authority;<br>b) maintain such measures, plant and equipment in a proper and efficient condition;<br>c) operate such measures, plant and equipment in a proper and efficient manner; and<br>d) ensure all instruments and devices used for the measurement or monitoring of any parameter under any condition of this environmental authority are properly calibrated. |
| **A5** | **Monitoring**<br>Except where specified otherwise in another condition of this environmental authority, all monitoring records or reports required by this environmental authority must be kept for a period of **not less than 5 years.** |
| **A6** | Upon request from the administering authority, copies of monitoring records and reports will be made available and provided to the administering authority's nominated office within 10 business days or an alternative timeframe agreed between the administering authority and the holder. |
| **A7** | Any management or monitoring plans, systems or programs required to be developed and implemented by a condition of this environmental authority should be reviewed for effectiveness in minimising the likelihood of environmental harm on an annual basis, and amended promptly if required, unless a particular review date and amendment program is specified in the plan, system or program. |
| **A8** | **Financial assurance**<br>The activity must not be carried out until the environmental authority holder has given financial assurance to the administering authority as security for compliance with this environmental authority and any costs or expenses, or likely costs or expenses, mentioned in section 298 of the *Environmental Protection Act 1994.* |
| **A9** | The amount of financial assurance must be reviewed by the holder of this environmental authority when a plan of operations is amended or replaced or the environmental authority is amended. |

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| **A10** | **Risk management**<br>The holder of this environmental authority must develop and implement a risk management system for mining activities which mirrors the content requirement of the Standards Australia Risk management — Principles and guidelines (AS/NZS ISO 31000:2009), or the latest edition of a Standards Australia for risk management, to the extent relevant to environmental management, prior to the commencement of mining activities. |
| **A11** | **Third-party reporting**<br>The holder of this environmental authority must:<br>a) **within 1 year** of the commencement of this environmental authority, obtain from an appropriately qualified person a report on compliance with the conditions of this environmental authority;<br>b) obtain further such reports at regular intervals, **not exceeding 3 yearly** intervals, from the completion of the report referred to above; and<br>c) provide each report to the administering authority **within 90 days** of its completion. |
| **A12** | Where a condition of this environmental authority requires compliance with a standard, policy or guideline and the standard is amended or changed subsequent to the issue of this environmental authority, the holder of this environmental authority must:<br>a) comply with the amended or changed standard, policy or guideline **within 2 years** of the amendment or change being made, unless a different period is specified in the amended standard or relevant legislation, or where the amendment or change relates specifically to regulated structures referred to in conditions **J1 to J33**, the time specified in that condition; and<br>b) until compliance with the amended or changed standard, policy or guideline is achieved, continue to remain in compliance with the corresponding provision that was current immediately prior to the relevant amendment or change. |
| **A13** | **Project milestone commencement dates**<br>The environmental authority holder must notify the administering authority as a nominated entity in accordance with Imposed Condition 2, contained within Appendix 1 of the 'New Acland Coal Mine Stage 3 project Coordinator-General's evaluation report on the environmental impact statement dated December 2014' (the CG's report). |
| **A14** | **Environmental monitoring reports**<br>The environmental authority holder must provide the environmental monitoring reports required by Imposed Condition 3 in Appendix 1 of the CG's report to the administering authority each month. |

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| **A15** | **Storage and handling of flammable and combustible liquids**<br>Spillage of all chemicals and fuels must be contained within an on-site containment system and controlled in a manner that prevents environmental harm (other than trivial harm) and maintained in accordance with Section 5.9 of AS1940 - Storage and Handling of Flammable and Combustible Liquids of 2004 (or more recent editions). |

| **Agency interest: Air** | |
|---|---|
| **Condition number** | **Condition** |
| **B1** | The environmental authority holder must ensure that dust and particulate matter emissions generated by the mining activities do not cause exceedances of the following levels when measured at any sensitive place or commercial place:<br>a) Dust deposition of 120 milligrams per square metre per day, averaged over 1 month, when monitored in accordance with the most recent version of Standards Australia AS/NZS 3580.10.1 Methods for sampling and analysis of ambient air - Determination of particulate matter - Deposited matter - Gravimetric method;<br>b) A concentration of particulate matter with an aerodynamic diameter of less than 10 micrometres ($PM_{10}$) suspended in the atmosphere of 50 micrograms per cubic metre over a 24-hour averaging time[1] and 25 micrograms per cubic metre over a 1 year averaging time, for no more than 5 exceedances recorded per year[2], when monitored in accordance with the most recent version of either:<br>(1) Standards Australia AS/NZS 3580.9.6 Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - $PM_{10}$ high volume sampler with size-selective inlet - Gravimetric method; or<br>(2) Standards Australia AS/NZS 3580.9.9 Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - $PM_{10}$ low volume sampler - Gravimetric method; or<br>(3) Standards Australia AS 3580.9.8 Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - $PM_{10}$ continuous direct mass method using a tapered element oscillating microbalance analyser;<br>c) A concentration of particulate matter suspended in the atmosphere of 80 micrograms per cubic metre over a 24-hour averaging time and 90 micrograms per cubic metre over a 1 year averaging time, when monitored in accordance with the most recent version of AS/NZS3580.9.3:2003 Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - Total suspended particulate matter (TSP) - High volume sampler gravimetric method.<br>d) A concentration of particulate matter with an aerodynamic diameter of less than 2.5 micrometres ($PM_{2.5}$) suspended in the atmosphere of 25 micrograms per cubic metre over a 24-hour averaging time[1] and 8 micrograms per cubic metre over a 1 year averaging time[1], when monitored in accordance with:<br>(1) the most recent version of Standards Australia AS/NZS 3580.9.12 Methods for sampling and analysis of ambient air - Determination of suspended particulate matter – $PM_{2.5}$ beta attenuation monitors; or<br>(2) the most recent version of Standards Australia AS/NZS 3580.9.13:2013 Determination of suspended particulate matter – $PM_{2.5}$ continuous direct mass method using a tapered element oscillating microbalance monitor, or |

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| | (3) another method as agreed to in writing by the administering authority.<br><br>*[1] These limits are based upon relevant air quality objectives contained in the Environmental Protection (Air) Policy 2008 and may be automatically amended to reflect any amendment or replacement of the relevant air quality objective in the Environmental Protection (Air) Policy 2008.*<br><br>*[2] The five exceedance allowed each year within* ***Condition B1(b)*** *are only permitted to allow for events that are known to occur, but which cannot be managed by the environmental authority holder. Such events could include emissions from bushfires, fuel reduction burning for fire management purposes, or dust storms. All exceedance due to such events would not be considered to be in breach of* ***Condition B1(b)*** *if the environmental authority holder can demonstrate that the exceedance was not generated by mining activities.* |
| **B2** | If monitoring indicates the potential for exceedance of the relevant limits in **Condition B1** then the environmental authority holder must immediately implement dust abatement measures to avoid exceeding the relevant limits. |
| **B3** | **Air emissions management**<br><br>An Air Emissions Management Plan must be developed by a suitably qualified and experienced person in relation to air emmissions and implemented for all stages of mining. The Air Emissions Management Plan must be submitted to the administering authority for review and comment **within 3 months upon the grant of ML50232 and ML700002**, and at intervals **not exceeding two (2) years thereafter.** |
| **B4** | **Air emissions management**<br><br>The Air Emissions Management Plan must incorporate a program for continuous improvements for the management of dust resulting from mining operations with respect to, but not limited to:<br><br>a) The collection of air quality and meteorological data in accordance with **Table B1: Air quality monitoring requirements**;<br>b) $PM_{10}$ trend monitoring[1], including 3 locations located to the north-west, north and east of the site, for a minimum period of **3 years**;<br>c) A trigger action response plan that requires the environmental authority holder to investigate, mitigate and manage TSP caused by mining activities at any sensitive place or commercial place when monitoring indicates exceedance of 80 micrograms per cubic metre over a 24-hour averaging time;<br>d) A forecasting system that provides daily predictions of upcoming meteorological conditions in order to identify adverse meteorological conditions likely to produce elevated levels of dust including $PM_{10}$ at a sensitive place or commercial place due to the mining activities;<br>e) A dust control strategy which activates a timely implementation of dust control management actions aimed to avoid or minimise elevated levels of dust including $PM_{10}$ at a sensitive place or commercial place due to mining activities;<br>f) Annual review of the Air Emissions Management Plan including its adequacy and effectiveness in avoiding and minimising air emissions and dust at a sensitive place or commercial place; and<br>g) A protocol and register for the recording of requests and installation of first flush diverter systems as required by **Condition B8**. |

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| | [1] *Trend monitoring as required by **Condition B4(b)** can be undertaken using different instruments and methods from those specified in **Table B1: Air quality monitoring requirements**.* |
| **B5** | Within **twenty (20) business days** of receiving comments from the administering authority as required by **Condition B3**, the Air Emissions Management Plan must be updated by a suitably qualified and experienced person in relation to air emmissions having regard to the comments, and submitted to the administering authority. |
| **B6** | The monitoring locations listed in **Table B1: Air quality monitoring requirements** must be reviewed by a suitably qualified and experienced person(s) in relation to air emmissions and a report must be provided to the administering authority within **two (2) years within 3 months upon grant of ML50232 and ML700002**, and at intervals not exceeding **two (2) years** thereafter. The review must include:<br>a) The effectiveness of the monitoring network;<br>b) The frequency and cause of any exceedances of air quality objectives measured by the monitoring program over a period of at least **two (2) years**;<br>c) Dust complaints;<br>d) Future progression of the mining activities;<br>e) Locations of sensitive receptors relative to the mining activities; and<br>f) Mining operating modes. |
| **B7** | All continuously monitored parameters required by **Table B1: Air quality monitoring requirements** and the forecasting system required by **Condition B4** must be made publically available online and in real-time. |

Table B1: Air quality monitoring requirements

| Monitoring location* | Air quality indicator | Instrument | Frequency | Air quality limit | Nuisance limit | Monitoring method |
|---|---|---|---|---|---|---|
| 1,2 (Acland) | $PM_{2.5}$ | BAM or TEOM | Continuous | 25µg/m³ (24 hr avg)<br>8µg/m³ (annual) | | AS3580.9.12-2013<br>AS3580.9.13-2013 |
| | $PM_{10}$ | TEOM | Continuous | 50µg/m³ (24 hr avg)<br>25µg/m³ (annual) | | AS 3580.9.8-2008 |
| | TSP | Hi-Vol Sampler^ | 24hr, 1 day in 6 | 90µg/m³ (annual) | 80µg/m³ (24 hr avg) | AS/NZS 3580.9.3:2003 |
| | TSP#^ | Modified TEOM#,^ | Continuous | 90µg/m³ (annual) | 80µg/m³ (24 hr avg) | Modified TEOM |
| | Insoluble solids | Dust gauge | Monthly | | 120mg/m² /day | AS/NZS 3850.10.1:2003 |
| | Wind speed and direction | | Hourly | | | AS 3580:14-2011 |
| 7, 8 (or an alternative location to the north of the Stage 3 New Acland mine identified in the Air Emissions Management Plan developed pursuant to condition B3). | $PM_{10}$ | TEOM | Continuous | 50µg/m³ (24 hr avg)<br>25µg/m³ (annual) | | AS 3580.9.8-2008 |
| | TSP | Hi-Vol Sampler^ | 24hr, 1 day in 6 | 90µg/m³ (annual) | 80µg/m³ (24 hr avg) | AS/NZS 3580.9.3:2003 |
| | Insoluble solids | Dust gauge | Monthly | 120mg/m²/day | 120mg/m²/day | AS/NZS 3850.10.1:2003 |
| 38, 39 (or an alternative location to the north-west of the Stage 3 New Acland mine identified in the Air Emissions Management Plan developed | $PM_{10}$ | TEOM | Continuous | 50µg/m³ (24 hr avg)<br>25µg/m³ (annual) | | AS 3580.9.8-2008 |
| | TSP | Hi-Vol Sampler^ | 24hr, 1 day in 6 | 90µg/m³ (annual) | 80µg/m³ (24 hr avg) | AS/NZS 3580.9.3:2003 |
| | Insoluble solids | Dust gauge | Monthly | 120mg/m² /day | 120mg/m² /day | AS/NZS 3850.10.1:2003 |

| Monitoring location* | Air quality indicator | Instrument | Frequency | Air quality limit | Nuisance limit | Monitoring method |
|---|---|---|---|---|---|---|
| pursuant to condition B3). | | | | | | |
| A location within 1 kilometre of the southern boundary of ML50232 | $PM_{10}$ | TEOM | Continuous | 50µg/m³ (24 hr avg) 25µg/m³ (annual) | | AS 3580.9.8-2008 |
| | TSP | Hi-Vol Sampler^ | 24hr, 1 day in 6 | 90µg/m³ (annual) | 80µg/m³ (24 hr avg) | AS/NZS 3580.9.3:2003 |
| | Insoluble solids | Dust gauge | Monthly | 120mg/m² /day | 120mg/m² /day | AS/NZS 3850.10.1:2003 |
| 35,36 (west of mine site) | $PM_{10}$ | TEOM | Continuous | 50µg/m³ (24 hr avg) 25µg/m³ (annual) | | AS/NZS 3580.9.8-2008 |
| | TSP | Hi-Vol Sampler^ | 24hr, 1 day in 6 | 90µg/m³ (annual) | 80µg/m³ (24 hr avg) | AS/NZS 3580.9.3:2003 |
| | Insoluble solids | Dust gauge | Monthly | 120mg/m²/ day | 120mg/m²/ day | AS/NZS 3850.10.1:2003 |
| Acland-Silverleigh Road (East,at site on Fig 6 where real time $PM_{10}$ and dust deposition is monitored) | $PM_{10}$ | TEOM | Continuous | 50µg/m³ (24 hr avg) 25µg/m³ (annual) | | AS/NZS 3580.9.8-2008 |
| | TSP | Hi-Vol Sampler^ | 24hr, 1 day in 6 | 90µg/m³ (annual) | 80µg/m³ (24 hr avg) | AS/NZS 3580.9.3:2003 |
| | Insoluble solids | Dust gauge | Monthly | 120mg/m²/ day | 120mg/m²/day | AS/NZS 3850.10.1:2003 |
| As per figure 6 | Insoluble solids | Dust gauge | Monthly | 120mg/m²/ day | 120mg/m²/day | AS/NZS 3850.10.1:2003 |
| Siting of monitoring equipment | | | | | | AS/NZS 3580.1.1:2007 |

**See Figures 5 and 6*
*# Data from the modified TEOM and Hi-Vol samplers to be used to calibrate the modified TEOM for monitoring TSP. Calibration needs to be undertaken over at least a 6 month period from June to December. Once the modified TEOM has been calibrated it can be used to measure TSP instead of the Hi-Vol sampler.*
*^ The modified TEOM can be used to measure TSP at other sites.*

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| **B8** | The environmental authority holder must provide and install "first flush" **systems within three (3) months** of request at those residences, within 5 km of the mine boundary, asking for the systems. |
| **B9** | **Odour Nuisance**<br>Subject to **Conditions M2 and B10**, the release of noxious or offensive odour(s) or any other noxious or offensive airborne contaminant(s) resulting from the mining activity must not cause an environmental nuisance at any sensitive place or commercial place. |
| **B10** | When requested by the administering authority, odour monitoring must be undertaken within a reasonable and practicable timeframe nominated by the administering authority to investigate any complaint (which is neither frivolous nor vexatious nor based on mistaken belief in the opinion of the authorised officer) of environmental nuisance at any sensitive place or commercial place, and the results must be notified within **fourteen (14) days** to the administering authority following completion of monitoring. |
| **B11** | If monitoring indicates **Condition B9** is not being met then the environmental authority holder must:<br>a) address the complaint including the use of appropriate dispute resolution if required; or<br>b) immediately implement odour abatement measures so that emissions of odour from the activity do not result in further environmental nuisance. |

| **Agency interest: Water** | |
|---|---|
| **Condition number** | **Condition** |
| **C1** | Contaminants that will, or have the potential to, cause environmental harm must not be released directly or indirectly to any waters as a result of the authorised mining activities, except as permitted under the conditions of this environmental authority. |
| **C2** | Unless otherwise permitted under the conditions of this environmental authority, the release of mine affected water to waters must only occur from the release points specified in **Table C1: Mine affected water release points, sources and receiving waters** and depicted **in Figure 2: Mine affected water release points, sources and receiving waters monitoring locations** attached to this environmental authority. |

**Table C1: Mine-affected water release points, sources and receiving waters**

| Release Point (RP) | Latitude (decimal degree, GDA94) | Longitude (decimal degree, GDA94) | Mine-affected water source and location | Monitoring Point | Receiving waters description |
|---|---|---|---|---|---|
| ED1 | 27° 15' 40.5603" S | 151° 41' 48.32659" E | ED1 | Overflow from ED1 | Spring Creek |
| ED2 | 27° 16' 54.96167" S | 151° 41' 36.83113" E | ED2 | Overflow from ED2 | Lagoon Creek |
| ED3 | 27° 18' 29.40913" S | 151° 42' 50.52694" E | ED3 | Overflow from ED3 | Lagoon Creek |
| ED4 | 27° 17' 41.49436" S | 151° 41' 33.60156" E | ED4 | Overflow from ED4 | Lagoon Creek |
| ED5 | TBA | TBA | ED5 | Overflow from ED5 | Lagoon Creek |
| ED6 | TBA | TBA | ED6 | Overflow from ED6 | Lagoon Creek |
| ED7 | TBA | TBA | ED7 | Overflow from ED7 | Lagoon Creek |

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| **C3** | The release of mine affected water to waters in accordance with **Condition C2** must not exceed the release limits stated in **Table C2: Mine-affected water release limits** when measured at the monitoring points specified in **Table C1: Mine-affected water release points, sources and receiving waters** for each quality characteristic. |

**Table C2: Mine-affected water release limits**

| Quality characteristic | Release limits | Monitoring frequency |
|---|---|---|
| Electrical conductivity (μS/cm) | Release limits specified in **Table C3** for variable flow criteria | Real time telemetry for EC and pH. Daily grab samples if telemetry not available<br>If telemetry is unavailable, the first sample must be taken within 2 hours of commencement of release |
| pH (pH Unit) | 6.0 (minimum)<br>9.0 (maximum) | |
| Total suspended solids (mg/L) | 100 | Daily during release (the first sample must be taken within 2 hours of commencement of release) |

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| **C4** | The release of mine affected water to waters from the release points must be monitored at the locations specified in **Table C1: Mine-affected water release points, sources and receiving waters** for each quality characteristic and at the frequency specified in **Table C2: Mine-affected water release limits**. |

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| **C5** | **Mine-affected water release events**<br>The holder must ensure a stream flow gauging station(s) is installed, operated and maintained to determine and record stream flows in Lagoon and Spring Creek upstream of the discharge sites. |
| **C6** | Notwithstanding any other condition of this environmental authority, the release of mine affected water to waters in accordance with **Condition C2** must only take place during periods of natural flow in accordance with the receiving water flow criteria for discharge specified in **Table C2: Mine-affected water release limits** for the release point(s) specified in **Table C1: Mine-affected water release points, sources and receiving waters**. |
| **C7** | The release of mine affected water to waters in accordance with **Condition C6** must not exceed the Maximum Release Rate (for all combined release point flows) for each receiving water flow criterion for discharge specified in **Table C3: Mine-affected water release during flow events** when measured at the monitoring points specified in **Table C1: Mine-affected water release points, sources and receiving waters**. |
| **C8** | The daily quantity of mine affected water released from each release point must be measured and recorded. |
| **C9** | Release to waters must be undertaken so not as to cause erosion of the bed and banks of the receiving waters or cause material build-up of sediment in such waters. |
| **C10** | **Notification of release event**<br>The environmental authority holder must notify the administering authority as soon as practicable and **no later than 24 hours after commencing** to release mine affected water to the receiving environment. Notification must include the submission of written advice to the administering authority of the following information:<br>a) release commencement date and time;<br>b) details regarding the compliance of the release with the conditions of Agency Interest: Water of this environmental authority (that is, contaminant limits, natural flow, discharge volume);<br>c) release point(s);<br>d) release rate;<br>e) release salinity; and<br>f) receiving water(s) including the natural flow rate.<br>NOTE: Notification to the administering authority must be made via the Pollution Hotline, (or WaTERS where applicable) or its successor. |

**Table C3: Mine-affected water release during flow events**

| Receiving waters/ stream | Release Point (RP) | Gauging Station Latitude (GDA94) | Gauging Station Longitude (GDA94) | Receiving Water Flow Criteria for discharge (m3/s) | Maximum release rate (for all combined RP flows) | Electrical Conductivity Release Limits |
|---|---|---|---|---|---|---|
| Lagoon Creek | ED2<br>ED3 | 27° 16' 54.96167" S<br>27° 18' 29.40913" S | 151° 41' 36.83113" E<br>151' 42' 50.52694" E | Low Flow<br><46.3 L/sec for a period of 28 days after natural flow events that exceed 4 ML/d | <17.4 L/sec | 700 |
| | ED4 | 27° 17' 41.49436" S | 151° 41' 33.60156" E | Medium Flow (low)<br>> 46.3 L/sec | <17.4 L/sec | 1500 |
| | ED5 | TBA | TBA | | < 8 L/sec | 2,500 |
| | ED6 | TBA | TBA | | < 5.8 L/sec | 3,500 |
| | ED7 | TBA | TBA | Medium Flow<br>(high)<br>> 133 L/sec | < 48.6 L/sec | 1500 |
| | | | | | < 23 L/sec | 2,500 |
| | | | | | < 15 L/sec | 3,500 |
| | | | | High Flow<br>>405 L/sec | < 144.7 L/sec | 1500 |
| | | | | | < 92.6 L/sec | 2,500 |
| | | | | | < 69.4 L/sec | 3,500 |
| Spring Creek | ED1 | 27° 15' 40.5603" S | 151° 41' 48.32659" E | Low Flow<br>< 46.3 L/sec for a period of 28 days after natural flow events that exceed 46.3 L/sec | < 17.4 L/sec | 700 |

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| **C11** | The environmental authority holder must notify the administering authority as soon as practicable and nominally **no later than 24 hours after cessation** of a release event of the cessation of a release notified under **Condition C10** and **within 28 days** provide the following information in writing:<br>a) release cessation date and time;<br>b) natural flow rate in receiving water;<br>c) volume of water released;<br>d) details regarding the compliance of the release with the conditions of Agency Interest: Water of this environmental authority (i.e. contaminant limits, natural flow, discharge volume);<br>e) all in-situ water quality monitoring results; and<br>f) any other matters pertinent to the water release event.<br>NOTE: Successive or intermittent releases occurring within **24 hours of the cessation** of any individual release can be considered part of a single release event and do not require individual notification for the purpose of compliance with **Conditions C10 and C11**, provided the relevant details of the release are included within the notification provided in accordance with **Conditions C10 and C11**. |
| **C12** | If the release limits defined in **Table C2: Mine-affected water release limits** are exceeded, the holder of the environmental authority must notify the administering authority within 24 hours of receiving the results. |
| **C13** | The environmental authority holder must, **within 28 days of a release** that is not compliant with the conditions of this environmental authority, provide a report to the administering authority detailing:<br>a) the reason for the release;<br>b) the location of the release;<br>c) the total volume of the release and which (if any) part of this volume was non-compliant;<br>d) the total duration of the release and which (if any) part of this period was non-compliant;<br>e) all water quality monitoring results (including all laboratory analyses);<br>f) identification of any environmental harm as a result of the non-compliance;<br>g) all calculations; and<br>h) any other matters pertinent to the water release event. |
| **C14** | **Receiving Environment Monitoring and Contaminant Trigger Levels**<br>The quality of the receiving waters must be monitored at the locations specified in **Table C5: Receiving water upstream background sites and downstream monitoring points** for each quality characteristic and at the monitoring frequency stated in **Table C4: Receiving waters contaminant trigger levels**. |

**Table C4: Receiving waters contaminant trigger levels**

| Quality Characteristic | Trigger Levels (µg/L) | Comment on Trigger Level | Monitoring Frequency |
|---|---|---|---|
| pH | 6.5 — 9.0 | | Daily during the release |
| Electrical Conductivity (µS/cm) | 700 | | |
| Total Suspended solids (mg/L) | To be determined | Turbidity may be required to assess ecosystems impacts and can provide instantaneous results. | |
| Aluminium | 55 | *For aquatic ecosystem protection, based on SMD guideline* | Commencement of release and thereafter weekly during release N |
| Arsenic | 13 | *For aquatic ecosystem protection, based on SMD guideline* | |
| Cadmium | 0.2 | *For aquatic ecosystem protection, based on SMD guideline* | |
| Chromium | 1 | *For aquatic ecosystem protection, based on SMD guideline* | |
| Copper | 2 | *For aquatic ecosystem protection, based on LOR for ICPMS* | |
| Iron | 300 | *For aquatic ecosystem protection, based on low reliability guideline* | |
| Lead | 4 | *For aquatic ecosystem protection, based on SMD guideline* | |
| Mercury | 0.2 | *For aquatic ecosystem protection, based on LOR for CV FIMS* | |
| Nickel | 11 | *For aquatic ecosystem protection, based on SMD guideline* | |
| Zinc | 8 | For aquatic ecosystem protection, based on SMD guideline | Commencement of release and thereafter weekly during release |
| Boron | 370 | For aquatic ecosystem protection, based on SMD guideline | |
| Cobalt | 90 | For aquatic ecosystem protection, based on low reliability guideline | |
| Manganese | 1900 | For aquatic ecosystem protection, based on SMD guideline | |
| Molybdenum | 34 | For aquatic ecosystem protection, based on low reliability guideline | |
| Selenium | 10 | For aquatic ecosystem protection, based on LOR for ICPMS | |
| Silver | 1 | For aquatic ecosystem protection, based on LOR for ICPMS | |
| Uranium | 1 | For aquatic ecosystem protection, based on LOR for ICPMS | |
| Vanadium | 10 | For aquatic ecosystem protection, based on LOR for ICPMS | |

| Quality Characteristic | Trigger Levels (µg/L) | Comment on Trigger Level | Monitoring Frequency |
|---|---|---|---|
| Ammonia | 900 | For aquatic ecosystem protection, based on SMD guideline | |
| Nitrate | 1100 | For aquatic ecosystem protection, based on ambient Queensland Water Quality Guidelines (2006) for TN | |
| Petroleum hydrocarbons (C6-C9) | 20 | | |
| Petroleum hydrocarbons (C10-C36) | 100 | | |
| Fluoride (total) | 2000 | Protection of livestock and short term irrigation guideline | |
| Sodium | TBA | | |
| Sulphate (SO42-) (mg/L) | 250 (Protection of drinking water Environmental Value) | Drinking water environmental values from NHMRC 2006 guidelines OR ANZECC | Daily during release |

***Table C4: Receiving waters contaminant trigger levels** notes:*

1. *All metals and metalloids must be measured as total (unfiltered) and dissolved (filtered). Trigger levels for metal/metalloids apply if dissolved results exceed trigger.*
2. *The quality characteristics required to be monitored as per **Table C4: Receiving waters contaminant trigger levels** can be reviewed once the results of 2 years monitoring data is available, or if sufficient data is available to adequately demonstrate negligible environmental risk, and it may be determined that a reduced monitoring frequency is appropriate or that certain quality characteristics can be removed from **Table C4: Receiving waters contaminant trigger levels** by amendment.*
3. *SMD - slightly moderately disturbed level of protection, guideline refers ANZECC & ARMCANZ (2000).*
4. *LOR - typical reporting for method stated. ICPMS/CV FIMS - analytical method required to achieve LOR.*

**Table C5: Receiving water upstream background sites and downstream monitoring points**

| Monitoring Points | Receiving Waters Location Description | Latitude (GDA94) | Longitude (GDA94) |
|---|---|---|---|
| **Upstream Background Monitoring Points** | | | |
| LCU1 | Lagoon Creek at a point upstream of mine | 27° 18' 9.7728" S | 151° 44' 23.136" E |
| LCU2 | Spring Creek at a point upstream of mine | 27° 14' 18.7728" S | 151° 41' 31.2864" E |
| **Downstream Monitoring Points** | | | |
| LCD1 | Lagoon Creek downstream of mine | 27° 18' 35.64" S | 151° 43' 4.3536" E |
| LCD2 | Lagoon Creek downstream of mine | 27° 18' 37.36" S | 151° 43' 1.8768" E |
| SCD1 | Spring Creek at a point downstream of mine | 27° 14' 47.364" S | 151° 40' 36.2028" E |
| DS1 | Located at the downstream boundary of ML50232* (*or any subsequent identifier for the ML required for the New Acland Coal Mine Stage 3 project) | 27° 19' 26.68" S | 151° 41' 7.02 E |

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| **C15** | If quality characteristics of the receiving water at the downstream monitoring points exceed any of the trigger levels specified in **Table C4: Receiving waters contaminant trigger levels** during a release event the environmental authority holder must compare the downstream results to the upstream results in the receiving waters and:<br>a) where the downstream result is the same or a lower value than the upstream value for the quality characteristic then no additional monitoring and reporting action is required; or<br>b) where the downstream results exceed the upstream results complete an investigation into the potential for environmental harm and provide a written report to the administering authority within 90 days of receiving the results and in the next annual return, outlining:<br>(1) details of the investigations carried out; and<br>(2) actions taken to prevent environmental harm.<br><br>NOTE: Where an exceedance of a trigger level has occurred and is being investigated, in accordance with **(b) of this condition**, no further reporting is required for subsequent trigger events for that quality characteristic. |
| **C16** | All determinations of water quality and biological monitoring must be performed by an appropriately qualified person. |

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| **C17** | **Annual water monitoring reporting**<br>The following information must be recorded in relation to all water monitoring required under the conditions of this environmental authority and submitted to the administering authority in the specified format:<br>a) the date on which the sample was taken;<br>b) the time at which the sample was taken;<br>c) the monitoring point at which the sample was taken;<br>d) the measured or estimated daily quantity of mine affected water released from all release points;<br>e) the release flow rate at the time of sampling for each release point;<br>f) the results of all monitoring and details of any exceedances of the conditions of this environmental authority;<br>g) water quality monitoring data must be provided to the administering authority in the specified electronic format upon request; and<br>h) water level monitoring data must be provided in the specified electronic format upon request. |
| **C18** | **Stormwater and water sediment controls**<br>An Erosion and Sediment Control Plan must be developed by an appropriately qualified person and implemented for all stages of the mining activities on the site to minimise erosion and the release of sediment to receiving waters and contamination of stormwater. |
| **C19** | Stormwater, other than mine affected water, is permitted to be released to waters from:<br>a) Erosion and sediment control structures that are installed and operated in accordance with the Erosion and Sediment Control Plan required by **Condition C18**; and<br>b) Water management infrastructure that is installed and operated, in accordance with a Water Management Plan that complies with **Condition C20** for the purpose of ensuring water does not become mine affected water. |
| **C20** | **Water Management Plan**<br>A Water Management Plan must be developed by an appropriately qualified person and implemented for all stages of mining. The Water Management Plan must be submitted to the administered authority for review and comment within **3 months upon the grant of ML50232 and ML700002.** |
| **C21** | The Water Management Plan must identify methods to:<br>a) identify the environmental values of the receiving waters including Lagoon and Spring Creek and water quality objectives and how they will be protected;<br>b) incorporate a risk management approach to how changing levels of flood, drought and water quality risks should be addressed;<br>c) manage stormwater discharge;<br>d) develop and implement a system for emergency spills or discharges including procedures to minimise extent and duration of release, staff training, investigation and reporting procedures;<br>e) manage the environmental impacts of any release of wastewater to the environment so that any impacts are minimised including restricting any discharge to waters to occasions where there is flow in receiving waters to provide considerable dilution; |

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| | f) separate clean water from undisturbed areas and water from disturbed areas;<br>g) manage site water quality and quantity during the three (3) phases of mining: development, operation and decommissioning and include a site water balance including groundwater generated through mine dewatering;<br>h) safeguard against the potential for soil erosion and acid drainage; and<br>i) provide details of operational monitoring and monitoring of hydrological processes including associated performance indicators. |
| **C22** | Within twenty (20) business days of receiving comments from the administering authority as required by **Condition C20**, the Water Management Plan must be updated by a suitably qualified and experienced person having regard to the comments, and submitted to the administering authority. |
| **C23** | A copy of the Water Management Plan and any subsequent amendment of the Water Management Plan must be kept at the place to which this environmentally relevant activity relates and be available for examination by Emergency Services Personnel or an authorised person on request. |
| **C24** | If an exceedance in accordance with **Condition C15(b)** is identified, the holder of the environmental authority must notify the administering authority in writing within **24 hours of receiving the result**. |

| **Agency interest: Groundwater** | |
|---|---|
| **Condition number** | **Condition** |
| **D1** | **Contaminant release**<br>The holder of this environmental authority must not release contaminants to groundwater. |
| **D2** | All determinations of groundwater quality and biological monitoring must be performed by an appropriately qualified person. |
| **D3** | Groundwater quality and levels must be monitored at the locations and frequencies defined in **Table D1 - Groundwater monitoring locations and** frequency for quality characteristics identified in **Table D2 - Groundwater quality triggers and limits**. |
| **D4** | Groundwater levels when measured at the monitoring locations specified in **Table D1 - Groundwater monitoring locations and frequenc**y must not exceed the groundwater level trigger change thresholds specified in **Table D3 - Groundwater level monitoring** below. |

Table D1: Groundwater monitoring locations and frequency

| Monitoring Point | Aquifer Compliance Bore (C) | Location (GDA94 – Zone 56) | | Parameter[1] and Monitoring Frequency |
|---|---|---|---|---|
| | | Easting (m) | Northing (m) | |
| 2289P | Coal measures (C) | 371265 | 6983532 | Groundwater levels: monthly<br>Groundwater quality: Six monthly to include: Al, As, Ca, Se, Cl, Cu, F, Fe, Total N, K, Mg, Mn, Na, $SO_4$, $HCO_3$, TDS, EC, pH |
| 2291P | Coal measures (C) | 374620 | 6980033 | |
| 18P | Coal measures (C) | 371028 | 6982641 | |
| 25P | Coal measures (C) | 374146 | 6982057 | |
| 26P | Coal measures (C) | 374266 | 6982977 | |
| 27P | Coal measures (C) | 373360 | 6983554 | |
| 28P | Coal measures (C) | 372328 | 6983977 | |
| 843 | Basalt (C) | 370698 | 6981283 | |
| 848 | Coal measures (C) | 370705 | 6981723 | |
| 81P | Coal measures (C) | 375003 | 6979638 | |
| 82P | Coal measures (C) | 373697 | 6978814 | |
| 83P | Coal measures (C) | 371854 | 6979679 | |
| 84P | Basalt (C) | 370355 | 6982187 | |
| BMH1 | Basalt (C) | 369658 | 6982204 | |
| CSMH1 | Coal measures (C) | 375404 | 6977336 | |
| 109P | Basalt | 368263 | 6982378 | |
| 122PGC | Coal measures | 370656 | 6977837 | |
| 114P | Coal measures | 371806 | 6976037 | |
| 116P | Coal measures | 374220 | 6975132 | |
| 119PGC | Coal measures | 371609 | 6973337 | |
| 120WB | Coal measures | 367523 | 6976115 | |
| 121WB | Coal measures | 368472 | 6978441 | |
| 1A | Basalt | 366548 | 6982090 | |
| 1B | Coal measures | 366548 | 6982090 | |
| 2A | Basalt | 365884 | 6979300 | |
| 2B | Coal measures | 365884 | 6979300 | |

| | | | | |
|---|---|---|---|---|
| 3A | Basalt | 369416 | 6973707 | |
| 3B | Coal measures | 369416 | 6973707 | |
| 4A | Basalt | 365800 | 6977025 | |
| 4B | Coal measures | 365800 | 6977025 | |
| 4C | Marburg Sandstone | 365800 | 6977025 | |
| 5A | Oakey Creek alluvium | 373845 | 6972482 | |
| 5B | Coal measures | 373845 | 6972482 | |
| 5C | Marburg Sandstone | 373845 | 6972482 | |
| 6 | Coal measures | 375435 | 6975738 | |
| 7A | Basalt | 367572 | 6982694 | |
| 7B | Coal measures | 367572 | 6982694 | |
| 8 | Mine Pit Backfill | 372514 | 6982689 | |
| 2289_ Lower | Coal measures (C) | 371266 | 6983554 | |
| 25P(R) | Coal measures (C) | 374036 | 6981883 | |
| 26P(R) | Coal measures (C) | 374158 | 6982801 | |
| 10Pb | Basalt (C) | 370359 | 6980896 | |
| 4517WB | Coal measures (C) | 369728 | 6980680 | |
| 4518WB | Coal measures (C) | 369265 | 6979260 | |

[1] - Aluminium (Al), Arsenic (As), Calcium (Ca). Selenium (Se), Chloride (Cl), Copper (Cu), Fluorine (F), Iron (Fe), Total Nitrogen (Total N), Potassium (K), Magnesium (Mg), Manganese (Mn), Sodium (Na). Sulphate (SO4), Bicarbonate (HCO3), Total dissolves solids (TDS), Electrical conductivity ( EC), Acidity/alkalinity (pH)

**Table D2: Groundwater quality triggers and limits**

| Parameter | Units | Contaminant Limit[1] | Monitoring frequency |
|---|---|---|---|
| Al | mg/l | 5.0 | Half yearly |
| As | mg/l | .05 | Half yearly |
| Ca | mg/l | 1000 | Half yearly |
| Se | mg/l | 0.02 | Half yearly |
| Cl | mg/l | TBA | Half yearly |
| Cu | mg/l | 1.0 [2] | Half yearly |
| F | mg/l | TBA | Half yearly |
| Fe | mg/l | TBA | Half yearly |
| $NO_3$ | mg/l | 400 | Half yearly |
| $NO_2$ | mg/l | 30 | Half yearly |
| K | mg/l | TBA | Half yearly |
| Mg | mg/l | TBA | Half yearly |
| Mn | mg/l | TBA | Half yearly |
| Na | mg/l | TBA | Half yearly |
| $SO_4$ | mg/l | 1000 | Half yearly |
| $HCO_3$ | mg/l | TBA | Half yearly |
| TDS | mg/l | 5000 [2,3] | Half yearly |
| EC | mg/l | 7460 [2,3,4] | Half yearly |
| pH | unit | TBA | Half yearly |

[1] *Based on Stockwater limits defined in ANZECC (2000)*

[2] *Defined for beef cattle based on landholder bore survey results*

[3] *Existing bores 27P, 28P, 2289 and 118P background levels already exceed this limit prior to mine operation*

[4] *Based on EC to TDS conversion factor of 0.67 as per ANZECC (2000)*

**Table D3: Groundwater level monitoring**

| Monitoring Point | Level trigger threshold |
|---|---|
| 2289P | TBA[1] |
| 2291P | 52.0 (±5m) |
| 18P | 130.0 (±5m) |
| 25P | TBA[1] |
| 26P | TBA[1] |
| 27P | 50.0 (±5m) |
| 28P | 50.0 (±5m) |
| 843 | TBA[1] |
| 848 | TBA[1] |
| 81P | 42.0 (±5m) |
| 82P | 48.0m (±5m) |
| 83P | TBA[1] |
| 84P | TBA[1] |
| BMH1 | 96.0 (±5m) |
| CSMH1 | 90.0 (±5m) |
| 109P | TBA[1] |
| 122PGC | TBA[1] |
| 114P | TBA[1] |
| 116P | TBA[1] |
| 119PGC | TBA[1] |
| 120WB | TBA[1] |
| 121WB | TBA[1] |
| 1A | TBA[1] |
| 1B | TBA[1] |
| 2A | TBA[1] |
| 2B | TBA[1] |
| 3A | TBA[1] |

| | |
|---|---|
| 3B | TBA[1] |
| 4A | TBA[1] |
| 4B | TBA[1] |
| 4C | TBA[1] |
| 5A | TBA[1] |
| 5B | TBA[1] |
| 5C | TBA[1] |
| 6 | TBA[1] |
| 7A | TBA[1] |
| 7B | TBA[1] |
| 8 | TBA[1] |
| 2289_ Lower | 59.7m (±5m) |
| 25P(R) | 97.8m (±5m) |
| 26P(R) | 90.0m (±5m) |
| 10Pb | 25.0m (±5m) |
| 4517WB | 43.5m (±5m) |
| 4518WB | 59.0m (±5m) |

[1]To be provided — Water level trigger thresholds will be proposed following 12 months of monitoring of the new bores and following the first update of the groundwater model prior to the operation of the revised project.

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| **D5** | **Exceedance investigation**<br>If quality characteristics of groundwater from compliance bores identified in **Table D1 - Groundwater monitoring locations and frequency** exceed any of the trigger levels stated in **Table D2 - Groundwater quality triggers and limits** or exceed any of the groundwater level trigger threshold stated in **Table D3 - Groundwater level monitoring**, the holder of this environmental authority must compare the compliance monitoring bore results to the reference bore results and complete an investigation in accordance with the ANZECC and ARMCANZ 2000. |
| **D6** | Results of monitoring of groundwater from compliance bores identified in **Table D1 - Groundwater monitoring locations and frequency** must not exceed any of the limits defined in **Table D2 - Groundwater quality triggers and limits**. |
| **D7** | **Bore construction and maintenance and decommissioning**<br>The construction, maintenance and management of groundwater bores (including groundwater monitoring bores) must be undertaken in a manner that prevents or minimises impacts to the environment and ensures the integrity of the bores to obtain accurate monitoring. |

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| **D8** | **Groundwater management and monitoring program**<br>The approved Groundwater Management and Monitoring Program required by Imposed Condition 10, in Appendix 1, of the CG's report must be provided, to the administering authority, within **20 business days** of it being approved. |
| **D9** | In addition to the requirements of Imposed Condition 10 in Appendix 1 of the CG's report, a plan must be developed and certified by an appropriately qualified person to meet the following objectives:<br>a) identification of groundwater drawdown level thresholds for monitoring the impacts to Groundwater Dependant Ecosystems; and<br>b) collection and analysis of data that identifies natural groundwater level trends for identification of water level impact to authorised water users from the mining operation as required by Schedule 3, recommended Condition 1 in Appendix 3 of the CG's report.<br>The plan must be provided to the administering authority in conjunction with submission of the approved program in **Condition D8**. |
| **D10** | **Monitoring Program Review**<br>The environmental authority holder must provide the approved report required by Imposed Condition 11, in Appendix 1, of the CG's report, to the administering authority, within **20 business days** of the report being approved. |
| **D11** | The plan required under **Condition D9** must be reviewed by an appropriately qualified person in accordance with the requirements of Imposed Condition 11 in Appendix 1 of the CG's report, and be provided to the administering authority in conjunction with the submission of the approved report in **Condition D10**. |
| **D12** | **Groundwater model review**<br>The environmental authority holder must provide the approved report required by Imposed Condition 12, in Appendix 1, of the CG's report, to the administering authority, within **20 business days** of it being approved. |
| **D13** | **General requirements — Oakey Creek Alluvial aquifer**<br>As a component of the second and subsequent reviews of the New Acland Coal numerical groundwater model the environmental authority holder must provide an approved (*under Water Act 2000*) report outlining the impact on the Oakey Creek Alluvial aquifer, to the administering authority. The report should:<br>a) Establish any identified impact associated with mining activities, if any, on the Oakey Creek Alluvial aquifer;<br>b) Include an assessment of natural and potential pumping based water level variation caused by non-mining authorised users, in the Oakey Creek Alluvial aquifer;<br>c) Outline any requirements for additional modelling or monitoring required;<br>d) If the investigation under **Condition D13(a)** concludes that there is an identified impact on the Oakey Creek Alluvial aquifer as a result of mining activities, the environmental authority holder must determine the volumetric impact associated with the identified impact; and<br>e) If the impact is determined to be the result of mining activities, the environmental authority may be required to construct additional monitoring bores. Additional monitoring bores are to be incorporated in the Groundwater Monitoring and Management Plan required by **Condition D8.** |

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| **D14** | **Main Range Volcanics aquifer**<br>The environmental authority holder must determine the long term impact of the take of water from the Main Range Volcanics aquifer and incorporate this into the second review of the New Acland Coal numerical groundwater model pursuant to **Conditions D8 — D12**. |
| **D15** | A groundwater monitoring network must be maintained. The network must:<br>a) be installed and maintained by a person possessing appropriate qualifications and experience in the fields of hydrogeology and groundwater monitoring program design to be able to competently make recommendations about these matters;<br>b) be constructed in accordance with methods prescribed in either the latest edition of the Agriculture and Resource Management Council of Australia and New Zealand manual titled 'Minimum Construction Requirements for Water Bores in Australia' or the 'Minimum standards for the construction and reconditioning of water bores that intersect the sediments of artesian basins in Queensland', whichever applies; and<br>c) include a sufficient number of 'bores of compliance' that are located at an appropriate distance from potential sources of impact from mining activities and provides the following:<br>(1) representative groundwater samples from the uppermost aquifer; and<br>(2) background water quality in hydraulically up-gradient or background bore(s) that have not been affected by any mining activities to groundwater's; and<br>(3) the quality of groundwater downgradient of any potential source of contamination including groundwater passing the relevant bore(s) of compliance. |

| **Agency interest: Waste Management** | |
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| **Condition number** | **Condition** |
| **E1** | Unless otherwise permitted by the conditions of this environmental authority or with prior approval from the administering authority and in accordance with a relevant standard operating procedure, waste must not be burnt. |
| **E2** | The holder of this environmental authority may burn vegetation cleared in the course of carrying out extraction activities provided the activity does not cause environmental harm at any sensitive place or commercial place. |
| **E3** | The holder of this environmental authority may dispose of inert waste (packing material) associated with blasting into open pits, buried in such a manner that it will not impede saturated aquifers. |
| **E4** | **Storage of tyres**<br>Tyres stored awaiting disposal or transport for take-back and, recycling, or waste-to-energy options - should be stockpiled in volumes less than 3m in height and 200m$^2$ in area and at least 10m from any other tyre storage area. |
| **E5** | **Disposal of tyres**<br>Scrap tyres resulting from the mining activities can be disposed of into open pits provided tyres are placed as deeply in the spoil as reasonably possible and this practice does not cause an unacceptable fire risk or compromise mine safety. |

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| **E6** | Scrap tyres resulting from the mining activities disposed within the operational land must not impede saturated aquifers or compromise the stability of the consolidated landform. |
| **E7** | **Tailings disposal**<br>Tailings must be managed in accordance with procedures contained within the current plan of operations. These procedures must include provisions for:<br>a) containment of tailings;<br>b) the management of seepage and leachates both during operation and the foreseeable future;<br>c) the control of fugitive emissions to air;<br>d) maintaining records of the relative locations of any other waste stored within the tailings;<br>e) rehabilitation strategy; and<br>f) monitoring of rehabilitation, research and/or trials to verify the requirements and methods for decommissioning and final rehabilitation of tailings, including the prevention and management of acid mine drainage, erosion minimisation and establishment of vegetation cover. |

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| **E8** | **Green waste storage**<br>The waste management hierarchy must be considered in the management of green waste. |

| **Agency interest: Noise** | |
|---|---|
| **Condition number** | **Condition** |
| **F1** | **Noise limits**<br>The holder of this environmental authority must ensure that noise generated by the mining activities does not cause the criteria in **Table F1 – Noise limits** to be exceeded at a noise sensitive place or commercial place. |
| **F2** | If monitoring indicates the potential for exceedance of the relevant limits in **Table F1 – Noise Limits** then the environmental authority holder must immediately implement noise abatement measures to avoid exceeding the relevant limits. |
| **F3** | Notwithstanding any other condition of this environmental authority, noise from the activity must not cause an environmental nuisance, at any noise sensitive place. |
| **F4** | **Monitoring and reporting**<br>A Noise Monitoring Program must be developed by a suitably qualified and experienced person in relation to noise and implemented for all stages of mining to monitor compliance with **Table F1 - Noise limits**. The Noise Monitoring Program must be submitted to the administering authority for approval **within 3 months upon grant of ML50232 and ML700002**. The Noise Monitoring Program must be implemented **within 3 months** of the administering authority approving the program. |

**Table F1 – Noise limits (includes construction activities)**

| **Noise level dB(A) measured as** | **All days** | | |
|---|---|---|---|
| | **7am – 6pm** | **6pm – 10pm** | **10pm – 7am** |
| | Noise measured at a 'Noise sensitive place' | | |
| $L_{Aeq,\ adj,\ 15\ min}$ | 42 | 35 | 35 |
| $L_{Amax}$ | - | - | 50 |
| $L_{Amax}$ rail spur | - | - | 56 |
| $L_{Aeq(24hr)}$ rail spur | - | - | 50 |

| | |
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| **F5** | Noise monitoring and recording must include the following descriptor characteristics and matters:<br>a) $L_{A01, adj, 15 min}$ - day, evening & night; $L_{A10, adj, 15 min}$ - day, evening & night; $L_{Aeq, adj, 15 min}$ - day, evening & night; and $L_{A90, adj, 15 min}$ - day, evening & night;<br>b) background noise $L_{A90}$;<br>c) the level and frequency of occurrence of impulsive or tonal noise and any adjustment and penalties to statistical levels;<br>d) atmospheric conditions including temperature, relative humidity and wind speed and directions;<br>e) effects due to any extraneous factors such as traffic noise and natural sources (e.g. insects, birds and wind);<br>f) location, date and time of monitoring;<br>g) if the complaint concerns low frequency noise, $L_{LINeq\ 10\ mins}$ (internal), $L_{Aeq\ 10\ mins}$ (internal) and one third octave band measurements in $L_{LINeq\ 10\ mins}$ (internal) for centre frequencies in the 10 – 200 Hz range;<br>h) maximum ($L_{Amax}$) noise levels - night (for a minimum of 30 minutes); and<br>i) ⅓ octave band spectrums. |
| **F6** | The Noise Monitoring Program must also include a system of real time performance monitoring against the criteria in **Table F1 - Noise limits** at:<br>a) location in Acland to be identified in the Noise Monitoring Program;<br>b) location to the east of the New Acland mine to be identified in the Noise Monitoring Program;<br>c) location to the north of the New Acland mine to be identified in the Noise Monitoring Program; and<br>d) location to the west of the New Acland mine to be identified in the Noise Monitoring Program.<br>NOTE: The performance monitoring required under this condition is to be used for performance management rather than monitoring for compliance with **Table F1 - Noise limits.** |
| **F7** | All real-time performance monitoring parameters required by **Condition F6** must be made publically available, online and in real-time. |
| **F8** | **Noise management**<br>A Noise and Vibration Management Plan must be developed by a suitably qualified and experienced person in relation to noise and be implemented for all stages of mining **within 3 months upon the grant of ML50232 and ML700002**. |

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| **F9** | The Noise and Vibration Management Plan must incorporate a program for continuous improvements for the management of noise emissions caused by mining operations and must include, but is not limited to:<br>a) a detailed description of the noise management system;<br>b) a description of the noise mitigation measures that would be implemented to ensure best practice noise management is being employed, is regularly benchmarked against contemporary industry standards and is regularly reviewed to ensure continual improvement;<br>c) the Noise Monitoring Program described in **Condition F4** and **Table F2 - Compliance noise monitoring locations and frequency**;<br>d) a comprehensive noise management system that uses a combination of predictive meteorological forecasting and real-time noise monitoring data to guide the day to day planning of mining operations and the implementation of both proactive and reactive mitigation measures to ensure compliance with these conditions, improved understanding of noise data at the monitoring locations in **Table F2 - Compliance noise monitoring locations and frequency** and its correlation with the noise data collected from the locations specified in **Condition F6**;<br>e) a protocol for determining exceedances of the conditions;<br>f) a protocol for recording and responding to complaints;<br>g) the content of the monthly compliance report required under **Condition 3** of the imposed conditions of the Coordinator-General, including for the provision of data in that report, and a peer review of that content. |
| **F10** | The environmental authority holder must, at their own cost, appoint an independent acoustic consultant to review the monthly noise report format for a **twelve (12) month period** following the commencement of reporting. A report must be produced to present information from noise monitoring in a manner that is clear, open and unambiguous. |
| **F11** | **Mitigation**<br>Upon receiving a written request from the owner of a noise sensitive place shown in **Figure 7 - Noise Sensitive Places (Mitigation)**, the environmental authority holder must implement additional reasonable and feasible noise mitigation measures at the noise sensitive place in consultation with the owner.<br>If within **3 months** of receiving this request, the environmental authority holder and the owner cannot agree on the measures to be implemented, or there is a dispute about the implementation of these measures, then either party may refer the matter to a suitably qualified and experienced person in relation to noise appointed by the Chief Executive or the President for the time being of the Institute of Engineers for resolution. The suitably qualified and experienced person's decision as to the mitigation measures to be implemented must be final.<br>The environmental authority holder is responsible for payment of costs of the suitably qualified and experienced person in relation to noise. |

**Table F2 - Compliance noise monitoring locations and frequency**

| Monitoring location* | Frequency |
|---|---|
| 1 (Acland) | Monthly |
| 34 (rail spur), 35 and 38 (or alternative noise sensitive places identified in the Noise Monitoring Program developed pursuant to condition F5) | Monthly |
| 4, 8 and 10 (or alternative noise sensitive places identified in the Noise Monitoring Program developed pursuant to condition F5) | Monthly |
| 11, 15 and 19 (or alternative noise sensitive places identified in the Noise Monitoring Program developed pursuant to condition F5) | Monthly |

*See Figure 5

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| **F12** | **Airblast overpressure nuisance**<br>The holder of this environmental authority must ensure that blasting does not cause the limits for peak particle velocity and air blast overpressure in **Table F3 – Blasting noise limits** to be exceeded at a sensitive place or commercial place. |
| **F13** | The holder of this environmental authority must develop and implement a blast monitoring program to monitor compliance with **Table F3 – Blasting noise limits** for:<br>a) At least 90% of all blasts undertaken on this site in each year at the nearest sensitive place or commercial place to the centroid of the blast; and<br>b) All blasts conducted during any time period specified by the administering authority at the nearest sensitive place or commercial place. |

**Table F3: Blasting noise limits**

| Blasting noise limits | Sensitive place or commercial place blasting noise limits | |
|---|---|---|
| | **Monday to Friday 7am to 6pm**<br>**Saturday 9am to 1pm** | **Monday to Friday 6pm to 7am**<br>**Saturday 1pm to 9am**<br>**Sunday and Public Holidays^** |
| Airblast overpressure | 115 dB (Linear) Peak for 9 out of 10 consecutive blasts initiated and not greater than 120 dB (Linear) Peak at any time | No blasting |
| Ground vibration peak particle velocity | 5mm/second peak particle velocity for 9 out of 10 consecutive blasts and not greater than 10 mm/second peak particle velocity at any time | No blasting |

^ Blasting not permitted on public holidays

| **Agency interest: Sewage Treatment** | |
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| **Condition number** | **Condition** |
| **G1** | All effluent released from the treatment plant must be monitored at the frequency and for the parameters specified in **Table G1 — Sewage Effluent Quality Targets for Dust Suppression and Irrigation**. |

**Table G1: Sewage Effluent Quality Targets for Dust Suppression and Irrigation**

| Contaminant | Unit | Release limit | Limit type | Frequency |
|---|---|---|---|---|
| 5-day Biochemical oxygen demand (uninhibited) | mg/L | 20 | Maximum | Quarterly |
| Faecal coliforms, based on the average of a minimum of five samples collected | Colonies/100m1 | 1000 | Maximum | Quarterly |
| Total suspended solids | mg/L | 30 | Maximum | Quarterly |
| Nitrogen | mg/L | 15 | Maximum | Quarterly |
| Phosphorus | mg/L | 1000 | Maximum | Quarterly |
| pH | pH units | 6.0 — 9.0. | Range | Quarterly |

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| **G2** | Treated sewage effluent used for dust suppression or irrigation must not exceed sewage release limits defined in **Table G1 — Sewage Effluent Quality Targets for Dust Suppression and Irrigation**. |
| **G3** | Sewage effluent used for dust suppression or irrigation must not cause spray drift or overspray to any sensitive place. |
| **G4** | Subject to Condition **G5**, sewage effluent from sewage treatment facilities must be reused or evaporated and must not be directly released from the sewage treatment plant to any water way or drainage line. |
| **G5** | In periods of wet weather or following wet weather, when no irrigation of effluent is reasonable practicable and when effluent storage ponds are full, the release of effluent to waters is permitted in accordance with the release limits in **Table G1 - Sewage Effluent Quality Targets for Dust Suppression and Irrigation** and locations specified in **Table C1 - Mine-affected water release points, sources and receiving waters**. |
| **G6** | The holder of the environmental authority must ensure that irrigation of effluent is carried out in such a manner that prevents and or minimises environmental harm. |
| **G7** | The holder of this environmental authority is authorised to accept treated wastewater from the Wetalla Wastewater Reclamation Facility. |

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| **G8** | Sewage effluent used for dust suppression or irrigation must not exceed sewage effluent release limits defined in **Table G1 - Sewage Effluent Quality Targets for Dust Suppression and Irrigation**. |

| **Agency interest: Land and Rehabilitation** | |
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| **Condition number** | **Condition** |
| **H1** | **Buffer Zone**<br>The holder of the environmental authority must not cause any disturbance within 50 metres of the high bank of Lagoon Creek (buffer zone) as shown on **Figure 3 - Lagoon Creek, buffer and levee** unless in accordance with **Condition H2 and H3**. |
| **H2** | The holder of the environmental authority is authorised to construct and maintain a flood protection levee and access road for inspection purposes, with the tow of the levee being no closer than 50 metres from the high bank of Lagoon Creek as shown on **Figure 3 - Lagoon Creek, buffer and levee** |
| **H3** | The holder of the environmental authority is authorised to access the 50 metre buffer zone as shown on **Figure 3 - Lagoon Creek, buffer and levee**, for the purposes of maintaining the integrity of the flood protection levee, riparian conservation and weed management purposes. |
| **H4** | The flood protection levee must be designed and inspected by a suitably qualified and experienced person. The final design level of the levee crest must be above the predicted 1,000 year ARI event flood level. |
| **H5** | Any section of the outside face of the levee must be treated with cover material and grass seeded (unless rock armoured) within **three months of completion** of the earthworks for that section of the outside face of the levee. |
| **H6** | The condition of the levee must at a minimum be assessed:<br>a) by the environmental authority holder **within 1 week** of any storm of such intensity that greater than 25mm of rain falls in less than 3 hours; and<br>b) by a suitably qualified and experienced person at least once per year between the months of May and October inclusive (i.e. during the 'dry' season and before the onset of the 'wet' season). |
| **H7** | Remedial works identified as necessary during assessments conducted under Condition **H6** must be commenced **within 30 days** unless delayed by inclement weather. |
| **H8** | Any actions and incidents on site that may impact upon the integrity of the levee bank must be notified to the administering authority in accordance with **Condition H4**. |
| **H9** | For Stage 3 New Acland Mine Project, land disturbed by mining must be rehabilitated in accordance with **Table H4: Rehabilitation Requirements Stage 3 New Acland Mine Project, Table H5: Rehabilitation Acceptance Criteria — Grazing Lands Stage 3 New Acland Mine Project and Table H6: Rehabilitation Acceptance Criteria — Treed Areas Stage 3 New Acland Mine Project.** |

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| **H10** | **Final Land Use and Rehabilitation Plan**<br><br>Within twelve (12) months **upon the grant of ML50232 and ML700002** the holder of this environmental authority must develop and implement a Final Land Use and Rehabilitation Plan to ensure that all areas disturbed by mining activities will be suitably rehabilitated in accordance with **Table H1 – Final Land Use and Rehabilitation Approval Schedule – ML50170 and ML50216, Table H2 - Landform design criteria for New Acland Coal Mine – ML50170 and ML50216, Table H3: Residual Void Design – ML50170 and ML50216, Table H4: Rehabilitation Requirements Stage 3 New Acland Mine Project, Table H5: Rehabilitation Acceptance Criteria — Grazing Lands Stage 3 New Acland Mine Project and Table H6: Rehabilitation Acceptance Criteria — Treed Areas Stage 3 New Acland Mine Project.**<br><br>The Plan must include, but is not limited to the following:<br>a) disturbance type;<br>b) disturbance area;<br>c) pre and post mine land descriptions;<br>d) pre and post mine land capability;<br>e) analogue site(s) identification;<br>f) a description of rehabilitation management techniques incorporating works and monitoring programs and timetables;<br>g) indicators for success; and<br>h) keeping of appropriate records or rehabilitation measures implemented including taking of photographs demonstrative of rehabilitation achieved and the preparation of annual rehabilitation progress reports.<br><br>**NOTE:** The Final Land Use and Rehabilitation Plan is to be managed through the Plan of Operations. |

**Table H1: Final Land Use and Rehabilitation Approval Schedule — ML 50170 and ML50216**

| | Disturbance Type | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Residual Voids** | **Tailings Dams** | **Recontoured spoil area** | **Waste Rock Dumps** | **Infrastructure & ROM Areas** | **Roads and Tracks** | **Water Supply and Sediment Dams** |
| **Tenure ID** | ML50216 | ML50170 | ML50170<br>ML50216 | ML50216 | ML50170 | ML50170<br>ML50216 | ML50216 |
| **Projective Surface Area (ha)** | 55 | 70 | 740 | 100 | 5 | 5 | 40 |
| **Post mine land use** | Possible water storage | Grazing | Grazing | Grazing | Grazing | Grazing | Possible water storage |
| **Post mine land suitability classification** | 5 | 5 | 3-4 | 4 | 4 | 4 | 5 |

**NOTE:** The Final Land Use and Rehabilitation Plan will be managed through the Plan of Operations.

**Table H2: Landform design criteria for New Acland Coal Mine – ML50170 and ML50216**

| Disturbance Type | Slope Range (%) | Projective Surface Area (ha) |
|---|---|---|
| Residual Voids (high wall) | 0 - 214 % or 65° | 55 |
| Residual Voids (low wall) | 0 - 100 % or 45° | |
| Tailings Dam Top | 0 - 20 % or 11.5°* | 60 |
| Tailings Dam Wall | 0 - 20 % or 11.5° * | 10 |
| Recontoured Spoil Area | 0 - 20 % or 11.5° * | 740 |
| Waste Rock Dumps | 0 - 20 % or 11.5° * | 100 |
| Infrastructure and ROM areas | 0 - 18% or 10° | 5 |
| Roads and Tracks | 0 - 10 % or 5.7° | 5 |

**NOTE:** *= The slope depends on the vertical height and slope length. See Landform Acceptance Criteria.

**Table H3: Residual Void Design – ML50170 and ML50216**

| Void Identification | Void wall - competent rock slope (%) | Void wall - incompetent rock slope (%) | Void maximum surface area (ha) |
|---|---|---|---|
| Central Pit/South Pit Void | 65° or 214% | 45° or 100% | 55 |

**Table H4: Rehabilitation Requirements Stage 3 New Acland Mine Project**

| Mine Domain | Rehabilitation Goal | Rehabilitation Objectives | Indicators | Completion Criteria |
|---|---|---|---|---|
| Solid Waste Rock Disposal | Safe | Site safe for humans and animals | Structurally safe and shallow slopes (geotechnically stable). No hazardous materials (geochemically benign). | Monitoring / observation demonstrates safe site |
| | Non-polluting | No environmental harm attributed to adverse chemical conditions within the waste rock dumps | Minimise erosion (to at least <10t/ha/yr) through selective placement of mine waste, adequate vegetation cover. Runoff and seepage does not cause environmental harm | Suitable for low intensity grazing. Runoff and discharge water (including seepage) meets specified limits. |
| | Stable | Minimise erosion | Wastes selectively placed above and below original ground level to agreed slopes. Adequate ground cover established to control erosion.<br>Runoff control measures (contour banks, etc) effective in controlling erosion. | Suitable for low intensity grazing |
| | Self-sustaining | To return to agreed grazing land capability | Slope and other landform design criteria achieved. Establish adequate vegetation cover. | Refer **Table H5** and **Table H6** |
| Tailings Dams | Safe | Site safe for humans and animals | Structurally safe (geotechnically stable). Adequate capping. Accessibility to voids is permanently removed. | Monitoring / observation demonstrates safe site |
| | Non-polluting | Acid mine drainage will not cause environmental harm | Adequately capped. Minimise erosion through adequate vegetation cover to less than 10t/ha/yr. Runoff and seepage controlled by water management. | Monitoring meeting release limits. Suitable for low intensity grazing |

| Mine Domain | Rehabilitation Goal | Rehabilitation Objectives | Indicators | Completion Criteria |
|---|---|---|---|---|
| | Stable | Minimise erosion | Stored in both pits below natural surface level and in dams above natural surface. Establish adequate vegetation cover. | Monitoring demonstrates revegetation success. No structural erosion present. Suitable for low intensity grazing |
| | Self-sustaining | To return to agreed grazing land capability | Monitoring demonstrates successful revegetation. | Refer **Table H5** and **Table H6** |
| Mine Infrastructure Areas | Safe | Site safe for humans and animals | Hazardous materials removed. | Monitoring / observation demonstrates safe site |
| | Non-polluting | Undertake contaminated land assessment. | Remediate contamination so that runoff and seepage are of good quality. | Monitoring meeting release limits. |
| | Stable | Minimise erosion | Remove infrastructure or allow continued use of useful infrastructure. Establish adequate vegetation cover. | Slope will be a maximum of 17° (30%) |
| | Self-sustaining | To return to agreed grazing land capability | Return to previous use (grazing). Establish adequate groundcover. | Refer **Table H5** and **Table H6** |
| Linear Infrastructure areas | Safe | Site safe for humans and animals | Structurally safe (geotechnically stable). | Monitoring / observation demonstrates safe site |
| | Non-polluting | No environmental harm attributed to adverse chemical conditions within the rehabilitation areas. | Runoff and seepage controlled by water management (e.g. dams). | Monitoring meeting release limits. |
| | Stable | Minimise erosion | Remove infrastructure, rip reshape and revegetate or allow continued use of useful infrastructure. | Suitable for low intensity grazing |

| Mine Domain | Rehabilitation Goal | Rehabilitation Objectives | Indicators | Completion Criteria |
|---|---|---|---|---|
| | Self-sustaining | To return to agreed grazing land capability | Remove infrastructure or allow continued use of useful infrastructure. Establish adequate vegetation cover. | Refer **Table H5** and **Table H6** |

**Table H5: Rehabilitation Acceptance Criteria Stage 3 New Acland Mine Project — Grazing Lands**

| Land Suitability Class | Acceptance Criteria — Grazing Land | | | | | | |
|---|---|---|---|---|---|---|---|
| | Non-polluting | Stability and Sustainability Land Use | | | | | |
| | Active Rill / Gully Erosion | Vegetation Cover | Native and Exotic Grass Species Diversity (spp./ha) | Slopes | Geo-technical Stability | Active Rill / Gully Erosion | Declared Weeds |
| 2 to 5 | Absence (<10t/ha/yr) | > 50% | ≥4 | Maximum 17° | stable | absence | absence |

**Table H6: Rehabilitation Acceptance Criteria Stage 3 New Acland Mine Project — Treed Areas**

| Land Suitability Class | Acceptance Criteria — Grazing Land Treed Areas | | | | | | |
|---|---|---|---|---|---|---|---|
| | Non-polluting | Stability and Sustainable Land Use | | | | | |
| | Active Rill / Gully Erosion | Vegetation Cover (including tree / shrub canopy) | Native Tree / Shrub & Native / Exotic Grass Species Diversity (spp./ha) | Slopes | Geo-technical Stability | Active Rill / Gully Erosion | Declared Weeds |
| 2 to 5 | Absence (<10t/ha/yr) | > 50% | Eucalyptus spp. ≥2<br>Acacia spp. ≥2<br>Other tree / shrub spp. ≥2<br>Grass ≥3 | Maximum 17° | stable | absence | absence |

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| **H11** | All areas significantly disturbed by mining activities must be rehabilitated in accordance with the Mine Closure Plan outlined in **Condition H13**. |
| **H12** | Rehabilitation must commence progressively in accordance with the plan of operations. |

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| **H13** | **Closure and post closure**<br><br>The environmental authority holder must submit a Mine Closure Plan to the administering authority at least **five years prior** to the surrender of this environmental authority. |
| **H14** | When the deposition of tailings ceases, the holder of this Environmental Authority must install a final cover system to the Tailings Storage Facility, which effectively minimises:<br>a) infiltration of water into the Tailings Storage Facility; and<br>b) the likelihood of any erosion occurring to either the final cover system, dumped spoil material or deposited tailings. |
| **H15** | The final cover system must include an inert layer to reduce infiltration and an upper/final layer of earthen material that is capable of sustaining plant growth. |
| **H16** | **Sustainable final land use outcomes**<br><br>Areas that are to be progressively rehabilitated must comply with, but not be limited to, the following outcomes:<br>a) All areas disturbed by mining activities must be rehabilitated to the landform design criteria defined in the Final Land Use and Rehabilitation Plan required by **Condition H10 to H13;** and<br>b) The final landforms must be stable with erosion rates comparable to a suitable analogue site. |
| **H17** | **Grazing pasture outcome for ML50170 and ML50216**<br>Areas which are to be progressively rehabilitated to grazing pasture must comply with the following outcomes;<br>a) generate a self-sustaining vegetation with projective cover, species composition and species distribution comparable with that of analogue sites to be determined by the study detailed in **Condition H10** e.g. planting local native grass and shrub species where possible. These vegetation species must be listed in the Final Land Use and Rehabilitation Plan;<br>b) all areas disturbed by mining activities must be rehabilitated to the landform design criteria defined in **Table H2 - Landform design criteria for New Acland Coal Mine – ML50170 and ML50216**;<br>c) a measure of productivity (e.g. sustainable dry matter production, stock live weight gain) are comparable to the selected analogue sites detailed in **Condition H18**. |
| **H18** | Complete an investigation into rehabilitation of disturbed areas and submit a report to the administering authority proposing acceptance criteria to meet the outcomes in **Condition H17** and landform design criteria in **Table H2 - Landform design criteria for New Acland Coal Mine – ML50170 and ML50216** within **twelve months** of the issue of the Environmental Authority. |

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| **H19** | **Residual void outcome**<br><br>Residual voids must comply with the following outcomes:<br>a) residual voids must not cause any serious environmental harm to land, surface waters or any recognised ground water aquifer, other than the environmental harm constituted by the existence of the residual void itself, and subject to any other condition within this Environmental Authority; and<br>b) residual voids must comply with **Table H3 - Residual Void Design – ML50170 and ML50216**. |
| **H20** | Complete an investigation into residual voids and submit the findings in the Mine Closure Plan outlined by **Condition H13** to the administering authority proposing acceptance criteria to meet the outcomes in **Condition H19** and landform design criteria in **Table H3 — Residual Void Design – ML50170 and ML50216**. |
| **H21** | All areas within the mining lease will be managed to reduce the spread of declared plants including both disturbed and undisturbed areas. |
| **H22** | **Topsoil**<br>a) The environmental authority holder must ensure that topsoil is removed and stockpiled prior to carrying out any disturbance activities such that topsoil must be strategically stripped ahead of mining activities, including the establishment of spoil dump areas; and,<br>b) Topsoil must not be disposed of in a pit or otherwise sterilised from reuse. |
| **H23** | **Contaminated land**<br><br>Before applying for surrender of a mining lease, the holder must (if applicable) provide to the administering authority a site investigation report under the Act, in relation to any part of the mining lease which has been used for notifiable activities or which the holder is aware is likely to be contaminated land, and also carry out any further work that is required as a result of that report to ensure that the land is suitable for its final land use. |
| **H24** | Before applying for progressive rehabilitation certification for an area, the holder must (if applicable) provide to the administering authority a site investigation report under the Act, in relation to any part of the area the subject of the application which has been used for notifiable activities or which the holder is aware is likely to be contaminated land, and also carry out any further work that is required as a result of that report to ensure that the land is suitable for its final land use in accordance with **Condition F10.** |
| **H25** | Minimise the potential for contamination of land by hazardous contaminants. |
| **H26** | **Impacted land**<br>The holder of the environmental authority must provide the approved report required by Imposed Condition 9, of Appendix 1, of the CG's report, to the administering authority, within **20 business days** of it being approved. |
| **H27** | The holder of the environmental authority must provide a report demonstrating fulfilment of the requirements of Imposed Condition 9(i) — (k) in the CG's report, to the administering authority with any surrender application. |

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| H28 | **Land resource survey**<br>The holder of the environmental authority must provide the approved report required by Imposed Condition 6, of Appendix 1, of the CG's report, to the administering authority, within **20 business days** of approval. |
| H29 | **Rehabilitation of disturbed land**<br>The holder of the environmental authority must provide the approved rehabilitation success criteria required by Imposed Condition 7, of Appendix 1, of the CG's report, to the administering authority within **20 business days** of approval. |

| **Agency interest: Biodiversity** | |
|---|---|
| **Condition number** | **Condition** |
| I1 | The holder of the environmental authority must ensure that staff induction and environmental awareness programs include reference to *Anomalopus mackayi* (Five-clawed Worm-skink, Long-legged Worm-skink) and *Tympanocryptis pinguicolla* (Grassland Earless Dragon, South-eastern Lined Earless Dragon) to ensure that any individuals that might be present in the project area are identified and reported to the mine site environmental officer for recovery and release into suitable habitat. |
| I2 | The holder of this Environmental Authority must develop a Conservation Management Plan for the riparian area of Lagoon Creek and existing stands of regional ecosystems RE11.8.5 and RE11.8.3 located on Bottle Tree Hill and submit the Plan to the Administering Authority and the Department of Natural Resources, Mines and Water within twelve months of the date this environmental authority takes effect. The Plan must for the two proposed conservation areas (Lagoon Creek and Bottle Tree Hill):<br>a) ensure the combined surface area to be protected and enhanced is no less than the surface area of the regional ecosystems proposed to be cleared by mining activities on Mining Leases 50170 and 50216;<br>b) develop appropriate conservation/rehabilitation objectives;<br>c) outline suitable conservation/rehabilitation techniques (including those areas where local native plant species/communities are to be re-established and/or enhanced);<br>d) develop an action plan/rehabilitation schedule for the planned conservation/rehabilitation activities;<br>e) propose specific conservation/rehabilitation acceptance criteria (including those areas where local native plant species/communities are re-established and/or enhanced);<br>f) detail a suitable monitoring program to quantify conservation/rehabilitation success (including those areas where local native plant species/communities are re-established and/or enhanced); and<br>g) propose appropriate remedial actions for conservation/rehabilitation areas not achieving the required conservation/rehabilitation objectives. |

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| **I3** | **Biodiversity offsets**<br>Significant residual impacts to prescribed matters of state environmental significance must not exceed the maximum authorised residual impact area listed for that matter in **Table I1 - Maximum authorised impacts on matters of state environmental significance** and shown in **Figure 4 —Impact on vegetation and habitat**.<br>**Note:** Deemed conditions in Sections 18, 22, 24 and 25 of *the Environmental Offsets Act 2014* are taken to be conditions of this authority. |
| **I4** | The holder of the environmental authority must provide an environmental offset for the following maximum significant residual impacts on matters of state environmental significance in accordance with the requirements of the *Environmental Offsets Act 2014* (including deemed conditions), the *Environmental Offsets Regulation 2014* and the *Queensland Environmental Offsets Policy 2014*. |

**Table I1 — Maximum authorised impacts on matters of state environmental significance**

| RE (Prescribed matter) | VM Act status | Maximum area of residual impact (ha) | Environmental offset required |
|---|---|---|---|
| 11.3.1# | Endangered | 12 | Yes |
| 11.3.21# | Endangered | 35.9 | Yes |
| 11.9.5# | Endangered | 12.6 | |
| 11.3.2 | Of concern | 4.8 | Yes |
| 11.3.17 | Of concern | 7 | Yes |
| 11.8.11# | Of concern | 4.1 | Yes |
| 11.9.10 | Of concern | 4.1 | Yes |
| 11.9.13 | Of concern | 3.6 | Yes |
| *Of concern RE within a defined distance from the defining banks of a relevant watercourse*<br>11.3.2 | Of concern | 2.39 | Yes |
| Koala<br>*Phascolarctos cinereus* | Special least concern | 19.5 | Yes |
| Belson's Panic#<br>*Homopholis belsoni* | Endangered | 70.8 | Yes |

*# These prescribed environmental values duplicate MNES values and, in the event of an Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) decision on the project, offsets for these matters may be conditioned for by the Commonwealth. Further, any offsets conditioned by the Commonwealth are likely to address offsetting for these matters as required by this environmental authority.*

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| **I5** | Residual impacts are not authorised on any Matters of State Environmental Significance not identified in **Table I1 — Maximum authorised impacts on matters of state environmental significance** |
| **I6** | **Environmental Offset Strategy (EOS)**<br>The environmental authority holder must provide the approved environmental offset strategy required by Imposed Condition 13 of the CG's report, to the administering authority within **20 business days** of its being approved. |
| **I7** | **Pre-clearance fauna and flora surveys**<br>Prior to commencement of any project construction activities, the environmental authority holder must conduct pre-clearance ecological surveys of areas to be impacted, consistent with:<br>a) Queensland state government survey guidelines;<br>b) Requirements of the *Nature Conservation Act 1992*; and<br>c) Australian government threatened species guidelines. |
| **I8** | The surveys must be sufficient to identify the extent to which the following will be unavoidably impacted by the project:<br>a) Protected wildlife listed under the *Nature Conservation Act* 1992;<br>b) Matters of state environmental significance (MSES) as defined by the State Planning Policy; and<br>c) MNES as listed under the EPBC Act |
| **I9** | The surveys must include areas of potential foraging, roosting or nesting habitat for the painted honeyeater (*Grantiella picta*). If the painted honeyeater is found during pre-clearance surveys, then any significant impacts on its habitat may require additional offsets in accordance with the EOS for the project. |
| **I10** | If protected plants are found during pre-clearance surveys, then impacts may require a permit under the *Nature Conservation Act 1992* and offsets under the *Environmental Offsets Act 2014*. |
| **I11** | Should additional MSES species and communities be located that were not previously identified during field surveys, the development of management plans and/or additional offsets may be required to address any significant residual impacts for matters of state environmental significance in accordance with the EOS for the project. |
| **I12** | Notification of the discovery of additional protected plants or MSES species and communities will be impacted is to be provided to the administering authority within five business days of the discovery. The proponent is required to propose how the species is to be managed and to seek advice from the administering authority on the undertaking. |
| **I13** | Survey results must be included in an updated EOS for the project. |
| **I14** | Surveys must include area of potential habitat for the vulnerable pale imperial hairstreak butterfly — *Jalmenus eubulus*. If the pale imperial hairstreak is found during pre-clearance surveys, then any significant impacts on its habitat may require additional offsets in accordance with the EOS for the project. |

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| I15 | **Lagoon Creek Conservation Zone Management Plan (CZMP)**<br>The holder of the environmental authority holder must provide the approved Lagoon Creek Conservation Zone Management Plan, which is in accordance with Imposed Condition 15 of the CG's report, to the administering authority, within **20 business days** of it being approved. |
| I16 | **Koala Species Management Plan (KSMP)**<br>The holder of the environmental authority holder must provide the approved Koala species management plan, which is in accordance with Imposed Condition 16 of the CG's report, to the administering authority, within **20 business days** of it being approved. |

| Agency interest: Regulated Structures | |
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| **Condition number** | **Condition** |
| J1 | **Regulated Dams and Levees**<br>The consequence category of any structure must be assessed by a suitable qualified and experienced person in accordance with the *Manual for Assessing Categories and Hydraulic Performance of Structures* (EM635) at the following times:<br>a) Prior to the design and construction of the structure, if it is not an existing structure; or<br>b) If it is an existing structure, prior to the adoption of this schedule; or<br>c) Prior to any change in its purpose or the nature of its stored contents. |
| J2 | A consequence assessment report and certification must be prepared for each structure assessed and the report may include a consequence for more than one structure. |
| J3 | Certification must be provided by the suitably qualified and experienced person who undertook the assessment, in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EM635). |
| J4 | **Design and construction of a regulated structure**<br>**Conditions J5** to **J9** inclusive do not apply to existing structures. |
| J5 | All regulated structures must be designed by and constructed under the supervision of a suitable qualified and experienced person in accordance with the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EM635). |
| J6 | Construction of a regulated structure is prohibited unless the holder has submitted a consequence category assessment report and certification to the administering authority that has been certified by a suitably qualified person for the design and the design plan and the associated operating procedures in compliance with the relevant condition of this authority. |
| J7 | Certification must be provided by the suitable qualified and experienced person who oversees the preparation of the design plan set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EM635), and must be recorded in the Regulated Dams/Levees register. |

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| **J8** | Regulated structures must:<br>a) be designed and constructed in accordance with and conform to the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EM635);<br>b) be designed and constructed with due consideration given to ensuring that the design integrity would not be compromised on account of: floodwaters from entering the regulated dam from any watercourse or drainage line; and wall failure due to erosion by floodwaters arising from any watercourse or drainage line;<br>c) (only for regulated dams associated with a failure to contain seepage) have the floor and sides of the dam designed and constructed to prevent or minimise the passage of the wetting front and any entrained contaminants through either the floor or sides of the dam during the operational life of the dam and for any period of decommissioning and rehabilitation of the dam. |
| **J9** | Certification by the suitable qualified and experienced person who supervises the construction must be submitted to the administering authority on the completion of construction of the regulated structure and state that:<br>a) The 'as constructed' drawings and specifications meet the original intent of the design plan for that regulated structure; and<br>b) Construction of the regulated structure is in accordance with the design plan. |
| **J10** | **Operation of a regulated structure**<br>Operation of a regulated structure, except for an existing structure, is prohibited unless the holder has submitted to the administering authority:<br>a) One paper copy and one electronic copy of the design plan and certification of the 'design plan' in accordance with **Condition J6**; and<br>b) A set of 'as constructed' drawings and specifications; and<br>c) Certification of those 'as constructed drawings and specifications' in accordance with **Condition J6;** and<br>d) Where the regulated structure is to be managed as part of an integrated containment system for the purpose of sharing the DSA volume across the system, a copy of the certified system design plan; and<br>e) The requirements of this authority relating to the construction of the regulated structure have been met; and<br>f) The holder has entered the details required under this authority into a Register of Regulated Dams; and<br>g) There is a current operational plan for the regulated structures. |
| **J11** | For existing structures that are regulated structures:<br>a) Where the existing structure that is a regulated structure is to be managed as part of an integrated containment system for the purposes of sharing DSA volume across the system, the holder must submit to the administering authority within **12 months of the commencement** of this condition a copy of the certified system design plan including that structure; and<br>b) There must be a current operational plan for the existing structures. |
| **J12** | Each regulated structure just be maintained and operated for the duration of its operational life until decommissioned and rehabilitated in a manner that is consistent |

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| | with the current operational plan and if applicable the current design plan and associated certified 'as constructed' drawings. |
| **J13** | **Mandatory reporting level**<br>**Conditions J14 to J17** inclusive apply to Regulated Structures which have not been certified as low consequence category for 'failure to contain — overtopping'. |
| **J14** | The Mandatory Reporting Level (the MRL) must be marked on a regulated dam in such a way that during routine inspections of the dam it is clearly observable. |
| **J15** | The holder must, as soon as practical and **within forty-eight (48) hours** of becoming aware, notify the administering authority when the level of the contents of a regulated dam reaches the MRL. |
| **J16** | The holder must, immediately on becoming aware that the MRL has been reached, act to prevent the occurrence on any unauthorised discharges from the regulated dam. |
| **J17** | The holder must record any changes to the MRL in the Register of Regulated Structures. |
| **J18** | **Design storage allowance**<br>The holder must assess the performance of each regulated dam or linked containment system over the preceding November to May period based on actual observations of the available storage in each regulated dam or linked containment system taken **prior to 1 July of each year.** |
| **J19** | **By 1 November of each year**, storage capacity must be available in each regulated dam (or network of linked containment systems with a shared DSA volume) to meet the Design Storage Allowance (DSA) volume of the dam (or network of linked containment systems). |
| **J20** | The holder must, as soon as possible and within **forty-eight (48) hours** of becoming aware that the regulated dam (or network of linked containment system) will not have the available storage to meet the DSA volume on 1 November of any year, notify the administering authority. |
| **J21** | The holder must, immediately on becoming aware that a regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on 1 November of any year, act to prevent the occurrence of any unauthorised discharge from the regulated dam or linked containment systems. |
| **J22** | **Annual inspection report**<br>Each regulated dam must be inspected each calendar year by a suitable qualified and experienced person. |
| **J23** | At each inspection the condition and adequacy of all components of the regulated structure must be assessed and a suitable qualified and experienced person must prepare an annual inspection report containing details of the assessment and include recommended actions to ensure the integrity of the regulated structure. |
| **J24** | The suitable qualified and experienced person who prepared the annual inspection report must certify the report in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EM635). |

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| **J25** | The holder must:<br>a) **Within 20 business days** of receipt of the annual inspection report provide to the administering authority:<br>(1) the recommendations section of the anneal inspection report; and<br>(2) if applicable, any actions being taken in response to those recommendations; and<br>b) If, following receipt of the recommendations and (if applicable) actions, the administering authority requests a full copy of the annual inspection report from the holder, provide this information to the administering authority **within 10 business days** of receipt of the request. |
| **J26** | **Transfer arrangements**<br>The holder must provide a copy of any reports, documentation and certifications prepared under this authority, including but not limited to and Register of Regulated Structures, consequence assessment, design plan and other supporting documentation, to a new holder on transfer of this authority. |
| **J27** | **Decommissioning and rehabilitation**<br>Dams must not be abandoned but be either:<br>a) Decommissioned and rehabilitated to achieve compliance with **Condition H30**; or<br>b) Be left in-situ for a beneficial use(s) provided that:<br>(1) it no longer contains contaminants that will migrate into the environment; and<br>(2) it contains water of a quality that is demonstrated to be suitable for the intended beneficial use(s); and<br>(3) the administrating authority, the holder of the environmental authority and the landholder agree in writing that the dam will be used by the landholder following cessation of the resource activity. |

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| **J28** | After decommissioning, all significantly disturbed land caused by carrying out of the resource activity must be rehabilitated to meet the final acceptance criteria:<br>a) The landform is safe for humans and fauna;<br>b) The landform is stable with no subsidence of erosion gullies for at least **three (3) years**;<br>c) Any contaminated land (e.g. contaminated soils) is remediated and rehabilitated;<br>d) Not allowing for acid mine drainage;<br>e) There is no ongoing contamination to waters (including groundwater);<br>f) All significantly disturbed land is reinstated as defined in **Table H1 — Rehabilitation requirements**;<br>g) For land that is not being cultivated by the landholder:<br>(1) groundcover, that is not a declared pest species is established and self-sustaining<br>(2) vegetation of similar species richness and species diversity to pre-selected analogue sites is established and self-sustaining, and<br>(3) the maintenance requirements for rehabilitated land is no greater than that required for the land prior to its disturbance caused by carrying out the petroleum activity(ies).<br>h) For land that is to be cultivated by the landowner, cover crop is revegetated, unless the landholder will be preparing the site for cropping **within 3 months** of resource activities being completed. |
| **J29** | **Register of Regulated Dams**<br>A Register of Regulated Dams must be established and maintained by the holder for each regulated dam. |
| **J30** | The holder must provisionally enter the required information in the Register of Regulated Dams when a design plan for a regulated dam is submitted to the administering authority. |
| **J31** | The holder must make a final entry of the required information in the Register of Regulated Dams once compliance with **Condition J10 and J11** has been achieved. |
| **J32** | The holder must ensure that the information contained in the Register of Regulated Dams is current and complete on any given day. |
| **J33** | All entries in the Register of Regulated Dams must be approved by the chief executive officer for the holder of this authority, or the delegate, as being accurate and correct. |
| **J34** | The holder must, at the same time as providing the annual return, supply to the administering authority a copy of the records contained in the Register of Regulated Dams, in the electronic format required by the administering authority. |

| Agency interest: Rail Infrastructure | |
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| **Condition number** | **Condition** |
| **K1** | **Train load-out facility: New Acland Coal Mine Stage 3**<br>The new train load-out facility, rail loop and rail spur for the project is required to be the sole distribution point for all railed product from the first day of operations of the stage 3 project. |
| **K2** | The holder of the EA must notify the administering authority once the Coordinator-General has been notified that the new train-load out facility has become operational. |
| **K3** | **New Acland Coal Mine Stage 3: Rail Spur Design**<br>A suitably qualified person must certify that the design and construction of the rail spur:<br>a) is in accordance with the design criteria in the Department of Transport and Main Roads (March 2010) Road Drainage Manual 2nd edition; and<br>b) meets the following criteria for a two per cent annual exceedance probability rainfall event (50-year Annual Recurrence Interval):<br>(1) not cause, or have the potential to increase flood damage at a domestic premises or commercial premises;<br>(2) a maximum increase in afflux of 0.1m at a domestic premises or commercial premises;<br>(3) a maximum increase in afflux of 0.2m at the Jondayran-Muldu road, or existing electricity, water supply, sewage or telecommunications infrastructure in the town of Jondaryan;<br>(4) a design objective of an increase in afflux of 0.3m, with a maximum increase in afflux of 0.5m at other locations;<br>(5) a maximum culvert outlet velocity of 2.5m/s; and<br>(6) any increase in duration of floodplain inundation is not to exceed 72 hours or 20 per cent of existing flood duration (whichever is greater). |
| **K4** | A copy of the certification required by **Condition K3** is to be provided to the Administering Authority upon request. |
| **K5** | Land owners, residents, asset owners likely to be impacted by changes to the existing flooding/drainage system, and, at a minimum, Toowoomba Regional Council and the Queensland Reconstruction Authority must be consulted prior to completion of the final rail spur design |
| **K6** | Where the rail spur cannot be designed, constructed and maintained so as not to cause or increase flood damage at residential premises or at a commercial premises, compensation is to be negotiated with affected land owners, residents, and asset owners. |

| Agency interest: Light | |
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| **Condition number** | **Condition** |
| **L1** | Subject to **Condition L2**, the emission of light resulting from the mining activity must not cause an environmental nuisance at any sensitive place. |
| **L2** | When requested by the administering authority, an assessment of the light nuisance* must be undertaken within a reasonable and practicable timeframe nominated by the administering authority to investigate any complaint (which is neither frivolous nor vexatious based on mistaken belief in the opinion of the authorised officer) of environmental nuisance at any sensitive place, and the results must be notified within **14 days** of the administering authority following completion of the assessment.<br>(* Assessment to be conducted according to and with reference to the limits specified in AS 4282-1997 Control of the Obtrusive Effects of Outdoor lights). |
| **L3** | If the assessment indicates **Condition L2** is not being met then the environmental authority holder must:<br>a) address the complaint including the use of appropriate dispute resolution if required; or<br>b) immediately implement light abatement measures so the emissions of light from the activity do not result in further environmental nuisance. |

| Agency interest: Community | |
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| **Condition number** | **Condition** |
| **M1** | **Complaints**<br>The holder of this environmental authority must record all environmental complaints received about the mining activities including:<br>a) name, address and contact number for of the complainant;<br>b) time and date of complaint;<br>c) reasons for the complaint;<br>d) investigations undertaken;<br>e) conclusions formed;<br>f) actions taken to resolve the complaint;<br>g) any abatement measures implemented; and<br>h) person responsible for resolving the complaint.<br>The information as outlined in **Condition M1 (a) to (h)** with the consent of the complainant must be sent to the administering authority (and the complainant) within 28 days of the action taken to resolve the complaint. |
| **M2** | The holder of this environmental authority must, when requested by the administering authority, undertake relevant specified monitoring within a reasonable timeframe nominated or agreed to by the administering authority to investigate any complaint of |

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| | environmental harm. The results of the investigation (including an analysis and interpretation of the monitoring results) and abatement measures, where implemented, must be provided to the administering authority **within 10 business days** of completion of the investigation, or no later than 10 business days after the end of the timeframe nominated by the administering authority to undertake the investigation. |
| **M3** | **Notification of emergencies, incidents and exceptions**<br>The holder of this environmental authority must notify the administering authority by written notification **within 24 hours** after becoming aware of any emergency or incident which results in the release of contaminants not in accordance, or reasonably expected to be not in accordance with, the conditions of this environmental authority. |
| **M4** | **Within 10 business days** following the initial notification of an emergency or incident, or receipt of monitoring results, whichever is the later, further written advice must be provided to the administering authority, including the following:<br>a) results and interpretation of any samples taken and analysed;<br>b) outcomes of actions taken at the time to prevent or minimise unlawful environmental harm; and<br>c) proposed actions to prevent a recurrence of the emergency or incident. |
| **M5** | At the completion of mining, the environmental authority holder must apply to the relevant authority to restore or provide alternative road access to Acland Township, in particular the war memorial. |
| **M6** | Basalt from stockpiles must only be transported within the approved mining area as indicated in **Figure 1 (Revised Project Overview - Mine Area)**, wherever possible. |
| **M7** | The environmental authority holder must provide an independent counselling service accessible to all local landowners located within 5km of the mining lease boundary to deal with concerns, stress and emotional distress associated with mining activities. |

**Definitions**

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| **acid rock drainage** | any contaminated discharge emanating from a mining activity formed through a series of chemical and biological reactions, when geological strata is disturbed and exposed to oxygen and moisture. |
| **acceptance criteria** | means the measures by which actions implemented are deemed to be complete. The acceptance criteria indicate the success of the decommissioning and rehabilitation outcomes or remediation of areas which have been significantly been disturbed by the mining activities. Acceptance criteria may include information regarding:<br>- stability of final land forms in terms of settlement, erosion, weathering, pondage and drainage;<br>- control of geochemical and contaminant transport processes;<br>- quality of runoff waters and potential impact on receiving environment;<br>- vegetation establishment, survival and succession;<br>- vegetation productivity, sustained growth and structure development;<br>- fauna colonisation and habitat development;<br>- ecosystem processes such as soil development and nutrient cycling, and the recolonisation of specific fauna groups such as collembola, mites and termites which are involved in these processes;<br>- microbiological studies including recolonisation by mycorrhizal fungi, microbial biomass and respiration;<br>- effects of various establishment treatments such as deep ripping, topsoil handling, seeding and fertiliser application on vegetation growth and development;<br>- resilience of vegetation to disease, insect attack, drought and fire;<br>- vegetation water use and effects on ground water levels and catchment yields. |
| **administering authority** | means the Environmental Protection Agency or its successor. |
| **affected person** | someone whose drinking water can potentially be impacted as a result of discharges from a dam or their life can be put at risk due to dwellings or workplaces being in the path of a dam break flood. |
| **airblast overpressure** | energy transmitted from the blast site within the atmosphere in the form of pressure waves. The maximum excess pressure in this wave, above ambient pressure is the peak airblast overpressure measured in decibels linear (dBL). |
| **ambient (or total) noise** | at a place, means the level of noise at the place from all sources (near and far), measured as the Leq for an appropriate time interval. |
| **appropriately qualified person** | a person who has professional qualifications, training, skills or experience relevant to the nominated subject matter and can give authoritative assessment, advice and analysis on performance relating |

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| | to the subject matter using the relevant protocols, standards, methods or literature. |
| **annual inspection report** | an assessment prepared by a suitably qualified and experienced person containing details of the assessment against the most recent consequence assessment report and design plan (or system design plan):<br>• against recommendations contained in previous annual inspections reports;<br>• against recognised dam safety deficiency indicators;<br>• for changes in circumstances potentially leading to a change in consequence category;<br>• for conformance with the conditions of this authority;<br>• for conformance with the 'as constructed' drawings;<br>• for the adequacy of the available storage in each regulated dam, based on an actual observation or observations taken after 31 May each year but prior to 1 November of that year, of accumulated sediment, state of the containment barrier and the level of liquids in the dam (or network of linked containment systems);<br>• for evidence of conformance with the current operational plan. |
| **Annual Exceedance Probability or AEP** | the probability that at least one event in excess of a particular magnitude will occur in any given year. |
| **appropriately qualified person** | means a person or body possessing appropriate experience and qualifications to perform these tasks. |
| **assessed or assessment by a suitably qualified and experienced person** in relation to a consequence assessment of a dam | a statutory declaration has been made by that person and, when taken together with any attached or appended documents referenced in that declaration, all of the following aspects are addressed and are sufficient to allow an independent audit of the assessment:<br>• exactly what has been assessed and the precise nature of that determination;<br>• the relevant legislative, regulatory and technical criteria on which the assessment has been based;<br>• the relevant data and facts on which the assessment has been based, the source of that material, and the efforts made to obtain all relevant data and facts; and<br>• the reasoning on which the assessment has been based using the relevant data and facts, and the relevant criteria. |
| **associated works in relation to a dam** | operations of any kind and all things constructed, erected or installed for that dam; and<br>any land used for those operations. |
| **authority** | an environmental authority or a development approval. |
| **background,** with reference to the water schedule | the average of samples taken prior to the commencement of mining from the same waterway that the current sample has been taken. |

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| **background noise level** | means noise, measured in the absence of the noise under investigation, as either:<br>• L A90,T being the A-weighted sound pressure level exceeded for 90 percent of the time period of not less than 15 minutes, using Fast response, or<br>• L LAbg,T being the arithmetic average of the minimum readings during a representative time period of not less than 15 minutes, using Fast response. |
| **blasting** | the use of explosive materials to fracture:<br>• rock, coal and other minerals for later recovery; or<br>• structural components or other items to facilitate removal from a site or for reuse. |
| **Certification** | assessment and approval must be undertaken by a suitably qualified and experienced person in relation to any assessment or documentation required by the Manual (*Manual for Assessing Categories and Hydraulic Performance of Structures* (EM635)), including design plans, 'as constructed' drawings and specifications, construction, operation or an annual report regarding regulated structures, undertaken in accordance with the Board of Professional Engineers of Queensland Policy Certification by RPEQs (ID: 1.4 (2A)). |
| **Certifying, certify or certified** | a corresponding meaning as certification |
| **chemical** | • an agricultural chemical product or veterinary chemical product within the meaning of the *Agricultural and Veterinary Chemicals Code Act 1994* (Commonwealth); or<br>• a dangerous good under the Australian Code for the Transport of Dangerous Goods by Road and Rail approved by the Australian Transport Council; or<br>• a lead hazardous substance within the meaning of the Workplace Health and Safety Regulation 1997;<br>• a drug or poison in the Standard for the Uniform Scheduling of Drugs and Poisons prepared by the Australian Health Ministers Advisory Council and published by the Commonwealth; or<br>• any substance used as, or intended for use as:<br>a) a pesticide, insecticide, fungicide, herbicide, rodenticide, nematocide, miticide, fumigant or related product; or<br>b) a surface active agent, including, for example, soap or related detergent; or<br>c) a paint solvent, pigment, dye, printing ink, industrial polish, adhesive, sealant, food additive, bleach, sanitiser, disinfectant, or biocide; or<br>d) a fertiliser for agricultural, horticultural or garden use; or |

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| | e) a substance used for, or intended for use for mineral processing or treatment of metal, pulp and paper, textile, timber, water or wastewater; or<br>f) manufacture of plastic or synthetic rubber. |
| **commercial place** | a workplace used as an office or for business or commercial purposes, which is not part of the mining activity and does not include employee accommodation or public roads. |
| **Consequence** in relation to a structure as defined | the potential for environmental harm resulting from the collapse or failure of the structure to perform its primary purpose of containing, diverting or controlling flowable substances. |
| **Consequence category** | a category, either low, significant or high, into which a dam is assessed as a result of the application of tables and other criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EM635). |
| **construction or constructed** in relation to a dam | includes building a new dam and modifying or lifting an existing dam, but does not include investigations and testing necessary for the purpose of preparing a design plan. |
| **dam** | a land-based structure or a void that contains, diverts or controls flowable substances, and includes any substances that are thereby contained, diverted or controlled by that land-based structure or void and associated works. |
| **dam crest volume** | the volume of material (liquids and/or solids) that could be within the walls of a dam at any time when the upper level of that material is at the crest level of that dam. That is, the instantaneous maximum volume within the walls, without regard to flows entering or leaving (for example, via spillway). |
| **dB (Linear) Peak** | is the maximum reading in decibels (dB) obtained using the "P" time — weighting characteristic as specified in AS 1259.1 — 1990 with all frequency — weighted networks inoperative |
| **declared plant** | means a plant that has been declared under the *Rural Lands Protection Act 1985* |
| **design plan** | a document setting out how all identified consequence scenarios are addressed in the planned design and operation of a regulated structure. |
| **design storage allowance or DSA** | an available volume, estimated in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EM635) published by the administering authority, must be provided in a dam as at 1 November each year in order to prevent a discharge from that dam to an **annual exceedance probability** (AEP) specified in that Manual. |
| **designer** for the purposes of a regulated dam | the certifier of the design plan for the regulated dam. |
| **development approval** | a development approval under the *Integrated Planning Act 1997* or the *Sustainable Planning Act 2009* in relation to a matter that involves an environmentally relevant activity under the *Environmental Protection Act 1994.* |

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| **disturbance of land** | includes:<br>• compacting, removing, covering, exposing or stockpiling of earth;<br>• removal or destruction of vegetation or topsoil or both to an extent where the land has been made susceptible to erosion;<br>• carrying out mining within a watercourse, waterway, wetland or lake;<br>• the submersion of areas by tailings or hazardous contaminant storage and dam/structure walls;<br>• temporary infrastructure, including any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads etc.) which is to be removed after the mining activity has ceased; or<br>• releasing of contaminants into the soil, or underlying geological strata.<br>However, the following areas are not included when calculating areas of disturbance:<br>• areas off lease (e.g. roads or tracks which provide access to the mining lease);<br>• areas previously disturbed which have achieved the rehabilitation outcomes;<br>• by agreement with the administering authority, areas previously disturbed which have not achieved the rehabilitation objective(s) due to circumstances beyond the control of the mine operator (such as climatic conditions);<br>• areas under permanent infrastructure. Permanent infrastructure includes any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads etc) which is to be left by agreement with the landowner;<br>• disturbance that pre-existed the grant of the tenure. |
| **EC** | electrical conductivity. |
| **effluent** | treated waste water released from sewage treatment plants. |
| **emergency action plan** | documentation forming part of the operational plan held by the holder or a nominated responsible officer, that identifies emergency conditions that sets out procedures and actions that will be followed and taken by the dam owner and operating personnel in the event of an emergency. The actions are to minimise the risk and consequences of failure, and ensure timely warning to downstream communities and the implementation of protection measures. The plan must require dam owners to annually update contact. |
| **environmental authority holder** | means the holder of this environmental authority |

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| **environmental nuisance** | is unreasonable interference or likely interference with an environmental value caused by:<br>a) noise, dust, odour, light; or<br>b) an unhealthy, offensive or unsightly condition because of contamination; or<br>c) another way prescribed by regulation. |
| **existing structure** | a structure that was in existence prior to the adoption of this schedule of conditions under the authority. |
| **Extreme Storm Storage** | a storm storage allowance determined in accordance with the criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EM635) published by the administering authority |
| **flowable substance** | matter or a mixture of materials which can flow under any conditions potentially affecting that substance. Constituents of a flowable substance can include water, other liquids fluids or solids, or a mixture that includes water and any other liquids fluids or solids either in solution or suspension. |
| **foreseeable future** | is the period used for assessing the total risk of an event occurring. Permanent structures and ecological sustainability should be expected to still exist at the end of a 150 year foreseeable future with an acceptable risk of failure before that time. |
| **hazard category** | a category, either low significant or high, into which a dam is assessed as a result of the application of tables and other criteria in Manual for Assessing Hazard Categories and Hydraulic Performance of Dams. |
| **holder** | • where this document is an environmental authority, any person who is the holder of, or is acting under, that environmental authority; or<br>• where this document is a development approval, any person who is the registered operator for that development approval. |
| **hydraulic performance** | the capacity of a regulated dam to contain or safely pass flowable substances based on the design criteria specified for the relevant consequence category in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EM635). |
| **infrastructure** | water storage dams, levees, roads and tracks, buildings and other structures built for the purpose of the mining activity. |
| **LAmax adj,T** | means the average maximum A-weighted sound pressure level, adjusted for noise character and measured over a time period of not less than 15 minutes, using Fast response |
| **land** in the land schedule of this document | land excluding waters and the atmosphere, that is, the term has a different meaning from the term as defined in the *Environmental Protection Act 1994*. For the purposes of the *Acts Interpretation Act 1954*, it is expressly noted that the term land in this environmental authority relates to physical land and not to interests in land. |

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| **land capability** | as defined in the DME 1995 Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland |
| **land suitability** | as defined in the DME 1995 Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland. |
| **land use** | the selected post mining use of the land, which is planned to occur after the cessation of mining operations. |
| **LAr, 1 hour** | means the specific noise level measured as the A-weighted equivalent continuous noise level (LAeq) plus any adjustment for the character of the noise (tonal and/or impulsive) determined over a reference time period of one hour |
| **leachate** | a liquid that has passed through or emerged from, or is likely to have passed through or emerged from, a material stored, processed or disposed of at the operational land which contains soluble, suspended or miscible contaminants likely to have been derived from the said material. |
| **levee** | an embankment that only provides for the containment and diversion of stormwater or flood flows from a contributing catchment, or containment and diversion of flowable materials resulting from releases from other works, during the progress of those stormwater or flood flows or those releases; and does not store any significant volume of **water** or **flowable substances** at any other times. |
| **licensed place** | the mining activities carried out at the mining tenements detailed in this environmental authority. |
| **low consequence dam** | any dam that is not a high or significant consequence category as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EM635) |
| **m** | metres |
| **mandatory reporting level or MRL** | a warning and reporting level determined in accordance with the criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EM635) published by the administering authority. |
| **manual** | the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EM635) published by the administering authority. |
| **maximum** | means that the measured value of the quality characteristic or contaminant must not be greater than the release limit stated |
| **Maximum Instantaneous Charge (MIC)** | is the maximum amount of explosive on any one specific delay detonator in any one blast hole. |
| **MaxLpA,T** | means the maximum A-weighted sound pressure level measured over a time period of not less than 15 minutes, using Fast response |

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| **measures** | includes any measures to prevent or minimise environmental impacts of the mining activity such as bunds, silt fences, diversion drains, capping, and containment systems. |
| **median** | means the middle value, where half the data are smaller, and half the data are larger. If the number of samples is even, the median is the arithmetic average of the two middle values |
| **mg/kg** | means milligrams per kilogram |
| **mg/L** | means milligrams per litre |

| | |
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| **mine-affected water** | the following types of water:<br>i. pit water, tailings dam water, processing plant water;<br>ii. water contaminated by a mining activity which would have been an environmentally relevant activity under Schedule 2 of the Environmental Protection Regulation 2008 if it had not formed part of the mining activity;<br>iii. rainfall runoff which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated, excluding rainfall runoff discharging through release points associated with erosion and sediment control structures that have been installed in accordance with the standards and requirements of an Erosion and Sediment Control Plan to manage such runoff, provided that this water has not been mixed with pit water, tailings dam water, processing plant water or workshop water;<br>iv. groundwater which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated;<br>v. groundwater from the mines dewatering activities;<br>vi. a mix of mine affected water (under any of paragraphs i-v, above) and other water.<br>does not include surface water runoff which, to the extent that it has been in contact with areas disturbed by mining activities that have not yet been completely rehabilitated, has only been in contact with:<br>• land that has been rehabilitated to a stable landform and either capped or revegetated in accordance with the acceptance criteria set out in the environmental authority but only still awaiting maintenance and monitoring of the rehabilitation over a specified period of time to demonstrate rehabilitation success; or<br>• land that has partially been rehabilitated and monitoring demonstrates the relevant part of the landform with which the water has been in contact does not cause environmental harm to waters or groundwater, for example:<br>a) areas that are been capped and have monitoring data demonstrating hazardous material adequately contained with the site;<br>b) evidence provided through monitoring that the relevant surface water would have met the water quality parameters for mine affected water release limits in this environmental authority, if those parameters had been applicable to the surface water runoff; or<br>c) both. |
| **minimum** | means that the measured value of the quality characteristic or contaminant must not be less than the release limit stated |
| **modification or modifying** | see definition of construction |
| **NATA** | National Association of Testing Authorities, Australia. |

| | |
|---|---|
| **natural flow** | the flow of water through waters caused by nature. |
| **ng/L** | means nanograms per litre |
| **noise sensitive place** | means:<br>• a legal dwelling, caravan park, residential marina or other residential premises; or<br>• a motel, hotel or hostel; or<br>• a kindergarten, school, university or other educational institution; or<br>• a medical centre or hospital; or<br>• a protected area; or<br>• a public park or gardens; and<br>• includes the curtilage of any such place.<br>but does not include<br>(a) places that are within the boundaries of the mining lease; or<br>(b) places that are owned or leased by the holder of the environmental authority or its related companies; or<br>(c) places for which an agreement has been entered into between the holder of the environmental authority and the owner of the place for the provision of alternative measures to mitigate the impact of mining activities for the Stage 3 New Acland Mine Project at the place, where those measures are reasonably expected to result in noise levels experienced at the place that are consistent with the relevant limits in Table F1 - Noise Limits. |
| **non polluting** | having no adverse impacts upon the receiving environment. |
| **noxious** | means harmful or injurious to health or physical well being, other than trivial harm |
| **offensive** | means causing unreasonable offence or displeasure; is unreasonably disagreeable to the sense; disgusting, nauseous or repulsive, other than trivial harm. |
| **operational plan** | includes:<br>• normal operating procedures and rules (including clear documentation and definition of process inputs in the DSA allowance);<br>• contingency and emergency action plans including operating procedures designed to avoid and/or minimise environmental impacts including threats to human life resulting from any overtopping or loss of structural integrity of the regulated structure. |
| **peak particle velocity (ppv)** | a measure of ground vibration magnitude which is the maximum rate of change of ground displacement with time, usually measured in millimetres/second (mm/s). |
| **protected area** | means: |

| | |
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| | • a protected area under the *Nature Conservation Act 1992*; or<br>• a marine park under the *Marine Parks Act 1992*; or<br>• a World Heritage Area. |
| **progressive rehabilitation** | means rehabilitation (defined below) undertaken progressively OR a staged approach to rehabilitation as mining operations are ongoing |
| **range** | means that the measured value of the quality characteristic or contaminant must not be greater than the higher release limit stated nor lower than the lower release limit stated |
| **receiving environment** in relation to an activity that causes or may cause environmental harm | the part of the environment to which the harm is, or may be, caused. The receiving environment includes (but is not limited to):<br>• a watercourse;<br>• groundwater; and<br>• an area of land. |
| **receiving waters** | the waters into which this environmental authority authorises releases of mine affected water. |
| **Register of Regulated Dams** | includes:<br>• Date of entry in the register;<br>• Name of the dam, its purpose and intended/actual contents;<br>• The consequence category of the dam as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EM635);<br>• Dates, names, and reference for the design plan plus dates, names, and reference numbers of all document(s) lodged as part of a design plan for the dam;<br>• Name and qualifications of the suitably qualified and experienced person who certified the design plan and as constructed drawings;<br>• For the regulated dam, other than in relation to any levees -<br>a) The dimensions (metres) and surface area (hectares) of the dam measured at the footprint of the dam;<br>b) Coordinates (latitude and longitude in GDA94) within five metres at any point from the outside of the dam including its storage area;<br>c) Dam crest volume (megalitres);<br>d) Spillway crest level (metres AHD).;<br>e) Maximum operating level (metres AHD);<br>f) Storage rating table of stored volume versus level (metres AHD);<br>g) Design storage allowance (megalitres) and associated level of the dam (metres AHD);<br>h) Mandatory reporting level (metres AHD); |

| | |
|---|---|
| | • The design plan title and reference relevant to the dam;<br>• The date construction was certified as compliant with the design plan;<br>• The name and details of the suitably qualified and experienced person who certified that the constructed dam was compliant with the design plan;<br>• Details of the composition and construction of any liner;<br>• The system for the detection of any leakage through the floor and sides of the dam;<br>• Dates when the regulated dam underwent an annual inspection for structural and operational adequacy, and to ascertain the available storage volume for 1 November of any year;<br>• Dates when recommendations and actions arising from the annual inspection were provided to the administering authority;<br>• Dam water quality as obtained from any monitoring required under this authority as at 1 November of each year. |
| **rehabilitation** | the process of reshaping and revegetating land to restore it to a stable landform |
| **release event** | a surface water discharge from mine affected water storages or contaminated areas on the licensed place. |
| **RL** | reduced level, relative to mean sea level as distinct from depths to water. |
| **representative** | a sample set which covers the variance in monitoring or other data either due to natural changes or operational phases of the mining activities. |
| **regulated dam** | any dam in the significant or high consequence category as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EM635) published by the administering authority. |
| **regulated structure** | includes land-based containment structures, levees, bunds and voids, but not a tank or container designed and constructed to an Australian Standard that deals with strength and structural integrity. |
| **residual drilling material** | waste drilling materials including muds and cuttings or cement returns from well holes and which have been left behind after the drilling fluids are pumped out. |
| **residual void** | means an open pit resulting from the removal of ore and/or waste rock, which will remain following the cessation of all mining activities and completion of rehabilitation processes |
| **saline drainage** | the movement of waters, contaminated with salts, as a result of the mining activity. |

| | |
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| **self sustaining** | means an area of land which has been rehabilitated and has maintained the required acceptance criteria without human intervention for a period nominated by the administering authority. |
| **sensitive place** | • a dwelling, residential allotment, mobile home or caravan park, residential marina or other residential premises; or<br>• a motel, hotel or hostel; or<br>• an educational institution; or<br>• a medical centre or hospital; or<br>• a protected area under the *Nature Conservation Act 1992*, the *Marine Parks Act 1992* or a World Heritage Area; or<br>• a public park or gardens. |
| **Structure** | dam or levee. |
| **Spillway** | a weir, channel, conduit, tunnel, gate or other structure designed to permit discharges form the dam, normally under flood conditions or in anticipation of flood conditions. |
| **spillway crest** | means the highest point (elevation) of the spillway, above which water will flow along the spillway and discharge from the dam if the flow rate is sufficient |
| **stable** | means land form dimensions are or will be stable within tolerable limits now and in the foreseeable future. Stability includes consideration of geotechnical stability, settlement and consolidation allowances, bearing capacity (traffic ability), erosion resistance and geochemical stability with respect to seepage and contaminant generation |
| **Stage 3 New Acland mine project** | means the Stage 3 New Acland mine project that was approved in the CG's report. |
| **suitably qualified and experienced person in relation to air emissions** | A person who is a Registered Professional Engineer of Queensland (RPEQ) under the provisions of the Professional Engineers Act 2002, and has demonstrated competency and relevant experience in relation to air emissions. |
| **suitably qualified and experienced person in relation to noise** | A person who is a Registered Professional Engineer of Queensland (RPEQ) under the provisions of the Professional Engineers Act 2002, and has demonstrated competency and relevant experience as an acoustician. |
| **suitably qualified and experienced person** in relation to regulated structures | a person who is a Registered Professional Engineer of Queensland (RPEQ) under the provisions of the *Professional Engineers Act 2002*, and has demonstrated competency and relevant experience:<br>• for regulated dams, an RPEQ who is a civil engineer with the required qualifications in dam safety and dam design.<br>• for regulated levees, an RPEQ who is a civil engineer with the required qualifications in the design of flood protection embankments.<br>Note: It is permissible that a suitably qualified and experienced person obtain subsidiary certification from an RPEQ who has demonstrated |

| | |
|---|---|
| | competence and relevant experience in either geomechanics, hydraulic design or engineering hydrology. |
| **system design plan** | a plan that manages an integrated containment system that shares the required DSA and/or ESS volume across the integrated containment system. |
| **the Act** | the *Environmental Protection Act 1994.* |
| **tolerable limits** | means that a range of values could be accepted to achieve an overall environmental management objective (eg a range of settlement of a tailing capping could still meet the objective of draining the cap quickly, preventing pondage and limiting infiltration and percolation) |
| **uS/cm** | microsiemens per centimetre. |
| **ug/L** | means micrograms per litre. |
| **void** | any constructed, open excavation in the ground. |
| **watercourse** | has the meaning in Schedule 4 of the *Environmental Protection Act 1994* and means a river, creek or stream in which water flows permanently or intermittently—<br>• in a natural channel, whether artificially improved or not; or<br>• in an artificial channel that has changed the course of the watercourse.<br>watercourse includes the bed and banks and any other element of a river, creek or stream confining or containing water. |
| **Waters** | includes all or any part of a river, stream, lake, lagoon, pond, swamp, wetland, unconfined surface water, unconfined water in natural or artificial watercourses, bed and banks of a watercourse, dams, non-tidal or tidal waters (including the sea), stormwater channel, stormwater drain, roadside gutter, stormwater run-off, and groundwater. |
| **Water quality** | the chemical, physical and biological condition of water. |
| **Water year** | the 12-month period from 1 July to 30 June. |
| **Wet season** | the time of year, covering one or more months, when most of the average annual rainfall in a region occurs. For the purposes of DSA determination this time of year is deemed to extend from 1 November in one year to 31 May in the following year inclusive. |

## Agency Interest — Figures

### Figure 1: Revised Project Overview — Mine Area

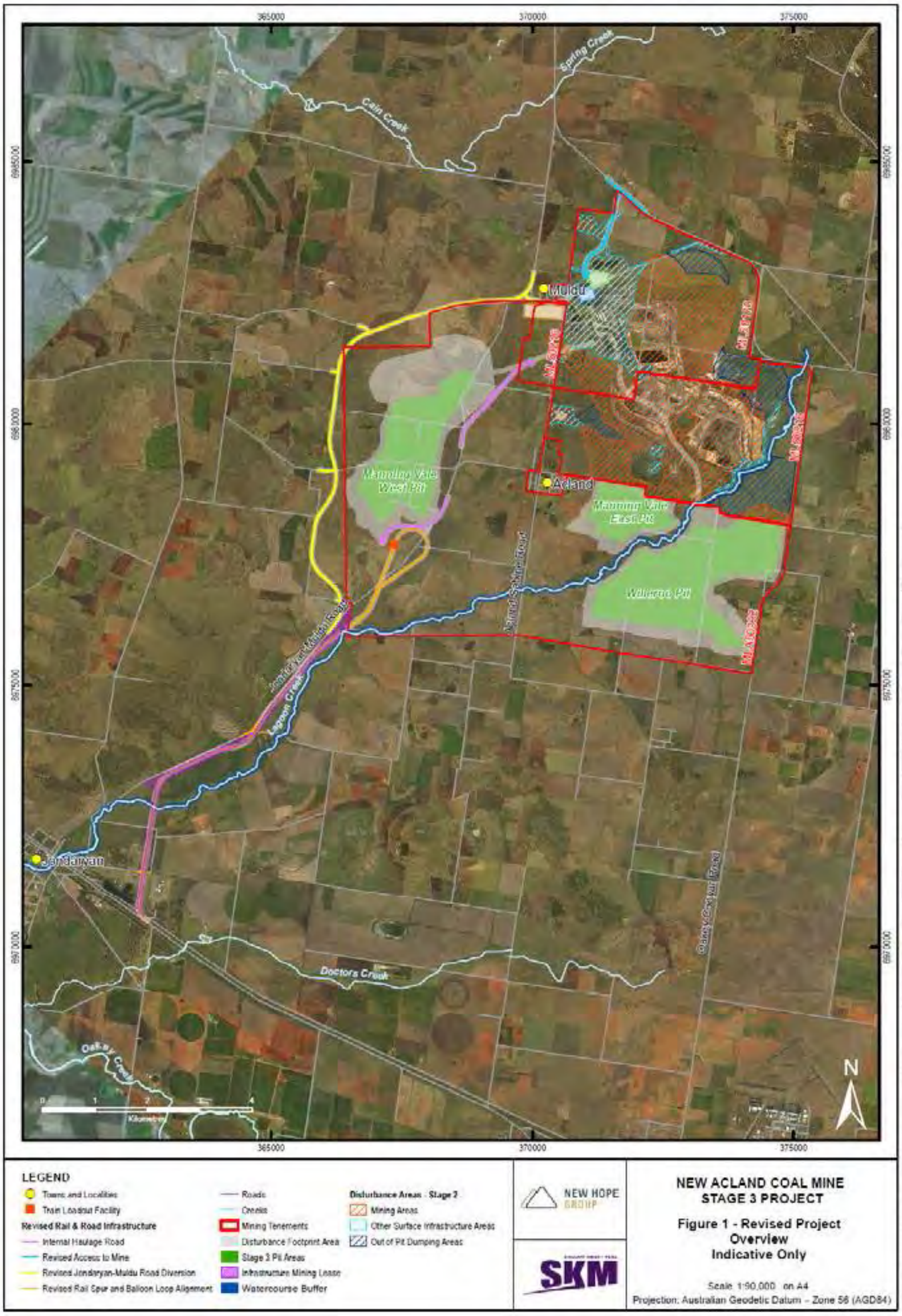


**Figure 2: Mine affected water release points, sources and receiving waters monitoring locations**

Figure 3: Lagoon Creek, buffer and levee

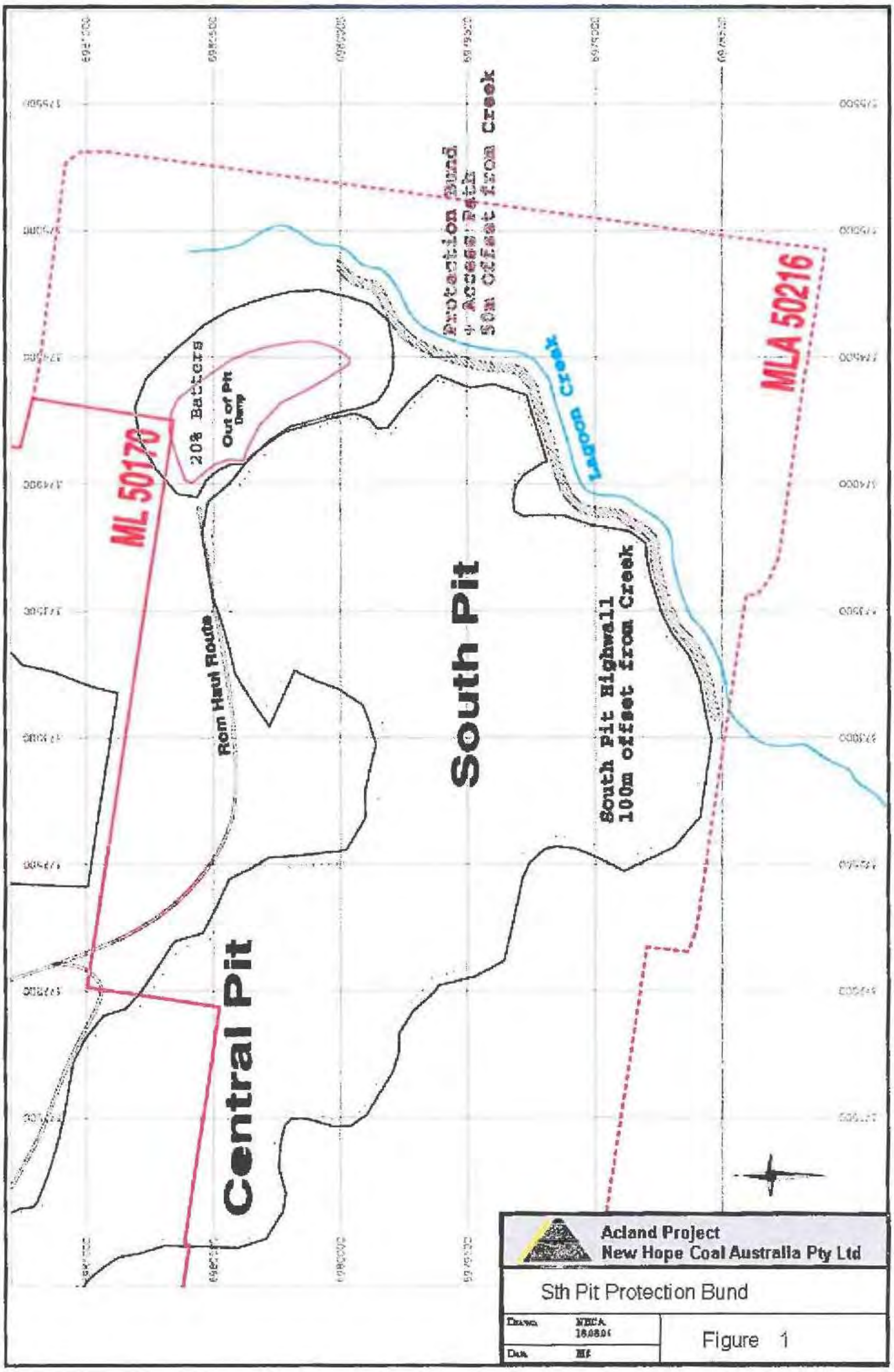


**Figure 4 - Impact on vegetation and habitat**

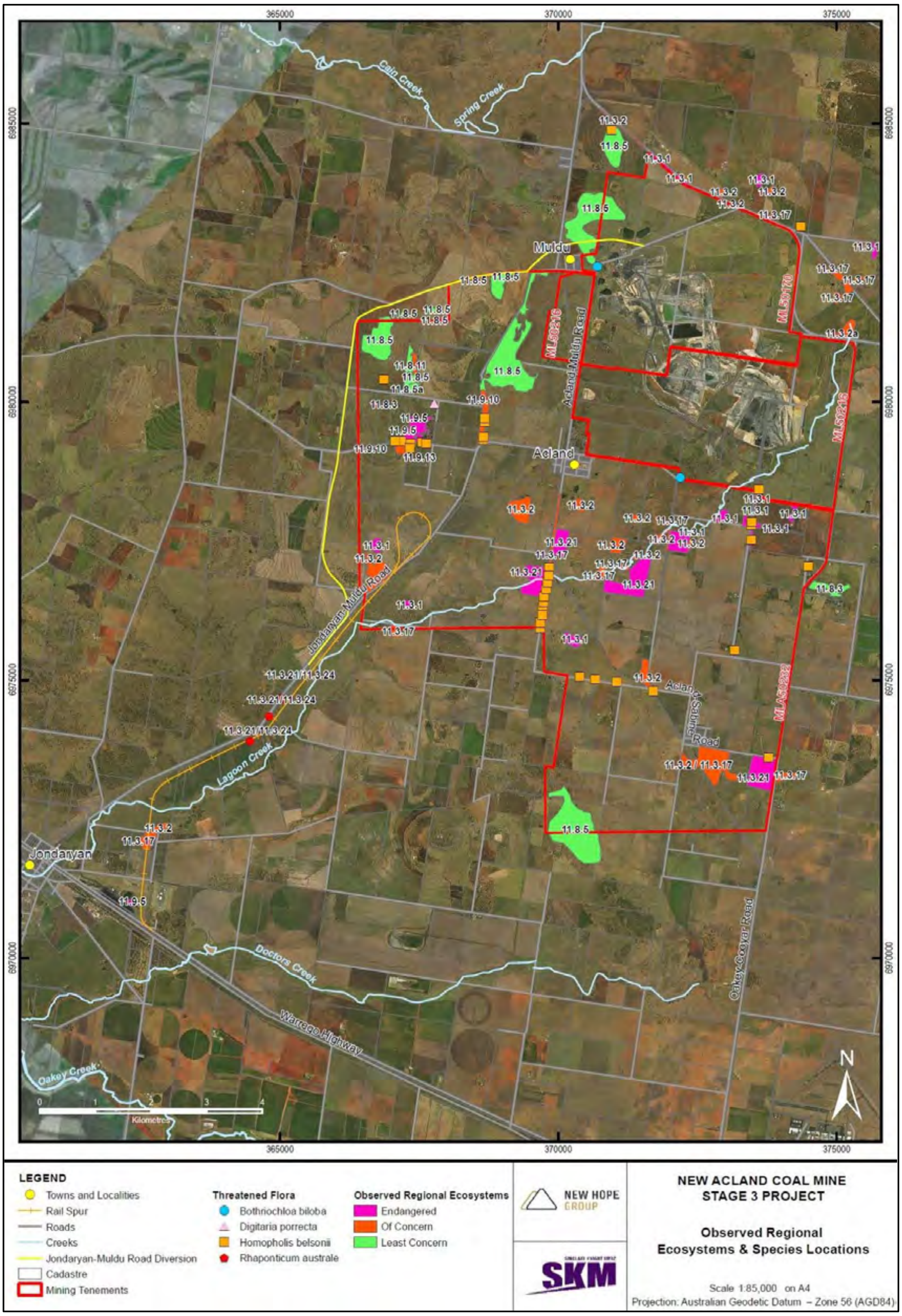


**Figure 5 — Location of sensitive receptors**

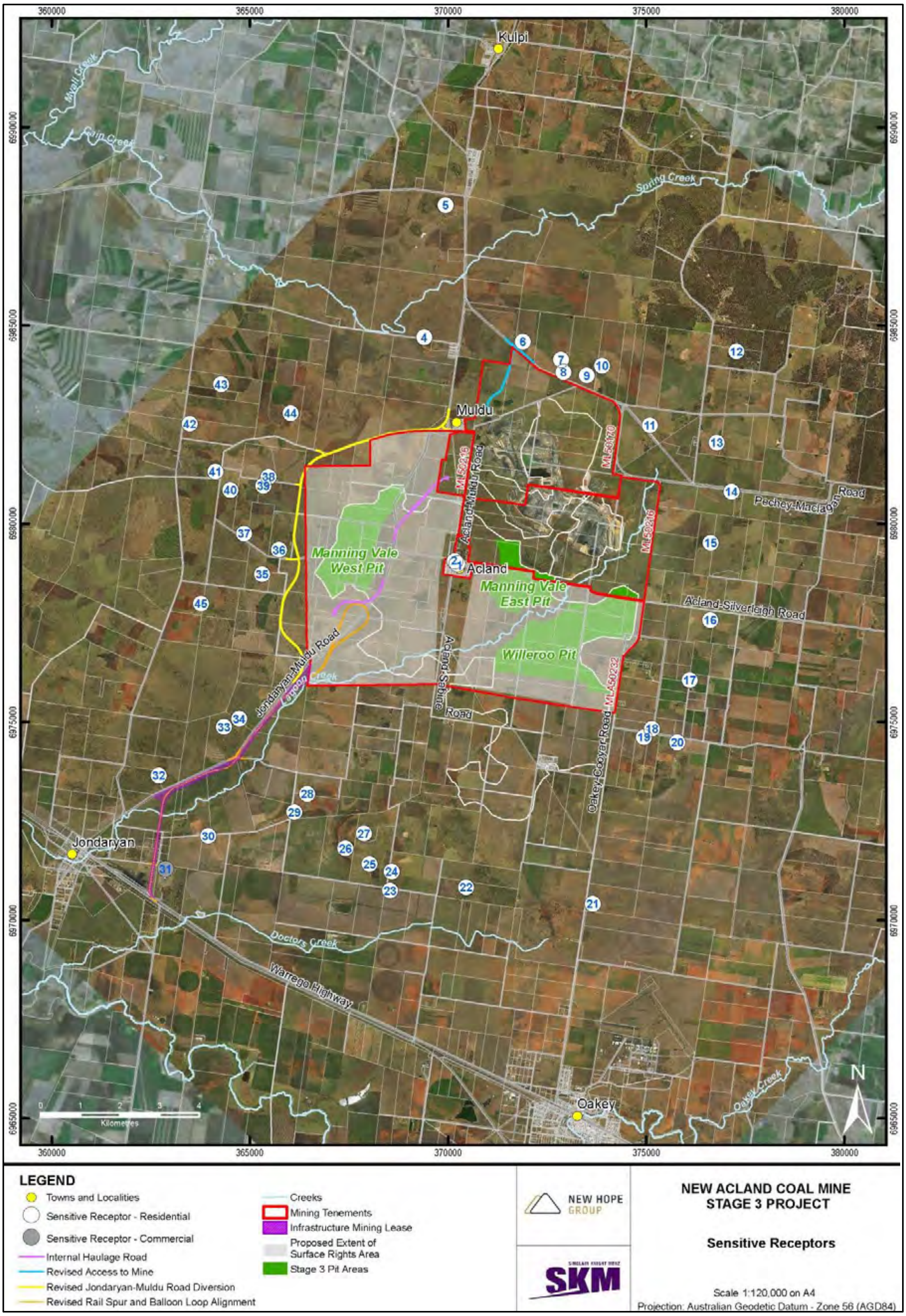


**Figure 6 — Air quality monitoring locations for the revised project (Stage 3)**

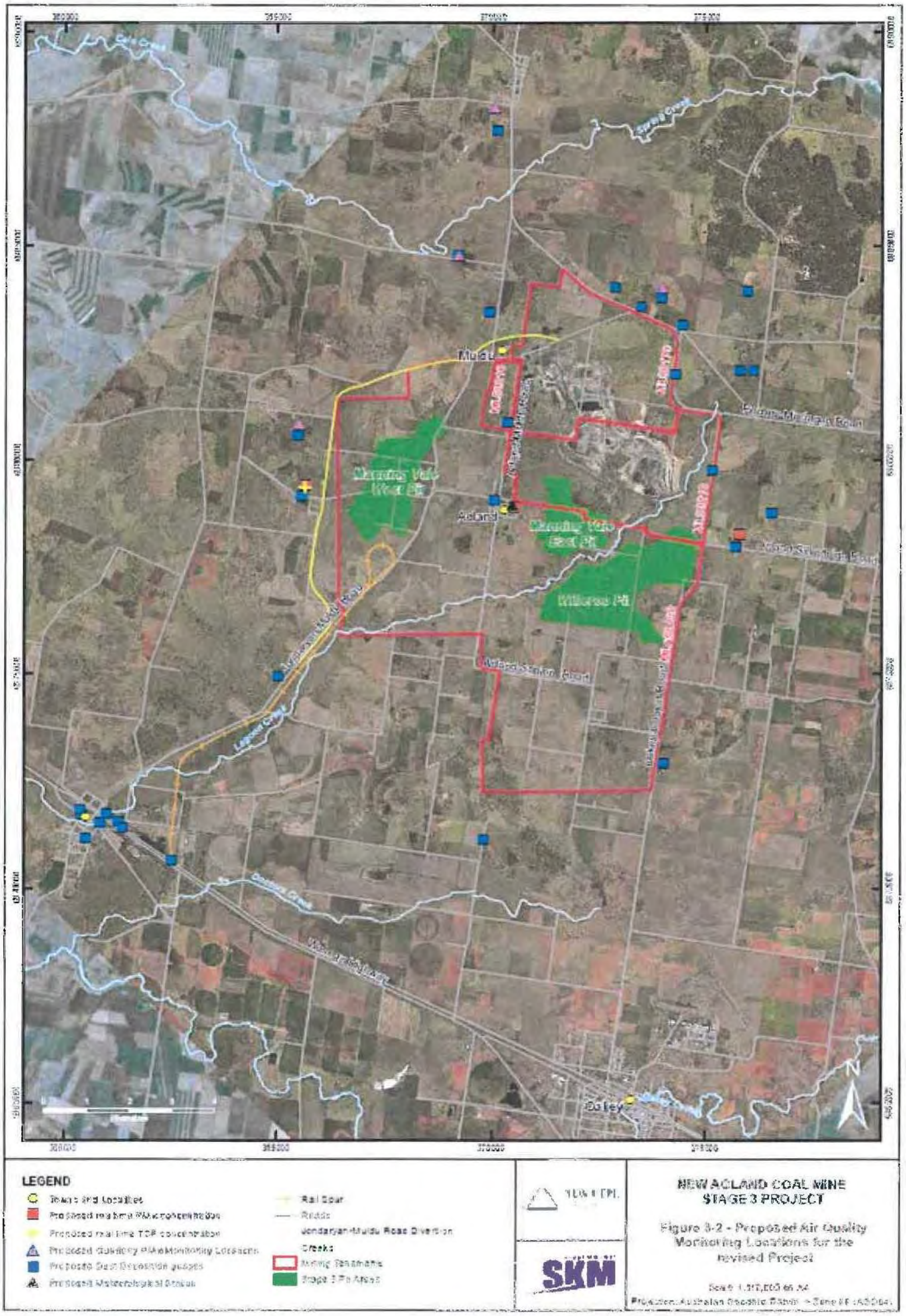
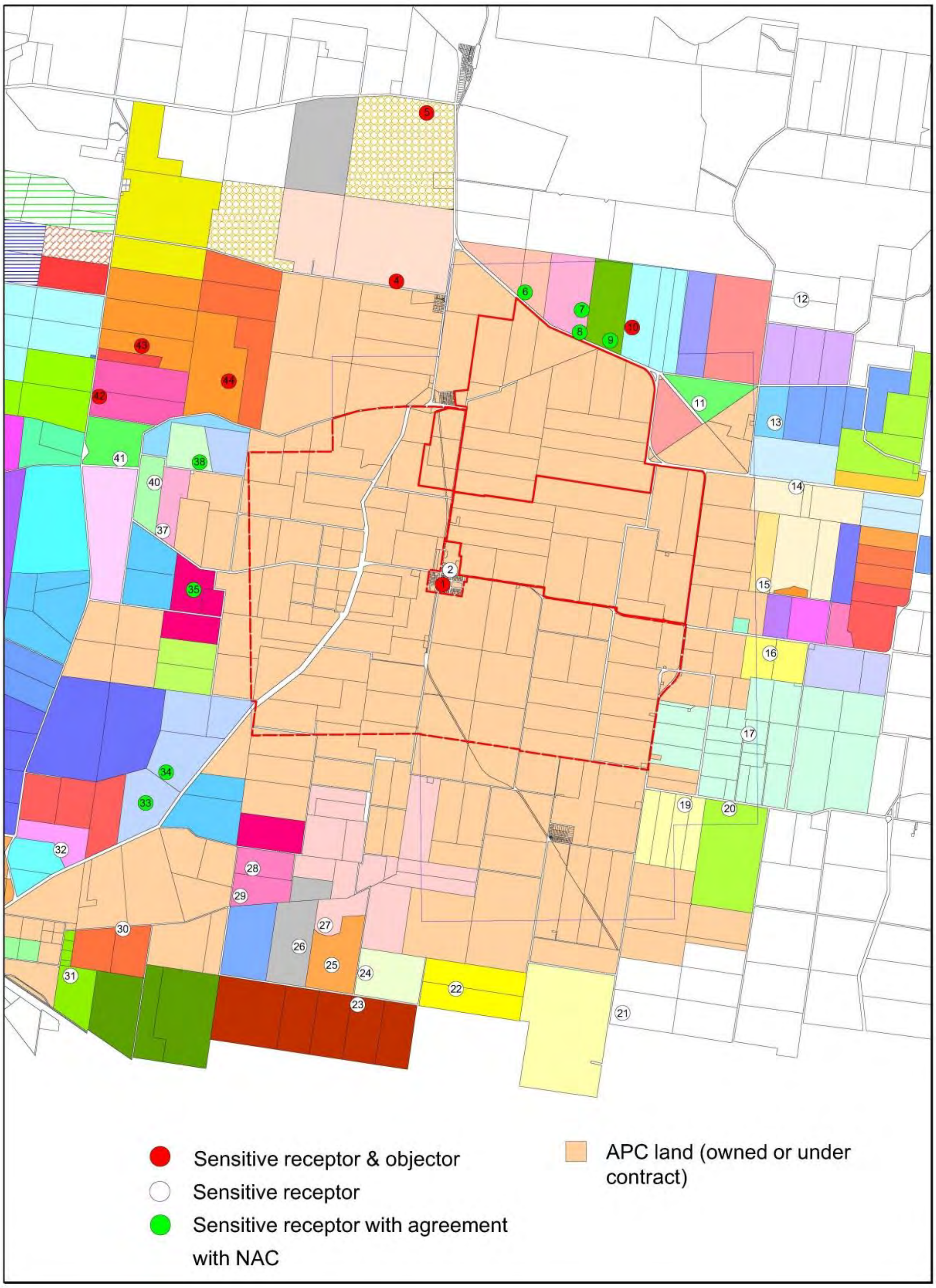


**Figure 7 - Noise Sensitive Places (Mitigation)**



**NAC Attachment 11 - DES Progressive Rehabilitation Certification**

# Notice

***Environmental Protection Act 1994***

## Decision about an application for progressive certification

*This notice is issued by the administering authority[1] pursuant to section 318ZJ of the* Environmental Protection Act 1994 *to advise of a decision made about an application for a progressive rehabilitation certification.*

New Acland Coal Pty Ltd
3/22 Magnolia Drive
BROOKWATER QLD 4300

ATTN: Thomas Sheppard
Email: tsheppard@newhopegroup.com.au

Our reference: EPML00335713

## Decision about an application for progressive certification for a resource project

### 1. Application details

The application for progressive certification of an environmental authority was received by the administering authority on **14 August 2018**

Land description: New Acland Coal Mine, ML50170 and ML50216

### 2. Decision

The administering authority has considered the criteria for making a decision on the progressive certification application under section 318ZI of the *Environmental Protection Act 1994* (the Act) and has decided to give the progressive certification under section 318ZH of the Act.

### 3. Reasons for the decision

The Department of Environment and Science has decided to approve 349ha of the 376.9ha applied for in this application for certification of progressive rehabilitation for the following reasons:

- The administering authority inspected the site on 14 May 2018.
- The area is considered safe, stable, self-sustaining and non-polluting. However, some erosion was recorded within the proposed rehabilitation area, with a majority occurring within the areas of rehabilitation less than 2 years in age.

[1] The Department of Environment and Science is the administering authority under the *Environmental Protection Act 1994*.

- The administering authority has considered the EA conditions, rehabilitation completion criteria, rehabilitation report and standard criteria.
- The approved progressive rehabilitation area (see Attachment 1) meets the EA conditions and rehabilitation completion criteria. The department proposes to undertake an amendment of the EA, by agreement, to include the approved progressive rehabilitation area detailed in Attachment 1 of this notice and relevant conditions for the management of this area.
- The holder of the EA must "*maintain the certified rehabilitated area for the relevant tenure under the conditions of the authority in force when the certification was given*", pursuant to section 318ZB of the Act.
- The risk assessment indicated only low and moderate risks and residual risks, and no residual risk payment is required.

## 4. Review and appeal rights

You may apply to the administering authority for a review of this decision within 10 business days after receiving this notice. You may also appeal against this decision to the Land Court. Information about your review and appeal rights is attached to this notice. This information is guidance only and you may have other legal rights and obligations.

Should you have any questions in relation to this notice, please contact the department using the contact details provided below.

| Signature | Date |
|---|---|
| | 1 November 2018 |

Rebecca Munro
Department of Environment and Science
Delegate of the administering authority
*Environmental Protection Act 1994*

**Enquiries:**
Charissa Allan
Coal Business Centre
PO Box 3028, Emerald QLD 4720
Phone: (07) 4987 9320
Email: CRMining@ehp.qld.gov.au

**Attachments**

- Attachment 1: New Acland Coal Mine Progressive Certification Area.
- Information sheet: Internal review and appeals (ESR/2015/1742)

**ATTACHMENT 1: NEW ACLAND COAL MINE PROGRESSIVE REHABILITATION CERTIFICATION AREA**

**NAC Attachment 12 - Project Soil Management Plan**

global environmental solutions

# Soil Management Plan

# New Acland Coal Mine

# Stage 3 Project

Report Number 620.11226

16 February 2017

Version: Final

# Soil Management Plan

# New Acland Coal Mine

# Stage 3 Project

PREPARED BY:

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## DOCUMENT CONTROL

| Reference | Status | Date | Prepared | Checked | Authorised |
|---|---|---|---|---|---|
| 620.11226 | Draft 1 | 29 October 2015 | Clayton Richards | | Clayton Richards |
| 620.11226 | Draft 2 | 17 February 20172016 | Clayton Richards | | Clayton Richards |
| 620.11226 | Final | 17 February 2017 | Clayton Richards | | Clayton Richards |
| | | | | | |
| | | | | | |
| | | | | | |

# Table of Contents

# Table of Contents



**TABLES**



**FIGURES**

# 1 INTRODUCTION

NAC currently operates the Mine as a 5.2 million tonne (product coal) per annum (Mtpa) open cut coal mine on Mining Lease (ML) 50170 and ML 50216, adjacent to Mineral Development Licence (MDL) 244, under the approval of Environmental Authority EPML00335713. The Mine reserve is forecast to be depleted in 2018. The Stage 3 Project involves the extension and operation of the Mine, while increasing production from 5.2 Mtpa up to 7.5 Mtpa of thermal product coal.

The Stage 3 Project involves the extension of the Mine's operating life to approximately 2029 with the inclusion and progressive development of two new resource areas within MLA 50232. These resource areas are identified as the Manning Vale and Willeroo resource areas. The revised Project will include mining in three new mine pits, namely Manning Vale West, Manning Vale East and Willeroo mine pits. This Soil Management Plan (SMP) has been prepared to demonstrate how both topsoil and subsoil will be preserved in a condition as near as possible to its pre-mining condition in order to allow successful mine rehabilitation. This SMP covers all soils to be removed and replaced within the Disturbance Boundary prior to mining. The SMP includes procedures for storage of topsoil during the life of the revised Project and appropriate use of topsoil during progressive rehabilitation. The SMP provides the following information:

- a description of the existing soils within the Project site (with reference to the Soil and land resource assessment (SLR 2015) and the Strategic Cropping Assessment Report (SLR 2015);
- a soil stripping procedure that aims to maximise volumes of suitable soil removed thereby maximising soil available for mine closure and rehabilitation works;
- a soil balance with recommended stripping depths;
- a stockpile design and maintenance procedure;
- erosion control techniques – for stockpiled topsoil and exposed subsoil following stripping and during mine rehabilitation;
- a topsoil application procedure – to be used during mine rehabilitation; and
- reporting and review requirements.

# 2 LEGISLATIVE FRAMEWORK

The SMP has been developed in accordance with the conditions of;

**New Acland Coal Mine Stage 3 project: Co-Ordinator-General's Evaluation Report on the EIS (December 2014) - Imposed Conditions:**

Condition 7. Rehabilitation of disturbed land

(a) Rehabilitation is to be undertaken so as to establish discrete land units (that is, no unjustified mixing of soil material from different land units) in the disturbed areas to be rehabilitated ('rehabilitation area'), each capable of ultimately being assigned a specific post-disturbance land use suitability.

(b) The rehabilitation of disturbed land is to result in the affected land units being able to support the best post-disturbance land use possible. The post-disturbance land suitability of each land unit is to:

(i) represent that achievable on an ongoing basis

(ii) be obtainable without the use of irrigation; and

(iii) be such that collectively at least 50 per cent of the total area of disturbed land originally meeting or exceeding the criteria for either Class 3 grazing land or Class 4 cropping land still meet or exceed those classifications.

Condition 8. Reports and management plans

(b) Subsequent to complying with Condition 6: Land resource survey, and prior to the commencement of project operations, the proponent must submit to and have approved by the Coordinator-General, the following documents:

(i) Final Land Use and Rehabilitation Plan; and

(ii) Topsoil Management Plan.

# 3 STAKEHOLDER CONSULTATION

This SMP has been prepared in consultation with personnel from New Hope Group, New Acland Coal Mine and SLR Consulting and has been submitted to the Coordinator General for approval as per imposed condition 8b(ii).

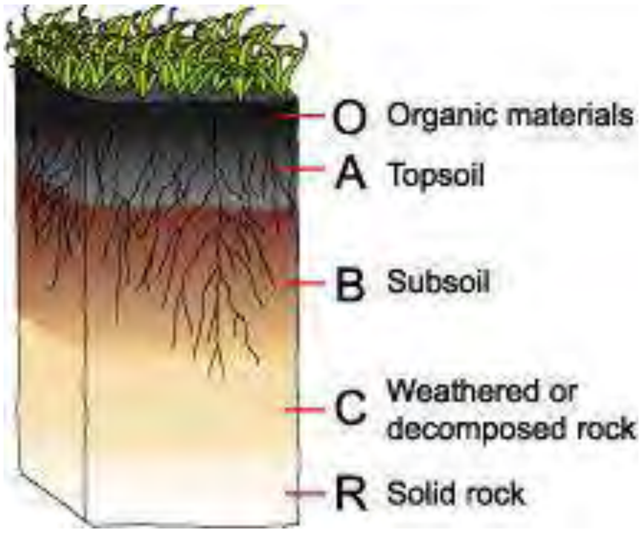
# 4 EXISTING SOIL RESOURCES

## 4.1 Soil Units within the Project Site

A typical soil profile is shown in Figure 2-1 and described below.

**A Horizon (Topsoil)**: This layer is generally darker than other horizons and may contain decomposed organic materials (humus). Topsoil includes the O layer (organic) which contains organic material in varying stages of decomposition. The A horizon has the maximum biological activity for any given soil profile.

**B Horizon (Subsoil)**: Layer has a distinctly different structure or consistency to the A horizon and usually contains a higher clay content. Plant roots penetrate through this layer although it has very little humus.



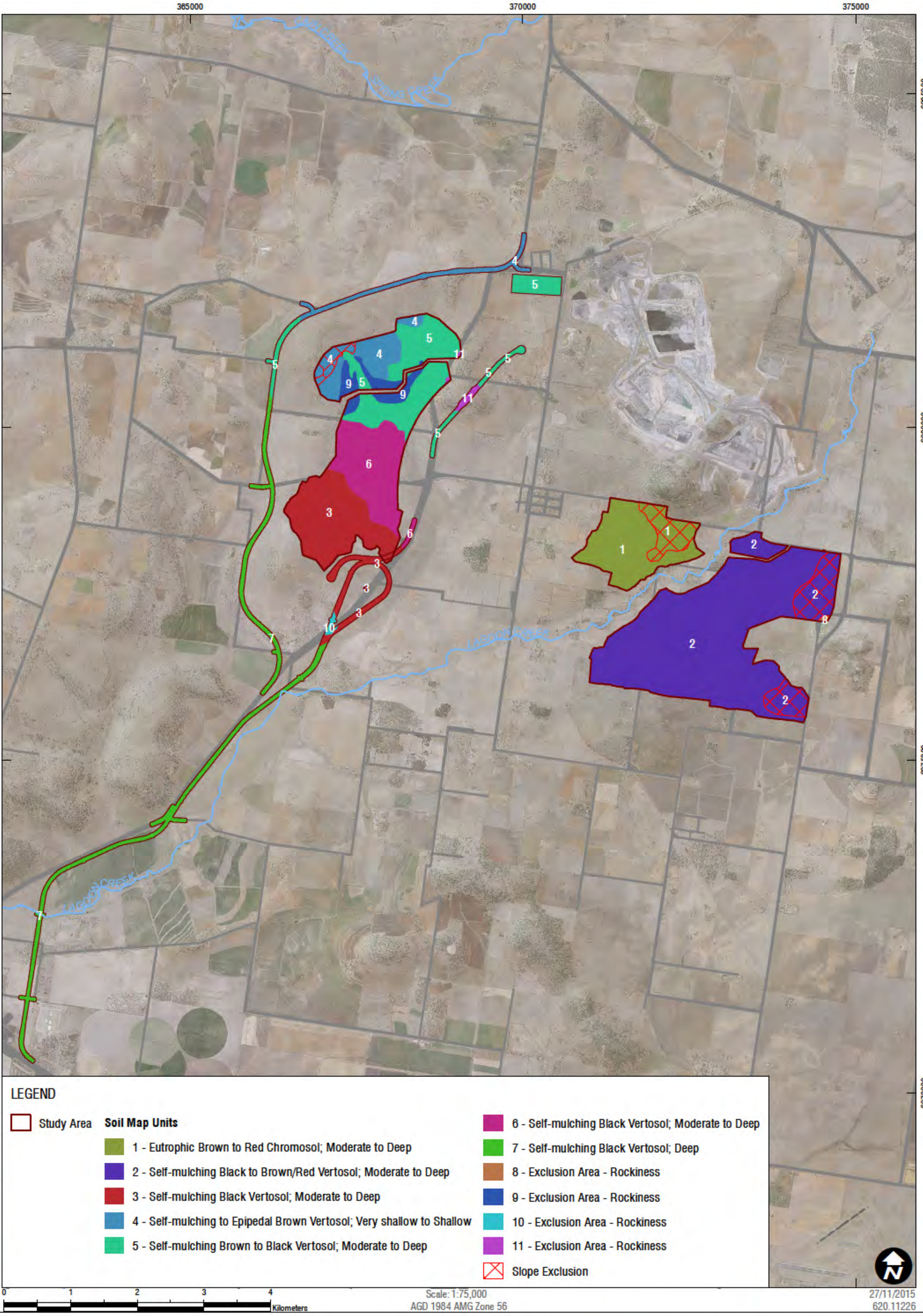

**Soil Profile Schematic** **(Figure Source: Government of Western Australia)**

The A horizon is generally referred to as ‘topsoil’ and the B horizon is referred to as ‘subsoil’, however throughout this document Topsoil is used to describe the top 300mm of soil in all vertosols and the top 200mm in the Chomosols on site. The Project’s topsoils and subsoils will be selectively handled (stripping depth and depth of return) dependant on the soil type, and will either be directly returned or stockpiled for later use dependant on the rehabilitation requirement and the stage of mine development. Topsoil and subsoil stockpiled for later use in rehabilitation will be required to be stored separately.

Soil types within the Project site were surveyed in May/June/July 2015 to determine land suitability, Strategic Cropping Land (SCL) classification, topsoil depth and subsoil depth (to refusal or 1.2m). The surveyed soil types are listed below in **Table 1** and described in **Section 3.1**. The distribution of soils within the Project site is shown in **Figure 1**.

**Table 1 Soil map units and associated areas to be stripped within mining disturbance**

| Soil Map Units | Stripping Areas (ha) |
|---|---|
| 1 - Eutrophic Brown to Red Chromosol; Moderate to Deep | 156.6 |
| 2 - Self-mulching Black to Brown/Red Vertosol; Moderate to Deep | 560.9 |
| 3 - Self-mulching Black Vertosol; Moderate to Deep | 141.9 |
| 4 - Self-mulching to Epipedal Brown Vertosol; Very shallow to Shallow | 68.2 |
| 5 - Self-mulching Brown to Black Vertosol; Moderate to Deep | 133.7 |
| 6 - Self-mulching Black Vertosol; Moderate to Deep | 122.1 |
| **Total Area able to be stripped** | **1183.4** |
| 8 - Exclusion Area - Rockiness | 1.1 |
| 9 - Exclusion Area - Rockiness | 35.5 |
| 11 - Exclusion Area - Rockiness | 1.0 |
| **Total Area unable to be stripped** | **37.6** |
| **Total Area** | **1221.0** |

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**Soil Map Units**

**FIGURE 1**

### 4.1.1 Soil Map Unit 1 - Eutrophic Brown to Red Chromosol; Moderate to Deep

| | |
|---|---|
| **ASC Name** | Eutrophic Brown Chromosol; Deep |
| **Site No.** | 96 |
| **Eastings; Northings** | 371636; 6978059 |
| **Geology** | Walloon Subgroup |
| **Microrelief** | Nil |
| **Landform Pattern** | Hillslope |
| **Landform Element** | Midslope |
| **Dominant Slope (%)** | 1-3% |
| **Slope Type** | Simple |
| **Surface Coarse Fragments** | 25% 10-20 mm ironstone |
| **Surface Fragments > 60 mm** | Nil |
| **Drainage** | Moderately well |
| **Permeability** | Moderate to slow |
| **Site Disturbances** | Previously cultivated |
| **Current Land Use** | Grazing pasture |
| **Surface Condition** | Hard-setting |
| **Vegetation** | Love Grass, QLD Purple Top, Wattle |

| Profile | Horizon / Depth (m) | Description |
|---|---|---|
|  | A1<br>0.0 – 0.10 | Dark brown (7.5YR 3/2) Clay Loam, Moderate structure of 10 mm polyhedral peds with a rough-ped fabric and firm consistence.<br><br>Nil mottling; 40% <10 mm ironstone stone content; Nil segregations; Clear and even boundary. |
| | B21<br>0.10 – 0.55 | Dark brown (7.5YR 3/3) Heavy Clay, Strong structure of 20-50 mm polyhedral peds with a smooth-ped fabric and firm consistence.<br><br>Nil mottling; 10% <10 mm ironstone stone content; Nil segregations; Gradual and even boundary. |
| | B22<br>0.55 – 1.10 | Brown (7.5YR 4/4) Heavy Clay, Strong structure of 100 mm subangular blocky peds with a smooth-ped fabric and very firm consistence.<br><br>Nil mottling; Nil stone content; 30% 20-50 mm calcareous soft segregations. |

### 4.1.2 Soil Map Unit 2 - Self-mulching Black to Brown/Red Vertosol; Moderate to Deep

| | |
|---|---|
| **ASC Name** | Self-mulching Black Vertosol; Deep |
| **Site No.** | 116 |
| **Eastings; Northings** | 373221; 6977690 |
| **Geology** | Walloon Subgroup |
| **Microrelief** | Linear gilgai |
| **Landform Pattern** | Hillslope |
| **Landform Element** | Midlslope |
| **Dominant Slope (%)** | 1-3% |
| **Slope Type** | Simple |
| **Surface Coarse Fragments** | 10% 20 mm ironstone |
| **Surface Fragments > 60 mm** | Nil |
| **Drainage** | Moderately well |
| **Permeability** | Moderate |
| **Site Disturbances** | Previously cultivated |
| **Current Land Use** | Grazing pasture |
| **Surface Condition** | Self-mulching |
| **Vegetation** | Hairy Panic, Turnip Weed, Black Thistle, Red Grass |

| Profile | Horizon / Depth (m) | Description |
|---|---|---|
|  | A1<br>0.0 – 0.10 | Very dark gray (10YR 3/1) Light-medium Clay, Moderate structure of <10 mm crumb peds with a rough-ped fabric and firm consistence. Nil mottling; 10% 10 mm ironstone stone content; Nil segregations; Clear and even boundary. |
| | B21<br>0.10 – 0.30 | Dark grayish-brown (10YR 4/2) Heavy Clay, Strong structure of 20-50 mm polyhedral peds with a smooth-ped fabric and firm consistence. Nil mottling; Nil stone content; Nil segregations; Gradual and irregular boundary. |
| | B22<br>0.30 – 0.80 | Very dark gray (10YR 3/1) Heavy Clay, Strong structure of 20-50 mm angular blocky peds with a smooth-ped fabric and firm consistence. Nil mottling; Nil stone content; 10% 5 mm calcareous soft segregations; Gradual and even boundary. |
| | B23<br>0.80 – 1.10 | Black (10YR 2/1) Heavy Clay, Strong structure of 50-100 mm angular blocky peds with a smooth-ped fabric and very firm consistence. 5% faint orange mottling; 10% 10 mm ironstone stone content; 20% 10 mm calcareous soft segregations. |

#### 4.1.3 Soil Map Unit 8 - Self-mulching Black to Brown/Red Vertosol; Moderate to Deep (Surface Rock)

| | |
|---|---|
| **Site No.** | E22 |
| **Eastings; Northings** | 374529; 6977122 |
| **Surface Coarse Fragments** | 25% >200mm basalt |
| **Surface Fragments > 60 mm** | 25% basalt |
| **Site** | |

### 4.1.4 Soil Map Unit 3 - Self-mulching Black Vertosol; Moderate to Deep

| | |
|---|---|
| **ASC Name** | Self-mulching Brown Vertosol; Moderate |
| **Site No.** | 75 |
| **Eastings; Northings** | 367125; 6978477 |
| **Geology** | Colluvium |
| **Microrelief** | Linear gilgai |
| **Landform Pattern** | Hillslope |
| **Landform Element** | Midslope (bench) |
| **Dominant Slope (%)** | 1-3% |
| **Slope Type** | Simple |
| **Surface Coarse Fragments** | Nil |
| **Surface Fragments > 60 mm** | Nil |
| **Drainage** | Moderately well |
| **Permeability** | Moderate |
| **Site Disturbances** | Previously cutivated |
| **Current Land Use** | Grazing pasture |
| **Surface Condition** | Self-mulching (cracked) |
| **Vegetation** | Red Grass, Rhodes. Acacia, QLD Purple Top |

| Profile | Horizon / Depth (m) | Description |
|---|---|---|
|  | A1<br>0.0 – 0.10 | Very dark grayish brown (10YR 3/2) Light Clay, Strong structure of 20 mm subangular blocky peds with a smooth-ped fabric and firm consistence. Nil mottling; <10% <10 mm ironstone stone content; Nil segregations; Clear and even boundary. |
| | B21<br>0.10 – 0.50 | Brown (10YR 4/3) Heavy Clay, Strong structure of 20 mm subangular blocky peds with a smooth-ped fabric and firm consistence.Nil mottling; Nil stone content; <1% <5 mm calcareous nodule segregations; Clear and wavy boundary. |
| | B22<br>0.50 – 0.90 | Dark grayish-brown (10YR 4/2) Heavy Clay, Strong structure of 20-50 mm polyhedral peds with a smooth-ped fabric and very firm consistence. Nil mottling; <5% <5 mm unidentified stone content; <2% <5 mm calcareous nodule segregations; Clear and wavy boundary. |
| | BC<br>0.9+ | Weathering Bedrock |

### 4.1.5 Soil Map Unit 4 - Self-mulching to Epipedal Brown Vertosol; Very Shallow to Shallow

| | |
|---|---|
| **ASC Name** | Self-mulching Brown Vertosol; Shallow |
| **Site No.** | 227 |
| **Eastings; Northings** | 367890; 6980794 |
| **Geology** | Basalt |
| **Microrelief** | Normal gilgai |
| **Landform Pattern** | Hillslope |
| **Landform Element** | Midslope (bench) |
| **Dominant Slope (%)** | 1-3% |
| **Slope Type** | Flat |
| **Surface Coarse Fragments** | <5% 50-100 mm basalt |
| **Surface Fragments > 60 mm** | <5% basalt |
| **Drainage** | Moderately well |
| **Permeability** | Moderate |
| **Site Disturbances** | Previously cultivated |
| **Current Land Use** | Grazing pasture |
| **Surface Condition** | Self-mulching / crusted |
| **Vegetation** | Red Grass |

| Profile | Horizon / Depth (m) | Description |
|---|---|---|
|  | A1<br>0.0 – 0.10 | Dark brown (10YR 3/3) Heavy Clay, Moderate structure of <10 mm crumb peds with a rough-ped fabric and weak consistence.<br>Nil mottling; Nil stone content; Nil segregations; Clear and even boundary. |
| | B21<br>0.10 – 0.30 | Dark brown (10YR 3/3) Heavy Clay, Strong structure of 10-20 mm polyhedral peds with a smooth-ped fabric and firm consistence.<br>Nil mottling; Nil stone content; Nil segregations; Gradual and even boundary. |
| | B22<br>0.40 – 0.70 | Weathering bedrock |
| | C<br>0.70+ | Bedrock |

### 4.1.6 Soil Map Unit 9 - Self-mulching to Epipedal Brown Vertosol; Very Shallow to Shallow (Surface Rock)

| | |
|---|---|
| **Assigned to ASC Order** | Self-mulching Brown Vertosol; Shallow |
| **Site No.** | 6 |
| **Eastings; Northings** | 367958; 6980578 |
| **Geology** | Colluvium |
| **Microrelief** | Normal gilgai (slight) |
| **Landform Pattern** | Hillslope |
| **Landform Element** | Crest |
| **Dominant Slope (%)** | 1-3% |
| **Slope Type** | Simple |
| **Surface Coarse Fragments** | 80% >200 mm basalt |
| **Surface Fragments > 60 mm** | 80% basalt |
| **Site Disturbances** | Extensive clearing |
| **Current Land Use** | Grazing pasture |
| **Surface Condition** | Loose |
| **Vegetation** | White box, Red Grass, three orn grass, Red Gum, couch, boxthorn. |

| **Profile** | **Description** |
|---|---|
|  | A1 (0.0 – 0.10): Silty Clay Loam, moderate structure, 30% 100 mm basalt stone content,10YR 3/3 (Dark brown), gradual boundary to;<br><br>B2 (0.10 – 0.20): Silty Clay, strong structure, 50% 10-20 mm basalt stone content, 10YR 3/3 (Dark brown), clear boundary to;<br><br>C (0.2+): Basalt bedrock |

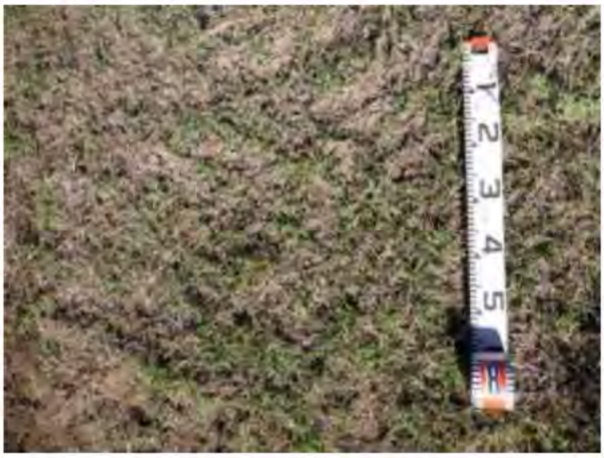
### 4.1.7 Soil Map Unit 5 - Self-mulching Brown to Black Vertosol; Moderate to Deep

| | |
|---|---|
| **ASC Name** | Self-mulching Black Vertosol; Deep |
| **Site No.** | 21 |
| **Eastings; Northings** | 368417; 6980302 |
| **Geology** | Alluvium |
| **Microrelief** | Linear gilgai |
| **Landform Pattern** | Hillslope |
| **Landform Element** | Lower slope |
| **Dominant Slope (%)** | 1-3% |
| **Slope Type** | Waning |
| **Surface Coarse Fragments** | <2% 100 mm basalt |
| **Surface Fragments > 60 mm** | <2% |
| **Drainage** | Moderately well |
| **Permeability** | Moderate |
| **Site Disturbances** | Previously cultivated |
| **Current Land Use** | Grazing pasture |
| **Surface Condition** | Self-mulching |
| **Vegetation** | Hairy panic, Chloris, Wild turnip |

| Profile | Horizon / Depth (m) | Description |
|---|---|---|
|  | A1<br>0.0 – 0.15 | Very dark gray (10YR 3/1) Heavy Clay, Strong structure of <10 mm crumb peds with a rough-ped fabric and firm consistence. Nil mottling; 10% <5 mm basalt stone content; <5% 10 mm calcareous nodule segregations; Gradual and even boundary. |
| | B21<br>0.15 – 0.40 | Black (10YR 2/1) Silty Clay, Strong structure of 20-50 mm polyhedral peds with a smooth-ped fabric and very firm consistence. Nil mottling; Nil stone content; <5% 10 mm calcareous nodule segregations; Gradual and irregular boundary. |
| | B22<br>0.40 – 1.00+ | Black (10YR 2/1) Heavy Clay, Strong structure of 50-100 mm angular blocky peds with a smooth-ped fabric and strong consistence. Nil mottling; Nil stone content; <2% 10 mm calcareous nodule segregations. |

### 4.1.8 Soil Map Unit 6 - Self-mulching Black Vertosol; Moderate to Deep

| | |
|---|---|
| **ASC Name** | Self-mulching Black Vertosol; Deep |
| **Site No.** | 1 |
| **Eastings; Northings** | 368019; 6980014 |
| **Geology** | Colluvium |
| **Microrelief** | Normal gilgai (slight) |
| **Landform Pattern** | Low hills |
| **Landform Element** | Footslope |
| **Dominant Slope (%)** | 1-3% |
| **Slope Type** | Waning |
| **Surface Coarse Fragments** | Nil |
| **Surface Fragments > 60 mm** | Nil |
| **Drainage** | Moderately well |
| **Permeability** | Moderate |
| **Site Disturbances** | Extensively cleared |
| **Current Land Use** | Grazing pasture |
| **Surface Condition** | Self-mulching (cracked) |
| **Vegetation** | Whitebox, Boxthorn, Couch, Panic, Red Grass, Rhodes |



| Profile | Horizon / Depth (m) | Description |
|---|---|---|
|  | A1<br>0.0 – 0.10 | Dark brown (7.5YR 3/2) Light-medium Clay, Moderate structure of 2-5 mm polyhedral peds with a rough-ped fabric and firm consistence.<br>Nil mottling; Nil stone content; Nil segregations; Clear and even boundary. |
| | B21<br>0.10 – 0.35 | Black (7.5YR 2.5/1) Silty Clay, Strong structure of 10-20 mm subangular blocky peds with a rough-ped fabric and firm consistence.<br>Nil mottling; Nil stone content; Nil segregations; Gradual and even boundary. |
| | B22<br>0.35 – 0.75 | Very dark gray (7.5YR 3/1) Heavy Clay, Strong structure of 20-50 mm subangular blocky peds with a smooth-ped fabric and very firm consistence.<br>Nil mottling; Nil stone content; <5% 10 mm calcareous nodule segregations; Clear and even boundary. |
| | B23<br>0.75 – 1.10 | Brown (7.5YR 4/2) Heavy Clay, Strong structure of 20-50 mm subangular blocky peds with a rough-ped fabric and very firm consistence.<br>Nil mottling; 20% <10 mm unidentified stone content; 10% 10-20 mm calcareous nodule segregations. |

## 4.2 Existing Land Suitability and Rehabilitation Requirements

The Land Suitability assessment was conducted in accordance with the *Regional Land Suitability Frameworks for Queensland* (DNRM, DSITIA, 2013) for the Eastern Downs Region. The suitability framework provides the detail for assessing which crops are suitable for individual mapped areas of land or soil.

The outcomes of the Land Suitability Assessment is shown in **Table 2** and **Figure 2** and summarised below as follows:

- The entire Study Area has been assessed as either Land Suitability Class 3 or Class 4 for all Land Uses, including dryland cereal and grain crops (i.e wheat, oats, barley and sorghum), sunflower and chickpeas (**Table 2**).
- The major limitations for Soil Map Units identified as Class 3 are Erosion Hazard and Surface Condition.
- The major limitations for Soil Map Units identified as Class 4 are Erosion Hazard, Soil Water Availability and Rockiness.

The Coordinator General's Evaluation Report on the EIS requires 50% of each Land Suitability Class to be re-instated post mining. The areas for rehabilitation have been separated into two categories:

1. SCL or Land Suitability (LS) Class 3 Standard – This category means the final rehabilitated landform is favourable to achieving SCL and LS Class 3 standard land and soil criteria.
2. Grazing Land LS Class 4 to 5 Standard – This category means the final rehabilitated landform is favourable to achieving LS Class 4 or 5 standard land and soil criteria. To satisfy the Coordinator Generals requirements, LS Class 4 needs to be achieved for the areas listed in Table 3. To achieve LS Class 4 a slope of less than 8% is required on the final landform within the required areas on the dumps or depressed areas.

**Table 3** shows the post mining land suitable for the above two categories, the areas required by the Coordinator General and the likely surplus or deficit of such land.

**Table 2 Overall Land Suitability**

<table>
<tr><th rowspan="2">Mining Area</th><th colspan="2">Land suitable for Rehabilitation</th><th colspan="2">Required Land (50% of Land suitability post mining)</th><th rowspan="2" colspan="2">Rehabilitation Area Available to meet Land Suitability Requirements Surplus or (-)Deficit</th></tr>
<tr><th>SCL or LS Class 3 Standard</th><th>Grazing Standard (LS Class 4 to 5)</th><th>LS Class 3 Cropping</th><th>LS Class 4 Grazing</th></tr>
<tr><td>Manning Vale West Mining</td><td>194.6</td><td></td><td>137.8</td><td></td><td>56.8</td><td>Surplus</td></tr>
<tr><td>Manning Vale West Dump</td><td></td><td>155.3</td><td></td><td rowspan="2">113.7</td><td rowspan="2">194.1</td><td rowspan="2">Surplus*</td></tr>
<tr><td>Manning Vale West Depressed</td><td></td><td>152.6</td><td></td></tr>
<tr><td>Manning Vale East Mining</td><td>57.0</td><td></td><td>59.3</td><td></td><td>-2.3</td><td>Deficit</td></tr>
<tr><td>Manning Vale East Depressed</td><td></td><td>99.1</td><td></td><td>19.0</td><td>80.1</td><td>Surplus**</td></tr>
<tr><td>Willaroo Mining</td><td>290.3</td><td></td><td>280.45</td><td></td><td>9.8</td><td>Surplus</td></tr>
<tr><td>Willaroo Dump</td><td></td><td>20.7</td><td></td><td rowspan="2">0.0</td><td rowspan="2">271.7</td><td rowspan="2">Surplus</td></tr>
<tr><td>Willaroo Depressed</td><td></td><td>251.0</td><td></td></tr>
<tr><td>Total Areas available</td><td>541.9</td><td>678.6</td><td>477.6</td><td>132.7</td><td>610.2</td><td>Surplus</td></tr>
</table>

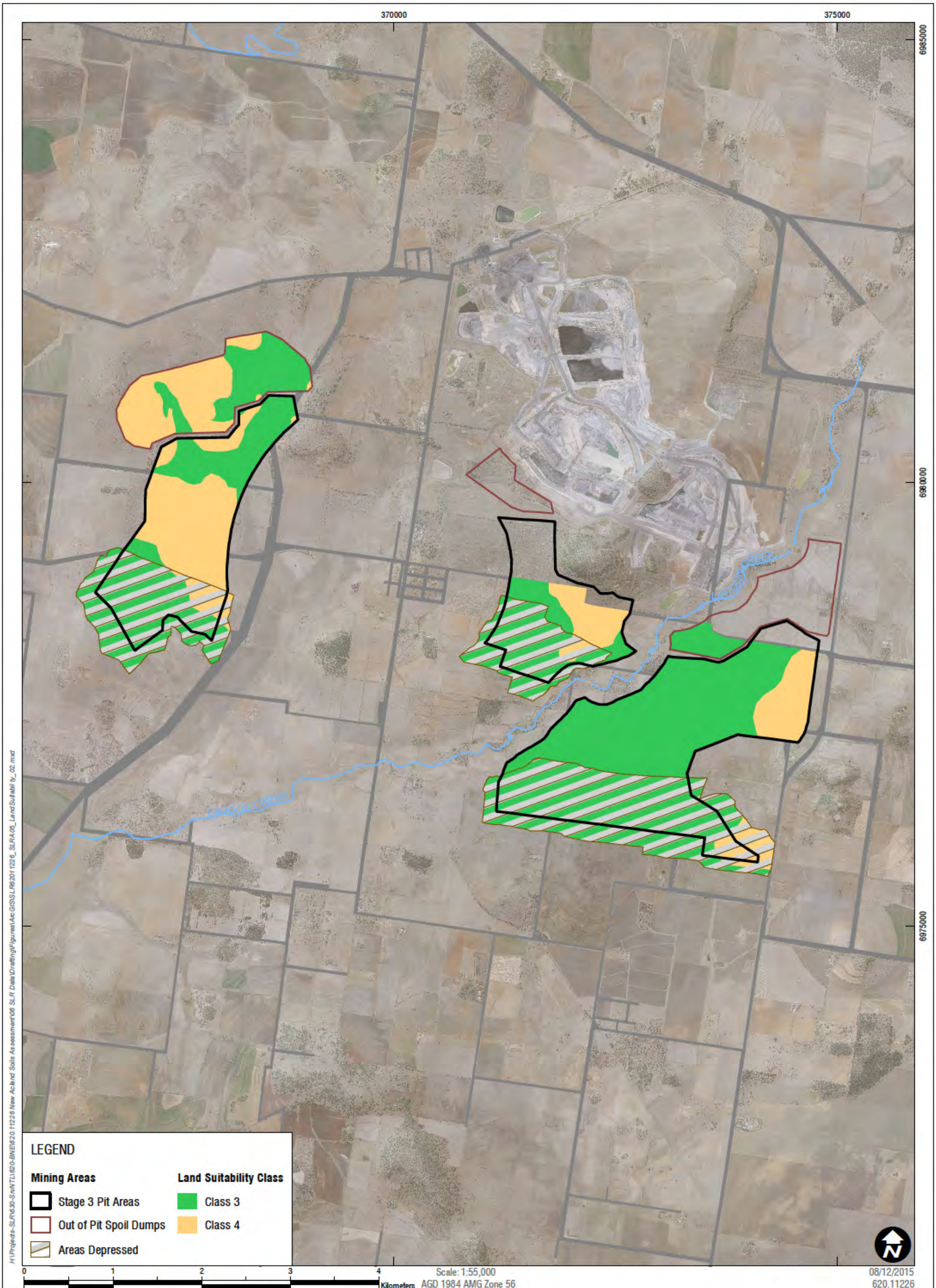
Note * after SCL/LS3 area is met, a minimum of 113.7 ha needs to have a slope < 8% on the dump and/or depressed area.
Note ** a minimum of 19 ha needs to have a slope < 8% on the dump and/or depressed area.

## 4.3 Existing Strategic Cropping land (SCL)

The SCL Assessment was prepared in accordance with the requirements of the following relevant strategic land use planning documents (SLR 2015):

- Regional Planning Interests Act 2014 (RPI Act);
- Regional Planning Interests Regulation 2014 (RPI Regulation); and
- RPI Act Guideline 08/14: How to demonstrate that land in the strategic cropping area does not meet the criteria for strategic cropping land (State of Queensland, 2014) (RPI Guideline).

The SCL Assessment identified 882.5 ha of land as verified SCL located within the proposed mining disturbance areas, and 74.7 ha of land as verified SCL located within the proposed infrastructure areas. A total of 338.5 ha and 145.1 ha was verified non SCL within the Mining disturbance areas and Infrastructure areas respectively. The areas identified as SCL are shown in **Figure 3**

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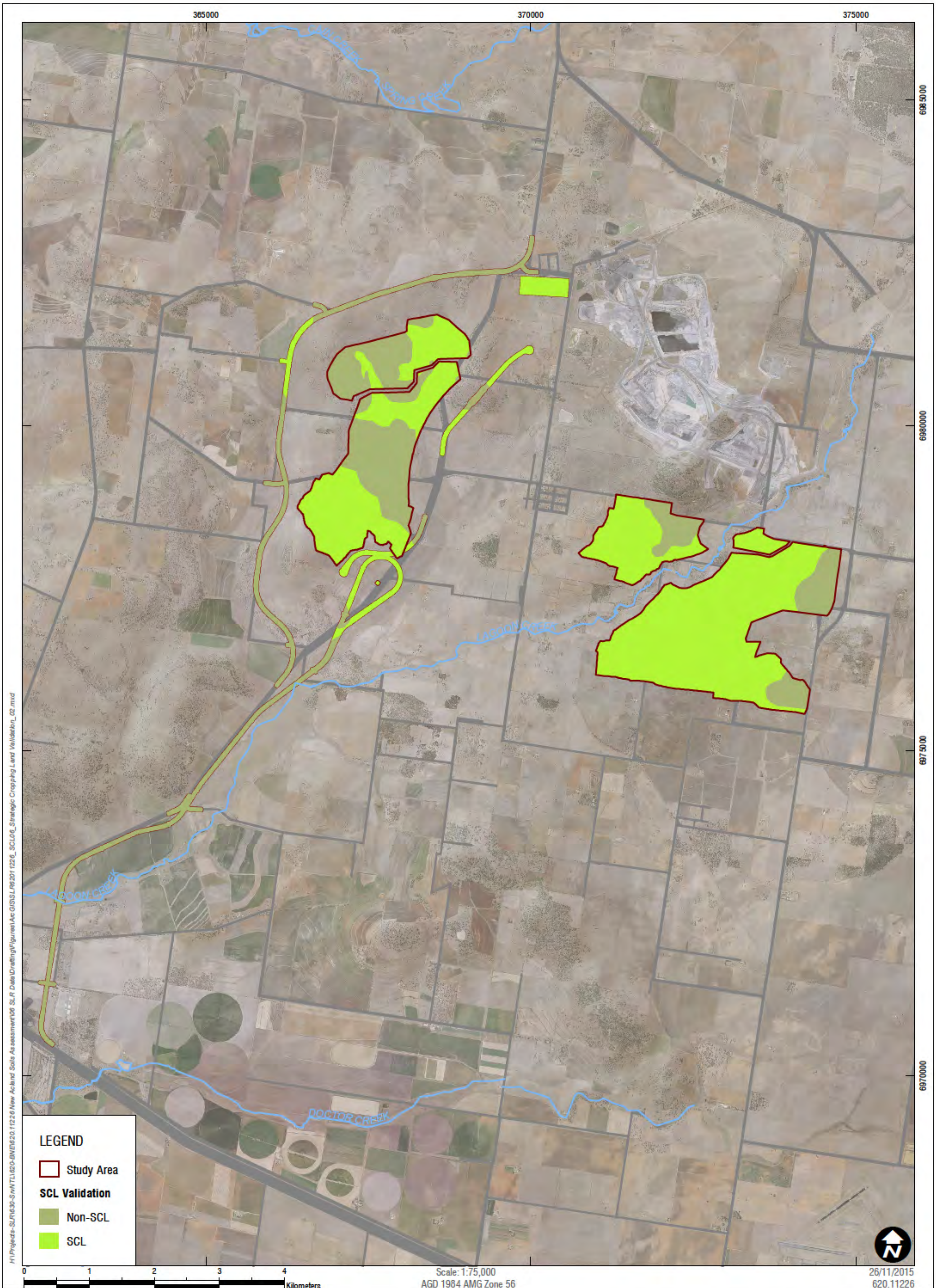
**Land Suitability Assessment**

**FIGURE 2**

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**Strategic Cropping Land Validation**

**FIGURE 3**

# 5 PROPOSED SOIL STRIPPING DEPTHS AND SOIL BALANCE

The overall aim of mine rehabilitation at the New Acland Coal Mine is to return the land to a productive, safe, stable, non-polluting landform, as per EMPL00335713.

Area and volume calculations were determined from GIS information provided as part of the Stage 3 project data package. Existing landform contours were used to create a terrain surface. Spatial interpolation techniques were used to derive topsoil and subsoil stripping zones as determined through field survey observation and detailed soil analysis. Volume calculations were then performed using the derived topsoil and subsoil stripping depth profiles.

Table 4 below summarizes the soil volumes available for stripping within the proposed disturbance areas. Note these values are based on a survey intensity of one inspection site every 10 ha, and any further detailed investigations undertaken during the stripping process will refine soil recovery.

**Table 3 Pre-mining Soil Stripping Volumes**

| Mining Area | Soil Map Units | Stripping Areas (ha) | Topsoil Stripping Depth (m) | Topsoil Volume Available (m3) | Subsoil Stripping Depth (m) | Subsoil Volume Available (m3) |
|---|---|---|---|---|---|---|
| Manning Vale East | 1 - Eutrophic Brown to Red Chromosol; Moderate to Deep | 156.6 | 0.2 | 313200 | 1.0 | 1566000 |
| Willaroo | 2 - Self-mulching Black to Brown/Red Vertosol; Moderate to Deep | 560.9 | 0.3 | 1682700 | 1.0 | 5609000 |
| Manning Vale West | 3 - Self-mulching Black Vertosol; Moderate to Deep | 141.9 | 0.3 | 425700 | 0.9 | 1277100 |
| | 4 - Self-mulching to Epipedal Brown Vertosol; Very shallow to Shallow | 68.2 | 0.3 | 204600 | 0.3 | 204600 |
| | 5 - Self-mulching Brown to Black Vertosol; Moderate to Deep | 133.7 | 0.3 | 401100 | 0.8 | 1069600 |
| | 6 - Self-mulching Black Vertosol; Moderate to Deep | 122.1 | 0.3 | 366300 | 0.9 | 1098900 |
| **Total Area able to be stripped** | | **1183.4** | | **3393600** | | **10825200** |
| 8 - Exclusion Area - Rockiness | | 1.1 | | | | |
| 9 - Exclusion Area - Rockiness | | 35.5 | | | | |
| 11 - Exclusion Area - Rockiness | | 1.0 | | | | |
| **Total Area unable to be stripped** | | **37.6** | | | | |
| **Total Area** | | **1221.0** | | | | |

There is a total of 3,393,600 m3 of topsoil and 10,825,200 m3 of subsoil suitable for stripping and re-use in mine rehabilitation, located within the proposed mining disturbance areas within the Project Site. All soil stripped from the infrastructure areas will be stockpiled to be used once decommissioning of the infrastructure is complete.

**Table 4** below shows the areas which will require soil placement on the final landform.

**Table 4 Post Mining Soil Placement**

| Rehabilitation Locations | Rehabilitation Areas | Topsoil Spreading Depth | Volume Required | Subsoil Spreading Depth | Volume Required |
|---|---|---|---|---|---|
| Manning Vale West Mining (SCL) | 194.6 | 0.30 | 583,776 | 0.70 | 1,362,144 |
| Manning Vale West Dump (Grazing) | 155.3 | 0.25 | 388,204 | 0.30 | 465,845 |
| Manning Vale West Depressed (Grazing) | 152.6 | 0.25 | 381,407 | 0.30 | 457,689 |
| Manning Vale East Mining (SCL) | 57.0 | 0.30 | 171,101 | 0.70 | 399,236 |
| Manning Vale East Depressed (Grazing) | 99.1 | 0.25 | 247,702 | 0.30 | 297,242 |
| Willaroo Mining (SCL) | 290.3 | 0.30 | 870,827 | 0.70 | 2,031,930 |
| Willaroo Dump (Grazing) | 20.7 | 0.25 | 51,802 | 0.30 | 62,162 |
| Willaroo Depressed (Grazing) | 251.0 | 0.25 | 627,432 | 0.30 | 752,918 |
| **Total Volumes Required** | **1,220.5** | | **3,322,251** | | **5,829,166** |

## 5.1 Respread Soil to Grazing Standard

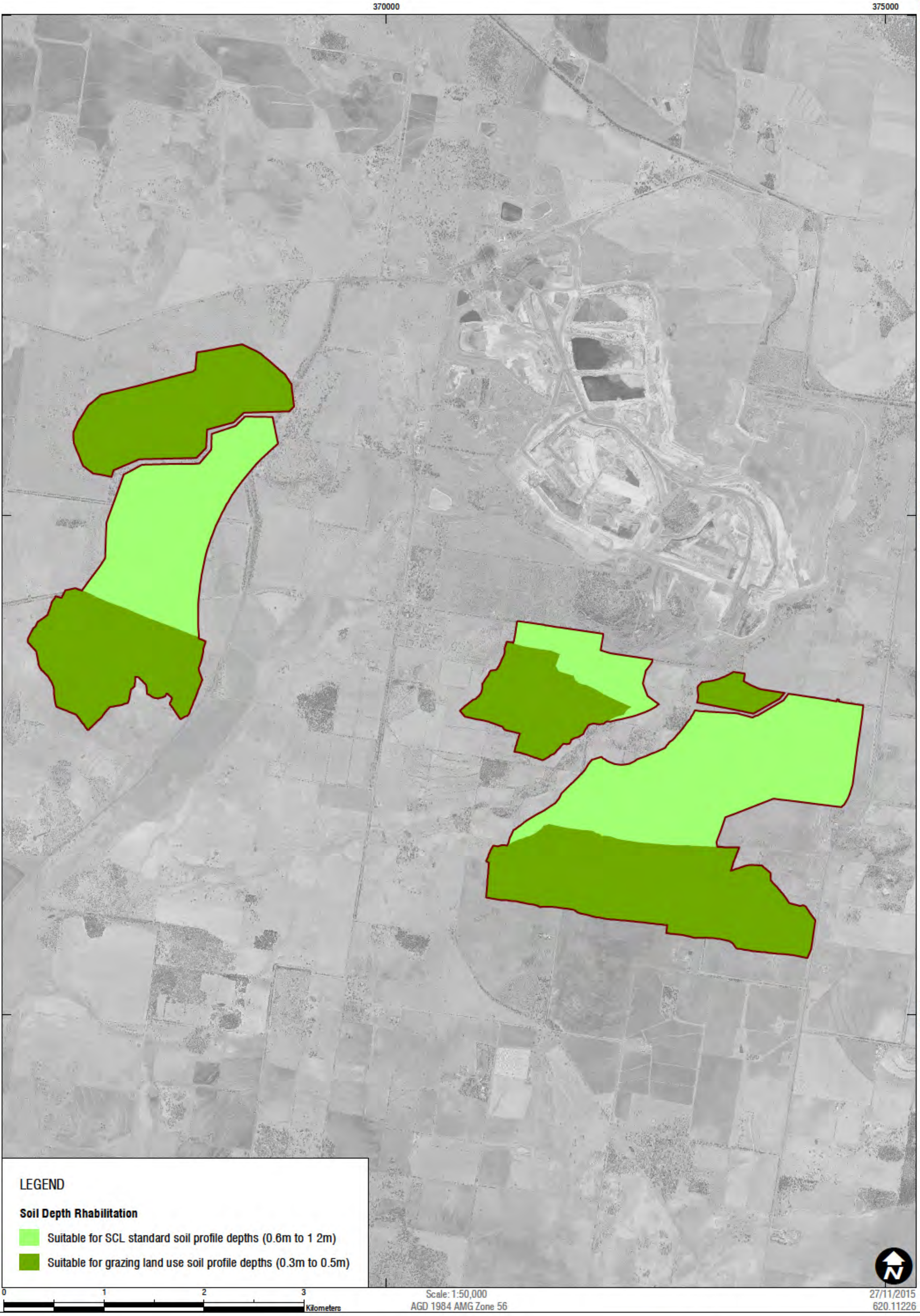
The re-instatement of grazing land within the rehabilitated landform involves similar soil profile depths as employed for Stage 2 operations. The standard level of soil currently re-spread on final landforms is a minimum of 0.3m. This commitment by New Acland Coal will continue for such land. As Table 6 indicates, the soil balance for grazing areas has been calculated on a 0.55m re-instatement depth to allow for variation in spreading as well as settling and potential soil loss through erosion during the pasture establishment phase. The 0.55 m proposed soil placement depth also is required to meet the Land Suitability Class 4 criteria for plant available water capacity (PAWC). This conservative approach also fulfils the commitment to rehabilitate the mined land to the best possible land use which can be considered as the most resilient grazing land due to the deeper soil profile of 0.55m.

## 5.2 Respread Soil to SCL Standard

The re-instatement of SCL areas within the rehabilitated landform is based on the SCL criteria, in particular the final landform needs to be less than 5% slope, minimised surface rock (less than 20% of rocks >60mm diameter), and the soil profile is to be 1.0m deep. The soil balance in Table 6 has allowed for a placement depth of 0.70m subsoil and 0.30m Topsoil to be used in order to calculate the likelihood of a surplus or deficit. There is a large surplus of Subsoil which may be used to increase the soil profile depth of proposed SCL areas. **Figure 4** shows areas suitable for achieving both grazing and SCL areas based on slope criteria.

## 5.3 Soil Balance

The available soil volumes and the required soil volumes are shown in **Table 3** and **Table 4** respectively. These values show there is a small overall topsoil surplus of 71,349 m3 and a large subsoil surplus of 4,996,034 m3. If practical, it is recommended that surplus material be stripped and used to increase the overall soil profile depths where possible. This will allow the post mining landform to be more resilient to droughts and provide a buffer depth to further ensure post mining profiles meet the required soil parameters.

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**Suitable Areas for Targeted Soil Profile Depths in Rehabilitation**

**FIGURE 4**

# 6 SOIL HANDLING AND MANAGEMENT

## 6.1 General Responsibilities

NAC's Technical Services and Production Departments will be responsible for the recovery, handling and management of site soils. These Department's responsibilities will include:

- clearance and grubbing prior to stripping – this will enable salvage of all suitable topsoil material and avoid loss of stripped topsoil quality caused by mixing with unsuitable soils;
- stripping operations are conducted in accordance with Soil Stripping Procedures including, but not limited to;
    - permit to disturb;
    - inspection of stripping activities by Supervisor;
    - delineation of areas to be stripped and date of stripping;
    - delineation of suitable stockpile areas (as required);
    - delineation of planned areas for direct return of soil (as required);
    - maintenance of acceptable dust levels during topsoil stripping;
    - recording of volumes, source, movements, and final placements of soil
    - application of the top soil stripping; and
    - management of topsoil placement within storage and/or direct return locations, with due consideration of economic factors, mine access constraints, machine availability, weather conditions and ground conditions.

Management of soils whilst in stockpile, their recovery, placement for reinstatement, effectiveness trials and monitoring of rehabilitation effectiveness will be managed by an environmental representative who in-turn will be advised by soil consultants where necessary.

## 6.2 Training and Awareness

All personnel involved in stripping and stockpiling of soil will have undertaken, as a minimum, communications in recognition of the Project area's SCL and the procedures put in place for its management. This Soil Management Plan combined with in field assessment of topsoil and sub-soil resources will act as a training process to ensure suitably skilled personnel will be supervising stripping operations.

## 6.3 Soil Stripping Management

### 6.3.1 Soil Stripping Requirement

Topsoil stripping is necessary wherever land is planned to be disturbed by mining activities to recover the soil resource for rehabilitation purposes. Topsoil stripping will be undertaken in areas of planned mining activity including the active pit areas, out-of-pit dumps, haul roads, hardstands and access roads.

New Acland Coal has prepared a Standard Work Procedure to define the topsoil stripping process for the revised Project.

### 6.3.2 Soil Inspections

The Soil and Land Resource Assessment (2015) was prepared at a survey intensity of one inspection site every 10 ha. During mining operations, inspections will be undertaken to ensure accuracy is obtained for verifying topsoil and subsoil resources and stripping depths. Current operational processes will continue in which the soil profile is inspected prior to or during stripping to confirm and record stripping depths.

Audits will be documented and form part of the soil management and rehabilitation records and will include:

- Topsoil thickness; and
- Subsoil thickness;

Such inspection sites will be used as a guide for topsoil and subsoil stripping depths and for removal of unsuitable layers.

Soil unit, land suitability and SCL boundaries as assessed by SLR (2015) will be used initially to indicate the class and type of topsoil being stripped. This in turn will govern its stockpile location. The location of soil boundaries will be based on the 2015 soil survey with boundary confirmation undertaken during stripping to ensure different soil types are kept separate following stripping. Any major change to such boundaries will be recorded.

### 6.3.3 Stripping Equipment

Equipment for stripping, stockpiling and reinstatement of topsoils and subsoils will be selected based on current operational fleet and as much as practical, selected to minimise compaction and to avoid breakdown of the soil structure. If necessary equipment and procedures used, based on experienced gained during stripping will be amended to minimise compaction and soil structure damage during recovery of stockpiles for reinstatement purposes.

### 6.3.4 Stripping Process

A general protocol for soil handling during topsoil stripping is presented below and includes soil handling measures which optimise the retention of soil characteristics (in terms of nutrients and micro-organisms) favourable to plant growth and propagules for natural regeneration (e.g. seed banks).

- Topsoil will be recovered using appropriate equipment as described above. Depending on compaction and recovery rates, deep ripping may be required to maximise topsoil recovery with care taken not to mix topsoil with subsoil.

- During the stripping process there may be some unexpected changes in the depth and the nature of the soil. Where practical the inclusion of obviously poorer quality material will be avoided such as material dominated with stones.

- Contractors bringing machinery onto the site will be required to present such machinery in a weed-free condition.

- Disturbance areas will be stripped progressively, as required, in order to reduce erosion and sediment generation, to reduce the extent of topsoil stockpiles and to utilise stripped topsoil as soon as possible for rehabilitation.

- Rehabilitation of disturbed areas, such as roads, embankments and batters, will be undertaken as soon as practicable after these structures are completed or as areas are no longer required for operational purposes.

- Covering vegetation can make the removal of specific topsoil depths difficult and excessive quantities of vegetative matter in long-term stockpiles may promote chemical and biological degradation of the seed reserves that are a future source of natural regeneration during rehabilitation. Therefore, prior to stripping, vegetation will be removed or reduced by grazing and/or clearing. Vegetative material may be buried in-pit (if weed infested), or if suitable, placed as habitat within the rehabilitation areas. In general, the requirement to clear larger vegetation (shrubs and trees) within the Study area is comparatively small as a result of the area's long history of agricultural production. If feasible, cleared vegetation may be chipped to provide a cost-effective mulch and soil amendment.

#### 6.3.5 Inventory Reconciliation

Actual volumes and position of topsoil and subsoil removed, stored, and placed, will be recorded and managed. These records will be updated. Such records will be used to reconcile actual soils stripped with soil quantities estimated from the original survey by SLR (2015).

Reconciliation shall be updated. Estimates are to be based on truck load counts and corrected based on survey.

### 6.4 Soil Stockpile Management

#### 6.4.1 Minimisation of Soil Stockpiles

The desired soil handling process at New Acland Coal Mine is to strip, transport, dump and respread directly onto shaped final landform to minimise soil handling and degradation. The following sections of this plan outline the requirements for managing soil stockpiles, which are stockpiles expected to exist for longer than 6 months.

#### 6.4.2 Stockpile Locations and Configurations

All soil units to be removed will remain separated from each other and the stockpile or final respread area will be recorded to ensure individual soil units are tracked from in situ to final rehabilitation. All top and sub soils stockpiled will be stored separately dependent upon classification. Stockpiles will only be disturbed for weed and erosion control or for seeding and fertilising purposes until required for rehabilitation.

Where feasible, stockpiles should be located as close as possible to final re-spread location in order to minimise second haulage length.

#### 6.4.3 Control of long term stockpile placement

The supervisor in charge of stripping and stockpiling operations will notify machine operators of the stockpile locations for that product and will check to ensure that material is taken to the correct stockpile location. Operators will immediately be notified of any changes to activities regarding stripping and dumping by the supervisor in charge of operations.

Regular checks and audits will be carried out in this regard by an environmental representative.

Signage

Signs nominating whether stockpiles contain topsoil or subsoil will contain the following information:

- Soil type (topsoil or sub soil referenced by colour)
- Stockpile number

A database will be maintained detailing;

- Soil type;

- Soil class (topsoil/subsoil);
- Date stripped;
- Volume; and
- Stockpile number.

#### 6.4.4 Erosion Control and Drainage

Long term stockpile areas will have contour drains built around its perimeter to divert water away from it. This water will be drained into existing mine sedimentation dams.

Stockpiles will be arranged in the stockpile area to run near parallel to natural contours as far as practical. Sediment controls may be placed in drainage paths as determined on site to capture silt from runoff. Long term stockpiles will be seeded after placement to minimise scouring..

#### 6.4.5 Seeding of Stockpiles

Completed topsoil and subsoil stockpiles will be broadcast seeded and cover established as prevailing weather conditions permit.

#### 6.4.6 Weed Control

Prior to stripping and placement of soils, inspections will be carried out to identify weed control measures.

#### 6.4.7 Stockpile Inspections

Regular inspections of the stockpile areas will be made particularly after significant rainfall events. The following features will be checked:

- Integrity of sediment control;
- Effectiveness of drainage;
- Integrity of erosion control measures;
- Grass growth; and
- Weed infestation.

Remedial measures will be undertaken as necessary. Revegetation and weed control will be carried out as assessed at the time.

### 6.5 Rehabilitation of Soil Profile

#### 6.5.1 Soil Rehabilitation Objectives

A progressive rehabilitation program will be implemented throughout the life of the Project, reported on each year, and will commence when areas become available within the operational land.

The primary design objective is the creation of productive, safe, stable, non-polluting, self-sustaining final landforms that achieve the proposed final land use per regulated conditions. The final landform design will be consistent with New Acland Coal's Final Land Use and Rehabilitation Plan for the Project. In general, stable landforms will be established following mining, using soils capable of supporting vegetation communities adapted to the local environment. The stability of the post-mine landform will be achieved by applying sound rehabilitation practices. The disturbed land will be rehabilitated to a condition that is self-sustaining or to a condition where the maintenance requirements are consistent with the proposed post-mining land use.

Surface run-off from all disturbed areas will pass through sedimentation controls to reduce the levels of suspended solids. Where possible, sedimentation dams will discharge to an environmental dam before eventual discharge off-site. Water in the environmental dams will be recycled to minimise the potential for off-site discharge.

New Acland Coal's rehabilitation strategy will allow a majority of the Project site to be reincorporated into Acland Pastoral Company's agricultural activities. The return of the Project land to grazing is consistent with the current land uses practised within the region (grazing and dryland cropping) and is considered a long term sustainable outcome for the revised Project.

New Acland Coal will develop a sustainable management regime for the former mined land through the on-going site-specific grazing trials and long term monitoring against approved rehabilitation acceptance criteria. In addition to meeting the Coordinator Generals requirement of 50% of the mapped Land Suitability post mining, New Acland Coal will assess selected rehabilitation areas within the Project site against the Strategic Cropping Land criteria.

#### 6.5.2 Respreading Soil

The application procedure is essentially the reverse of the stripping procedure. First, the overburden materials will be formed to the design slopes, then secondary media (subsoil) should be placed in position, followed by the primary media (topsoil). The Soil and Land Resource Assessment (SLR 2015) found that most soil tested from the revised Project site is likely to be suitable for revegetation. All soils used in rehabilitation will be applied in line with the depths specified in the soil balance as shown in **Table 4**.

The mine rehabilitation strategy may include the following measures which are designed to minimise the loss of topsoil material re-spread on rehabilitated areas and promote successful vegetation establishment.

- Balance the topsoil requirement for rehabilitation areas against stored stockpile inventories and proposed stripping volumes.
- Maximise the opportunities for direct placement of topsoil from pre-strip to rehabilitation areas.
- Minimise the length of time that topsoil material is to be stockpiled.
- During removal of soils from the stockpiles, take care to minimise structural degradation of the soils.
- Travel lanes may be set out on the areas being rehabilitated to SCL standards to reduce the potential for soil compaction during placing;
- Respread soil material in even layers at a thickness appropriate for the landform and land capability of the area to be rehabilitated.
- Contour rip between overburden and soil layers to 'key' soil layers together, encourage rainfall infiltration and minimise run-off and mass movement soil slip.
- Soon after respreading, seed with sterile cover crops and pasture grasses and/or native tree species to establish revegetation cover as early as possible.
- Construct contour banks in accordance with the applicable landform design criteria to limit slope lengths and control run-off.
- Construct collection drains and sedimentation dams to collect run-off and remove suspended sediment.

- Regularly inspect and maintain rehabilitation areas to facilitate sediment and erosion control and revegetation success.
- Rehabilitation areas of returned topsoil will be ripped, with care taken not to bring subsurface materials to the surface (e.g. large rocks). Ripping should only be sufficient to allow equipment to work efficiently. Ripping along slopes should be along contour.
- Regularly inspect rehabilitated areas for declared plants and environmental weeds, and control significant weed outbreaks using chemical or mechanical control methods.
- Apply appropriate fire, grazing, and hygiene management procedures.
- Continue to implement the SOP to ensure soil application is conducted in a consistent manner to ensure rehabilitation success.

## 6.6 Records and Reporting

Reconciliation will be carried out as indicated in **Section 5.5.6.**

Records will facilitate reporting of:

- Cumulative stripped quantities;
- Updated reconciliation records;
- Stockpiles and soil face positions;
- Seeding and reseeding details; and
- Weed control measures.

An inventory recording system shall be kept for each soil type and soil class on a stockpile basis. This shall be updated and shall be used as a means of tracking soils movements from stripped areas to stockpile and respread locations and for reconciliation purposes. The inventory system will enable cross referencing with soil face plans and soil stockpiles positions.

The Soil Management Plan is to be reviewed at least every five years or as otherwise directed by New Acland Coal's management. The review will reflect changes in environmental requirements, technology and operational procedures. Results of the assessments will be incorporated into future rehabilitation planning.

# 7 REFERENCES

- Department of Natural Resources and Mines & Department of Science, Information Technology and Innovation (2013) Regional Land Suitability Frameworks for Queensland.
- Isbell RF (2002) The Australian Soil Classification (rev. edn.). *CSIRO Publishing: Melbourne*.
- New Hope Group (2014) EIS Appendix J.3 Topsoil Management Plan – New Acland Coal Mine Stage 3 Project.
- SKM (2013) *New Acland Coal Mine Stage 3, Road and Rail Corridor – Technical Report*.
- SLR (2016a) Soil and Land Resource Assessment – New Acland Stage 3 Project.
- SLR (2016b) Strategic Cropping Land Assessment – New Acland Stage 3 Project.
- State of Queensland (2014) RPI Act Guideline 08/14: How to demonstrate that land in the strategic cropping area does not meet the criteria for strategic cropping land

**NAC Attachment 13 - Final Land Use and Rehabilitation Plan (FLURP)**

# FINAL LAND USE & REHABILITATION PLAN

## *New Acland Coal Mine Stage 3 Project*

*New Acland Coal Pty Ltd*

April 2020

## PREPARED BY

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## BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with New Hope Group (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

## DOCUMENT CONTROL

| Reference | Date | Prepared | Checked | Authorised |
|---|---|---|---|---|
| 620.11226.003 | August 2019 | Clayton Richards | Murray Fraser | Rod Masters |
| 620.11226.003 | April 2020 | Murray Fraser | Rod Masters | Rod Masters |

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## APPENDICES

# 1 Introduction

New Acland Coal Pty Ltd (NAC) is the proponent of the New Acland Coal Mine Stage 3 Project (Project), which involves the proposed extension of the operating life of the New Acland Coal Mine (Mine) by up to 15 years.

NAC has received initial approval for the Project from the Coordinator-General, under the *State Development and Public Works Organisation Act 1971*, through the release of an evaluation report on the environmental impact statement for the Project dated 19 December 2014 (the Coordinator-General's Report). In addition, NAC was granted amended Environmental Authority EPML00335713 (EA) for the Project, under the *Environmental Protection Act 1994* (EP Act), by the Department of Environment and Science on 12 March 2019.

This Final Land Use and Rehabilitation Plan (FLURP) has been developed for the life of mining to address Imposed Conditions 7 and 8 of the Coordinator-General's Report and EA Condition H10.

# 2 Project Description

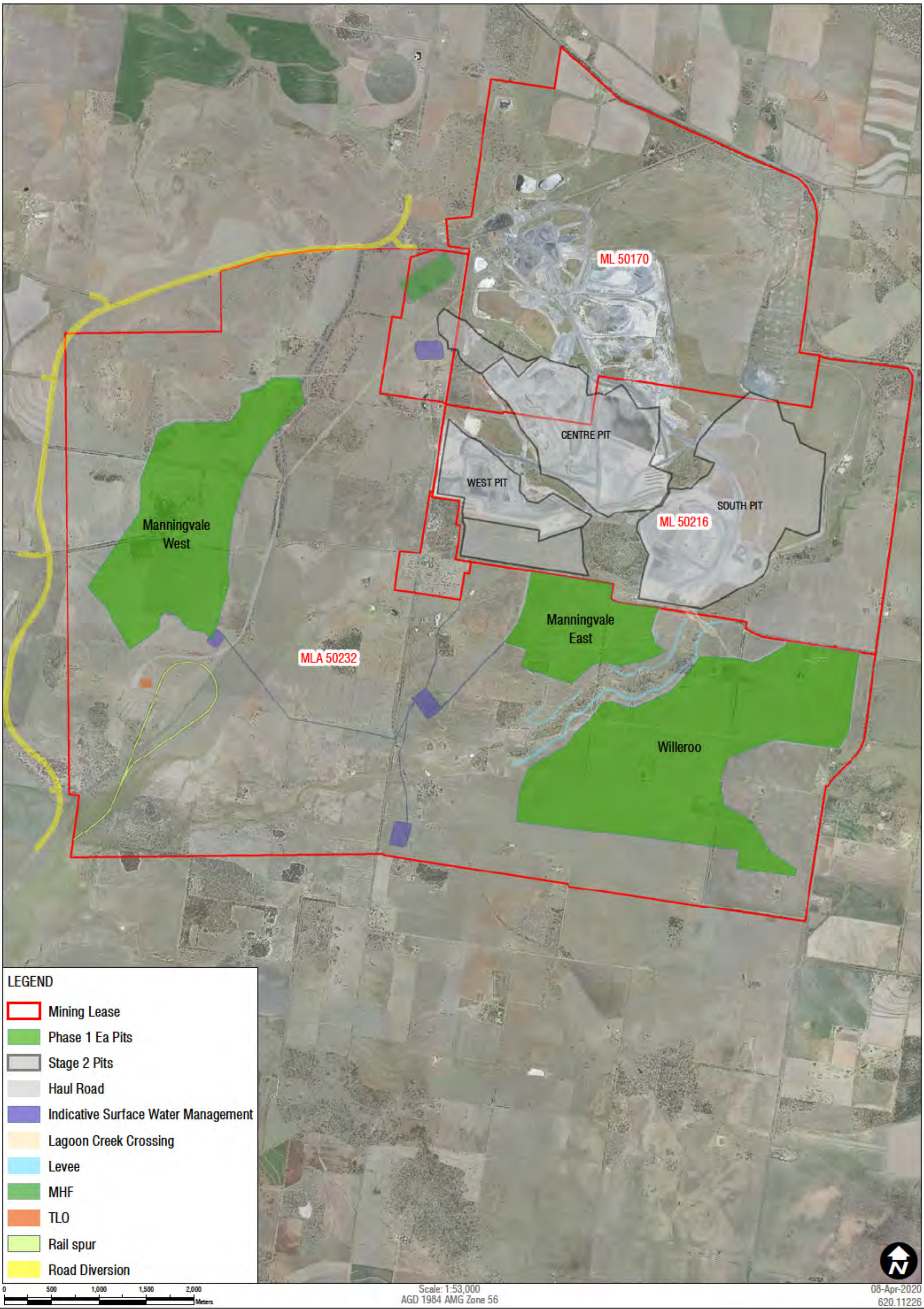
NAC has operated the Mine since 2002. The Mine's operations are currently authorised under Mining Lease (ML) 50170 and ML 50216 and EA EPML00335713. At present, the Mine has approval to produce 5.2 million tonnes per annum (Mtpa) of product coal as an open cut coal mine. The Project will allow the continuation of open cut mining operations on ML 50232 and will provide an opportunity for the Mine to expand production up to 7.5 Mtpa of product coal if economic and operational circumstances permit (**Figure 1**).

The Project proposes the extension of the Mine's operating life through the inclusion and progressive development of three new resource areas within ML 50232 as three new pits, construction of a rail spur and balloon loop from Jondaryan within ML 700002 and ML 50232, construction of a new train loading facility on ML 50232, and the development of associated operational infrastructure (e.g. roads). The mining activities for the Project's new resource areas will involve the same open cut mining method used for the existing operations.

The Project's coal will be sourced from the Manning Vale West, Manning Vale East and Willeroo Pits on ML 50232. The key rehabilitation elements of the Project are the:

- completion of mining and the continued progressive rehabilitation of the West Pit;
- continued progressive rehabilitation of South Pit;
- continued management of the rehabilitated surfaces of Tailings Storage Facility (TSF) 1 and the TSF 1 Extension;
- ongoing capping and rehabilitation works of inactive In-Pit Tailings Dams (IPT) 1, 2/1 and 2/2;
- completion of fine tailings disposal within IPT3 and its preparation for capping and rehabilitation works;
- development of a new tailings disposal facility within the Centre Pit;
- disposal of coarse reject within active spoil dumps, and use of coarse reject for road sheeting, and tailings capping;

- continued and progressive development of the mine surface water management system involving various water management structures;
- continued grazing of rehabilitated land (including on-going cattle trials);
- development, mining and eventual progressive rehabilitation of the Manning Vale West, Manning Vale East, Willeroo Pit.

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**Site Layout**

**FIGURE 1**

# 3 Statutory Requirements

## 3.1 State Development and Public Works Organisation Act 1971

As a statutory requirement of the Coordinator-General's Report, NAC has received a number of 'Imposed Conditions (IC)' that are prescriptive about the Project's rehabilitation outcomes from an agricultural perspective (i.e. about maintaining a certain level of land capability post-mining). **Table 1** details IC 7 which outlines the Coordinator-General's key rehabilitation requirements for the Project.

### Table 1 Imposed Condition 7 – Coordinator General's Report

**Condition 7. Rehabilitation of disturbed land**

(a) Rehabilitation is to be undertaken so as to establish discrete land units (that is, no unjustified mixing of soil material from different land units) in the disturbed areas to be rehabilitated ('rehabilitation area'), each capable of ultimately being assigned a specific post-disturbance land use suitability.

(b) The rehabilitation of disturbed land is to result in the affected land units being able to support the best post-disturbance land use possible. The post-disturbance land suitability of each land unit is to:

(i) represent that achievable on an ongoing basis;

(ii) be obtainable without the use of irrigation; and

(iii) be such that collectively at least 50 per cent of the total area of disturbed land originally meeting or exceeding the criteria for either Class 3 grazing land or Class 4 cropping land still meet or exceed those classifications.

(c) Prior to commencement of mining operations, the project proponent must:

(i) identify parcels of land, unaffected by mining operations (the land can be land owned by the proponent/associated company), that are able to provide at least three separate reference sites for each land suitability class to be represented in rehabilitated areas; and

(ii) Undertake investigations at each reference site, consistent with the requirements in Condition 6(b): Land resource survey, and sufficient to demonstrate that each reference site satisfies the criteria for the applicable suitability class.

(d) Within nine months of the commencement of project operations, the proponent is to submit for approval by the Coordinator-General a set of rehabilitation success criteria.

(e) The set of rehabilitation success criteria is to include elements specific to each land suitability class identified in the land resource survey undertaken in accordance with Condition 6: Land resource survey.

(f) Rehabilitation success criteria should include measures related to the following:

(i) landform;

(ii) soil physical and chemical attributes;

(iii) erosive soil loss (estimated using the Revised Universal Soil Loss Equation (RUSLE))

(iv) vegetative cover;

(v) plant density;

(vi) dry matter yield of harvestable material; and

(vii) botanical composition (pasture) or weed population characteristics (crops).

(g) The rehabilitation and restoration of the disturbed land is to be subject to ongoing and regular monitoring. At a minimum, the monitoring program is to:

(i) require monitoring twice in a calendar year (in spring and autumn in areas sown to pasture and at early flowering and at harvest in cropped areas)

(ii) provide a statistically valid sampling intensity for assessing compliance with the rehabilitation success criteria in each land unit (note: a sampling intensity providing 95 per cent confidence level that the sample mean values reported for a land unit are within ±20 per cent of the true mean for that unit.)

(iii) Include relevant climatic data, including rainfall, for both the rehabilitation and reference sites; and

(iv) by way of comparison with the corresponding reference sites, determine progress in meeting restoration success criteria, including identifying any failings; and proposing means to rectify those failings.

The Coordinator-General is to have jurisdiction for this condition.

In addition, IC 8 requires NAC to submit a FLURP to the Coordinator-General for approval before the Project can commence operations.

## 3.2 Environmental Protection Act 1994

A FLURP is required to be developed and implemented within 12 months of the Project's EA taking effect, which is upon grant of MLs 50232 and 700002. **Table 2** outlines the FLURP's requirements under *Agency Interest: Land and Rehabilitation – Condition H10* of the EA and the corresponding section references within this FLURP.

Prior to 1 April 2019, the FLURP was managed through NAC's Plan of Operations. Since 1 April 2019, the statutory requirement for a Plan of Operations was removed and replaced by an 'Estimated Rehabilitation Cost' decision.

Importantly, from 1 November 2019, all Queensland mines will gradually transition to the implementation of a 'Progressive Rehabilitation and Closure Plan (PRCP)'. As a consequence of this regulatory change, in the future the FLURP and all other rehabilitation-related conditions of the EA will be incorporated into a PRCP for New Acland Coal Mine.

### Table 2 EA Condition H10 – Details and FLURP Reference

| Condition H10 Details | FLURP Reference |
|---|---|
| **Final Land Use and Rehabilitation Plan**<br><br>*Within twelve (12) months upon the grant of ML50232 and ML700002 the holder of this environmental authority must develop and implement a Final Land Use and Rehabilitation Plan to ensure that all areas disturbed by mining activities will be suitably rehabilitated in accordance with **Table H1 – Final Land Use and Rehabilitation Approval Schedule – ML50170 and ML50216**, **Table H2 - Landform design criteria for New Acland Coal Mine – ML50170 and ML50216**, **Table H3: Residual Void Design – ML50170 and ML50216**, **Table H4: Rehabilitation Requirements Stage 3 New Acland Mine Project**, **Table H5: Rehabilitation Acceptance Criteria — Grazing Lands Stage 3 New Acland Mine Project** and **Table H6: Rehabilitation Acceptance Criteria — Treed Areas Stage 3 New Acland Mine Project**.* | |
| *The Plan must include, but is not limited to the following:* | |
| *(a) disturbance type* | Section 4 |
| *(b) disturbance area* | Section 4 |
| *(c) pre- and post-mine land descriptions &*<br><br>*(d) pre- and post-mine land capability* | Sections 6.2, 6.3, 7 |
| *(e) analogue site(s) identification* | Sections 10.2, 10.2.1, 10.2.2, 10.2.3,<br><br>10.2.4 |
| *(f) a description of rehabilitation management techniques incorporating works and monitoring programs and*<br><br>*timetables* | Sections 9.4, 9.7, 9.7.1, 9.7.2, 9.7.3,<br><br>9.7.4, 9.7.5, 9.7.6, 9.7.7, 9.8, 12.1, 12.2 |
| *(g) indicators for success;* | Sections 11, 11.1.1, 11.2, 12.1, 12.2,<br><br>12.3 |
| *(h) keeping of appropriate records or rehabilitation measures implemented including taking of photographs demonstrative of rehabilitation achieved and the preparation of annual rehabilitation progress reports.* | Sections 12, 12.1, 12.2, 12.3 |

# 4 Area and Type of Disturbance

## 4.1 Mining Sequence

Mining activities in North Pit commenced during late 2002 and ceased in 2008 and is now fully rehabilitated, with 349 hectares of this land parcel ‘certified’ as progressive rehabilitation by the Department of Environment and Science. Mining activities in South Pit commenced during early 2008 and ceased in late 2018. In the Centre Pit, mining activities commenced in 2012 and are scheduled to cease during 2020. West Pit mining commenced during early 2016 and are scheduled to cease in late 2020. The Manning Vale West Pit is scheduled to commence in 2021 and cease in 2031. The Manning Vale East Pit is scheduled to commence in 2020 and cease in 2029. The Willeroo Pit is scheduled to commence in 2020 and cease in 2031. The Project’s projected pit lives are subject to changes based on when the final primary approvals are granted, noise management requirements, alterations to planned mining rates and the continued refinement of the economic mining models for each pit as mining progresses. The proposed mine development sequence is illustrated in **Figure 2**.

## 4.2 Mining Methods

The open cut mining method employed for the Project will continue to be a conventional open cut strip-mining process using excavator, truck, dozer and loader operations. The current mining method allows removal of multiple coal seams from benches at varying depths, based on coal seam quality, depth and thickness until the maximum depth (economic limit) of mining is reached.

Overburden (the strata above the coal seams) and interburden (the strata between the coal seams) is either dumped in the active pit, if pit development has progressed sufficiently, or in previously mined pits or an out-of-pit dump. A portion of the overburden from active pits will be utilised for final rehabilitation of the TSFs. In addition, the Project’s spoil will be used to help backfill the existing Mine’s pits. For example, spoil from the Willeroo Pit (Stage 3) will be used to help backfill the South Pit void (Stage 2).

Dump construction comprises a series of progressive 10-20 metre lifts placed from the toe to the final height (allowing for profiling for final slope grade) to a maximum height of 30 metres above natural ground level as per NAC’s FLURP. Surface drainage infrastructure associated with the dumps are constructed with due consideration of the slope angles, slope lengths, the erosion potential of topsoil and overburden, and hydrological factors.

To provide adequate coal access and opportunities for coal blending, multiple blocks operate at any one time in each pit. The block size is typically 150 by 150 metres. The mining fleet facilitates the production profile. Equipment used includes surface miners, excavators, front-end loaders, scrapers, dozers, graders, rear dump trucks, light vehicles, service trucks, and water trucks.

For the existing Mine, NAC's EA permits a final void area of 55 hectares, to be located within the Centre and South Pits. In reality, this void area will be backfilled by spoil from the Project's Willeroo and Manning Vale East mining areas, which will also remove the requirement for out-of-pit dumps to be constructed within these mining area.

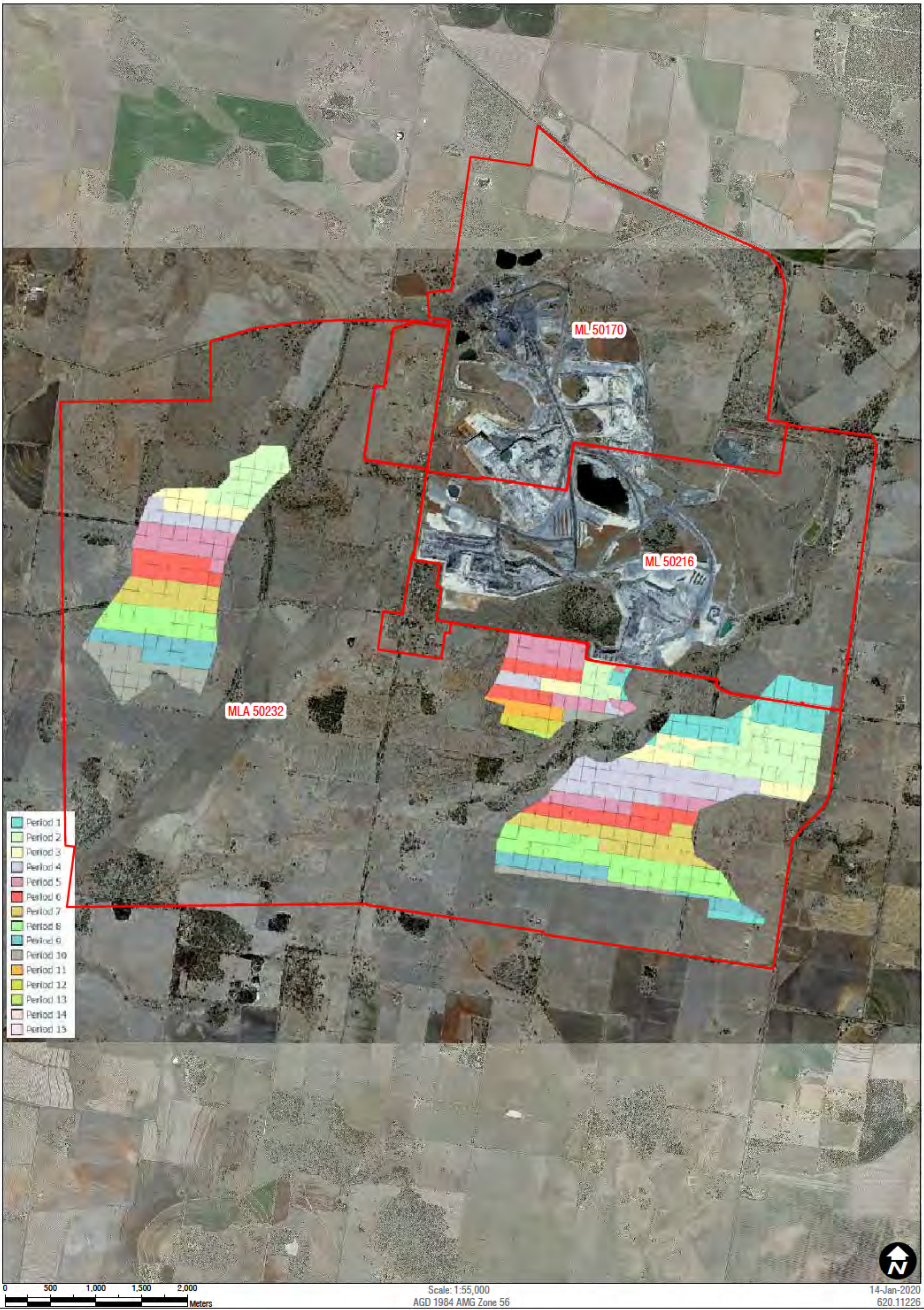
For the Project, NAC has committed to re-contouring the three planned voids at the end of mining to the following landforms:

- 163 hectares depressed landform area to be located in the Manning Vale West Pit area;
- 154 hectares depressed landform area to be located in the Manning Vale East Pit area; and
- 213 hectares depressed landform area to be located in the Willeroo Pit area.

The depressed landform concept is a rehabilitation strategy for the Project's final voids that was originally provided within the 'Land Resources Chapter' of the Project's EIS. The full details of the concept were described in the 'Final Landform Technical Report (NHG 2014)' located within 'Appendix G1 Land Resources' of the Project's EIS.

In summary, NAC proposes that the final voids' in-pit dump/low wall and high wall slopes will be battered down to an angle of 8.5 to 17 degrees. This slope from current available geotechnical information is identified as being safe and stable long term, and following the re-application of topsoil, will allow the establishment of grass and legume species to stabilise the surface layer from erosion and permit the future use of the land for grazing (beef production) purposes.

NAC has made this commitment to ensure the Project's final landforms are safe, stable and non-polluting once fully rehabilitated. The final areas of the depressed landforms may vary slightly at the end of mining depending on the operational variables experienced over the life of the Project.

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**Life of Mine**
**Progressive Pit Development**

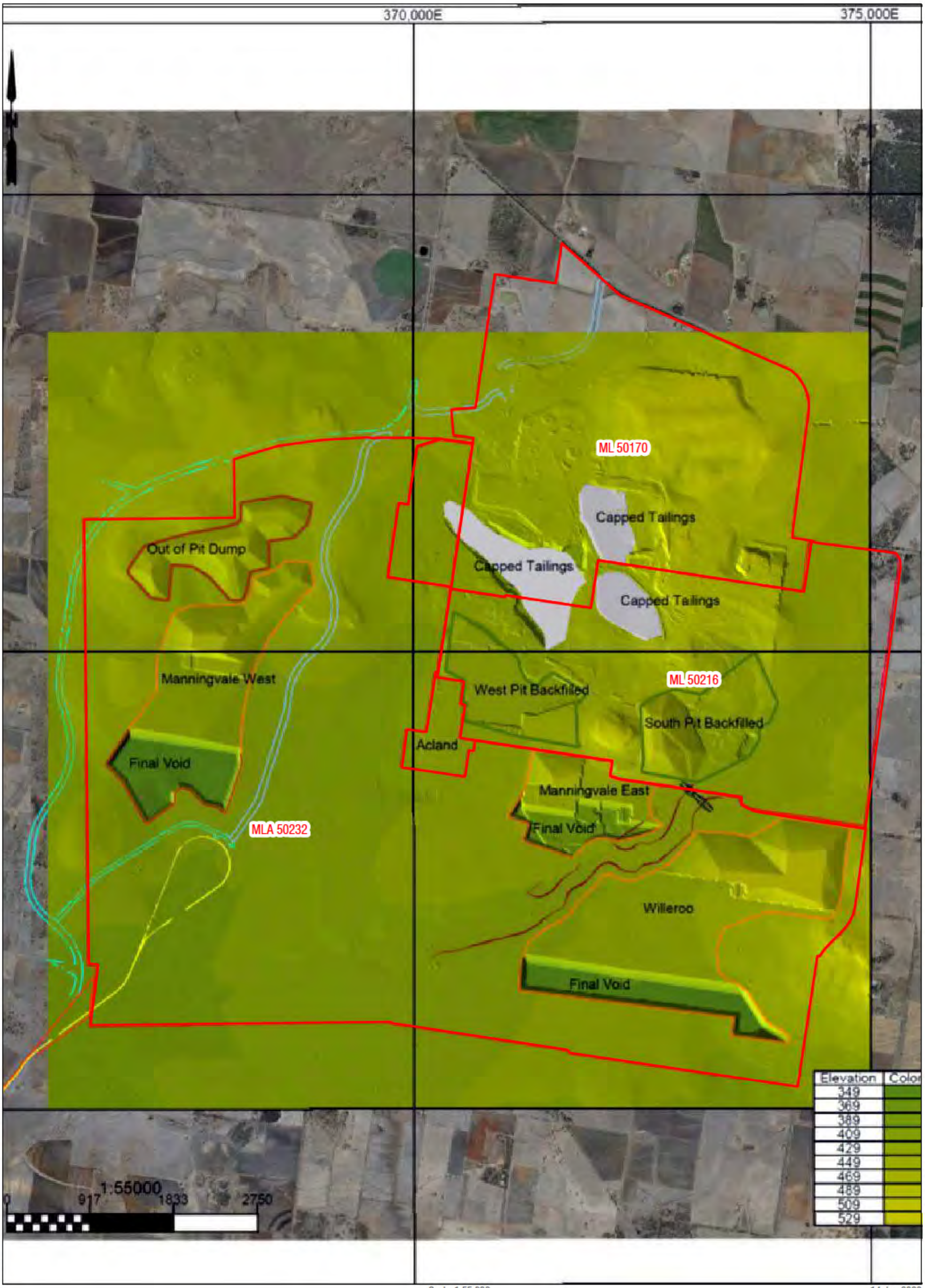
**FIGURE 2**

## 4.3 Progressive Rehabilitation

The rehabilitation of mining areas will utilise a variety of topographical features to complement the post mine land use. Landforms may be designed in a variety of ways, including but not limited to:

- reshaped landform – a reshaped area of previously mined land supporting vegetative cover on a grade that does not promote erosion;
- basin catchment – a reshaped area of previously mined land that is designed in such a way to capture and direct rainfall runoff:
    - to a depressed landform (former residual void); and/or
    - along a drainage path to a water management structure or a series of water management structures;
- contour banks – contour banks may be used on the final landform to reduce catchment areas and slope lengths, increase water infiltration and direct water:
    - to a depressed landform (former residual void); and/or
    - along a drainage path to a water management structure or a series of water management structures;
- drainage networks – a drain or a network of drains may be used on the final landform to direct water:
    - to a depressed landform (former residual void); and/or
    - along a drainage path to a water management structure or a series of water management structures.

The Project's final rehabilitated landform is shown on **Figure 3**.

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**Final Landform**

**FIGURE 3**

# 5 Soils

General soil investigations have been completed for the existing Mine as part of impact assessment activities undertaken for the approval of ML 50170 (Stage 1) and ML 50216 (Stage 2), respectively. This soils information has been used to define the land suitability, soil erosion potential, rehabilitation requirements and storm water runoff quality for the existing Mine.

During investigations for the Project, sampling and profile inspection points have been completed across the proposed disturbance areas to characterise all landform elements and geological units. The surveys were designed to provide sufficient information on land resources to allow the determination of land suitability, soil erosion, rehabilitation potential, and storm water runoff quality consistent with the methods set out by the following documents.

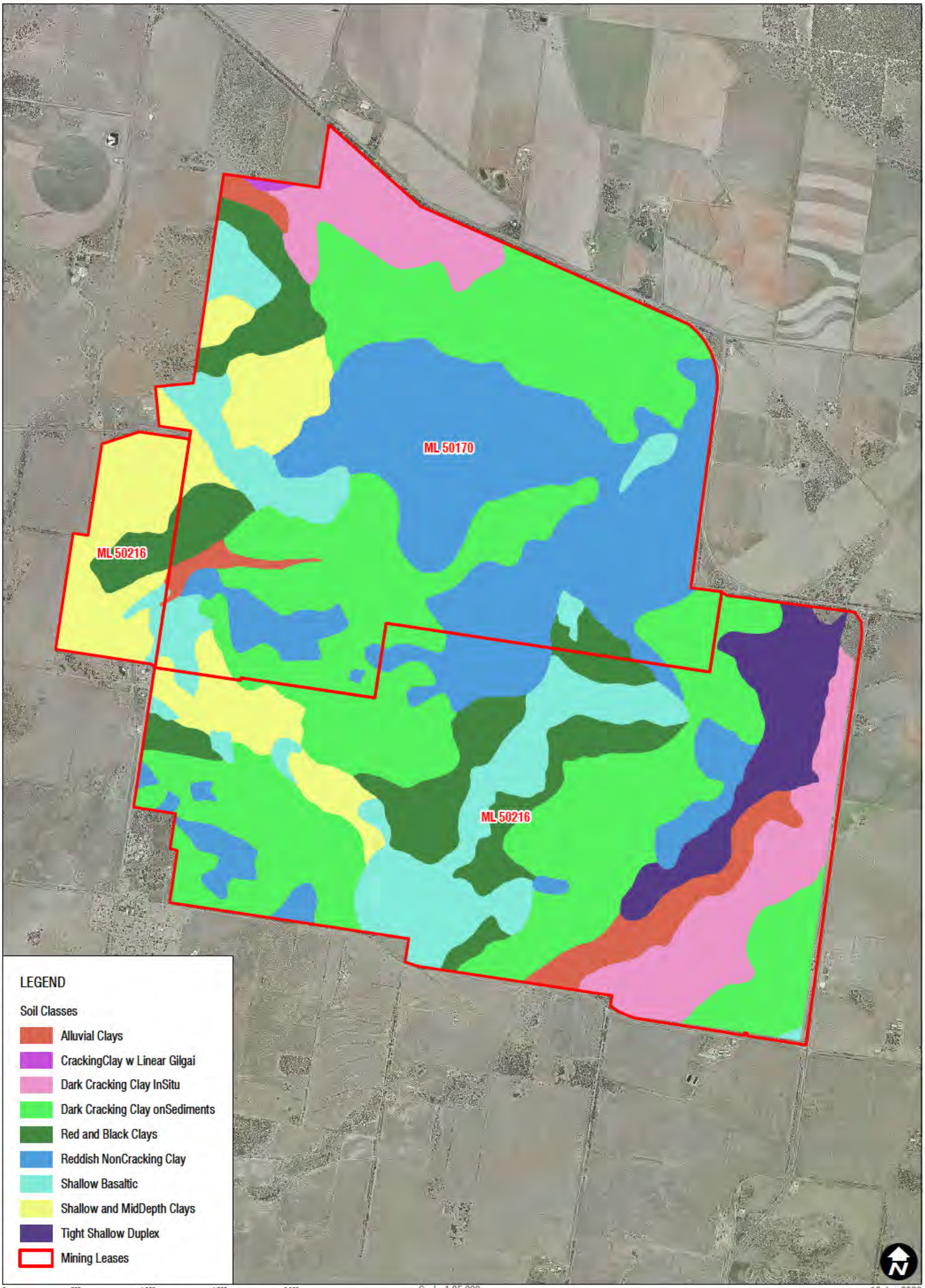
For the Mine:

- Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques (DME, 1995); and
- Shields and Williams (1991).

For the Project,

- Australian Soil and Land Survey Field Handbook 3rd Edition (NCST 2009);
- The Australian Soil Classification Revised Edition (Isbell 2002); and
- Regional Land Suitability Frameworks for Queensland (DNRM, DSITIA, 2013).

A detailed outline of previous soil assessment methodologies and soil mapping units for the current Mine are outlined in **Appendix A**. The *Soil and Land Resource Assessment New Acland Mine Stage 3 (NAC03) Project* (SLR, 2015) provides details of assessment methodologies and soil types. The extent of the soil mapping units for the current Mine and the NAC03 Project are outlined on **Figure 4** and **Figure 5**, respectively.

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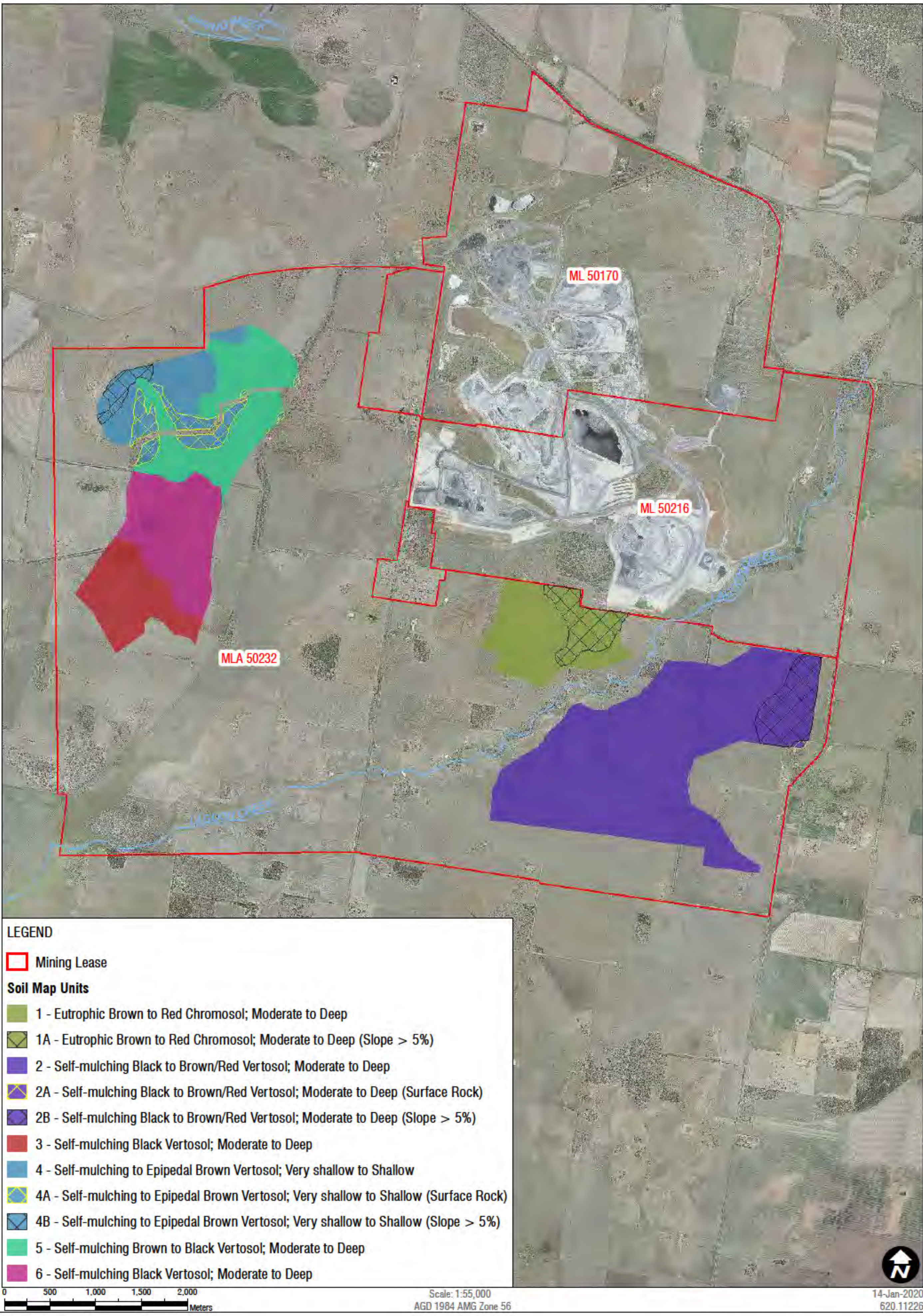
**Current Mine Soil Types**

**FIGURE 4**

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**NAC03 Soil Types**

**FIGURE 5**

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# 6 Current Mine Land Suitability Assessment

The Land Suitability Assessment was undertaken pre-mining for the current Mine's disturbance areas under the Land suitability classification, based on the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland* (DME, 1995). These technical guidelines were revised and updated for the assessment of land suitability in Queensland in 2013 with the introduction of the *Regional Land Suitability Frameworks for Queensland* (DNRM, DSITIA, 2013). The Project was assessed pre-mining using the updated Framework. The two methodologies and associated results are outlined separately in the sections below

## 6.1 Current Mine Assessment Methodology

Land suitability assessment is a means to consider the type of land use activity which is appropriate on a particular area. This section discusses the pre-mining and post-mining land suitability assessment of areas within the current Mine. Pre-mine land use suitability for beef cattle grazing and dryland cropping were determined for the majority of the current Mine area. These two land uses have been considered within the context of the pre-mining and post-mining land suitability.

Land suitability classification is based on the Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland (DME, 1995) and identifies limitations of the different soil types at the Project site and identifies suitable uses.

Information provided in Vandersee and Mullins' (1977) and personal communications with Mr Andrew Biggs (DNRM Land Management Manual author for the area) were also utilised during the land suitability assessment. The Project site was assessed, as part of previous EIS processes, for suitability for dryland cropping and grazing land uses and assigned land suitability classes as defined in Shields and Williams (1991) and DME (1995).

The soils present in the area were generally suitable for cropping on the less steep areas and away from drainage lines. All soils are considered to be suitable for cattle grazing on improved pastures with the exception of some of the upper slope areas where clearing should not take place. Land suitability classifications are outlined below:

- Class 1 - Suitable land with negligible limitations and is highly productive requiring only simple management practices;
- Class 2 - Suitable land with minor limitations which either reduce production or require more than simple management practices to sustain the use;
- Class 3 - Suitable land with moderate limitations - Land which is moderately suited to a proposed use but which requires significant inputs to ensure sustainable use;
- Class 4 - Marginal land with severe limitations which make it doubtful whether the inputs required to achieve and maintain production outweigh the benefits in the long term; and
- Class 5 - Unsuitable land with extreme limitations that precludes its use.

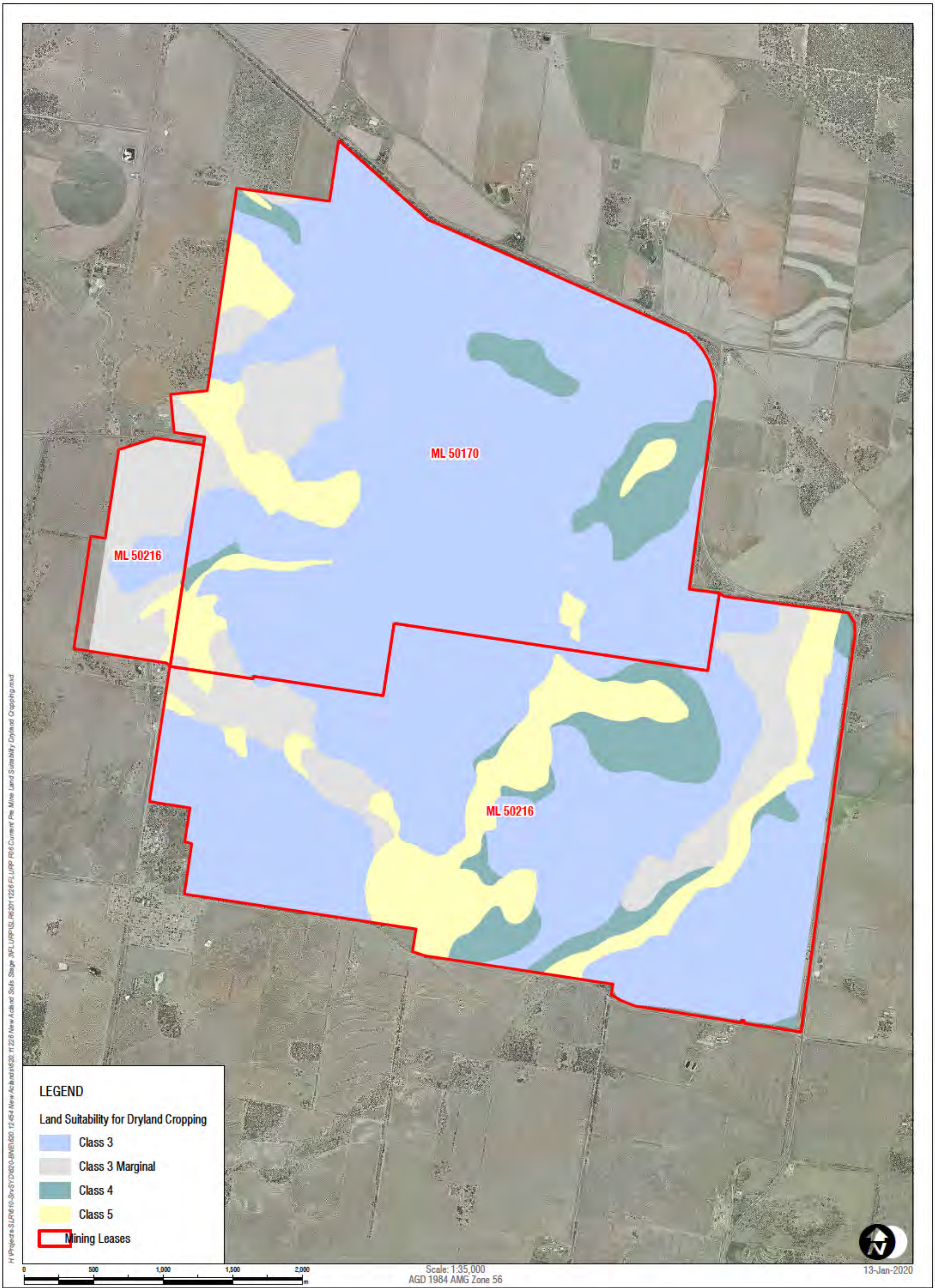
The Project site was also assessed for Good Quality Agricultural Land (GQAL) in accordance with the Planning Guidelines: the identification of Good Quality Agricultural Land (DPI/DLGP, 1993). Agricultural land is defined as land used for crop or animal production, excluding intensive animal uses. GQAL is land which is capable of sustainable use for agriculture, with a reasonable level of inputs, and without causing degradation of land or other natural resources.

The DPI/DLGP (1993) guidelines were introduced to provide local authorities and development proponents with a system to identify areas of GQAL for planning and project approval purposes. GQAL classification descriptions are summarised below:

- A – Crop land that is suitable for a wide range of current and potential crops with nil to moderate limitations to production;
- B – Limited crop land that is suitable for a narrow range of current and potential crops. Land that is marginal for current and potential crops due to severe limitations but is highly suitable for pastures. Land may be suitable for cropping with engineering or agronomic improvements;
- C – Pasture land that is suitable only for improved or native pastures due to limitations which preclude continuous cultivation for crop production. Some areas may tolerate a short period of ground disturbance for pasture establishment; and
- D – Non-agricultural land and land not suitable for agricultural uses due to extreme limitations. This may be undisturbed land with significant conservation or catchment values, land that may be unsuitable because of very steep slopes, shallow soils, rock outcrop, poor drainage, salinity, acidic drainage, or is an urbanised area.

## 6.2 Current Mine Pre Mining Land Suitability

A summary of the pre-mine land suitability assessments undertaken over the current Mine site to date is provided in **Appendix B** and **Appendix C**. The extent of pre- mine land suitability for Dryland Cropping is outlined on **Figure 6** and the extent of pre- mine land suitability for Improved Pasture is outlined on **Figure 7**.

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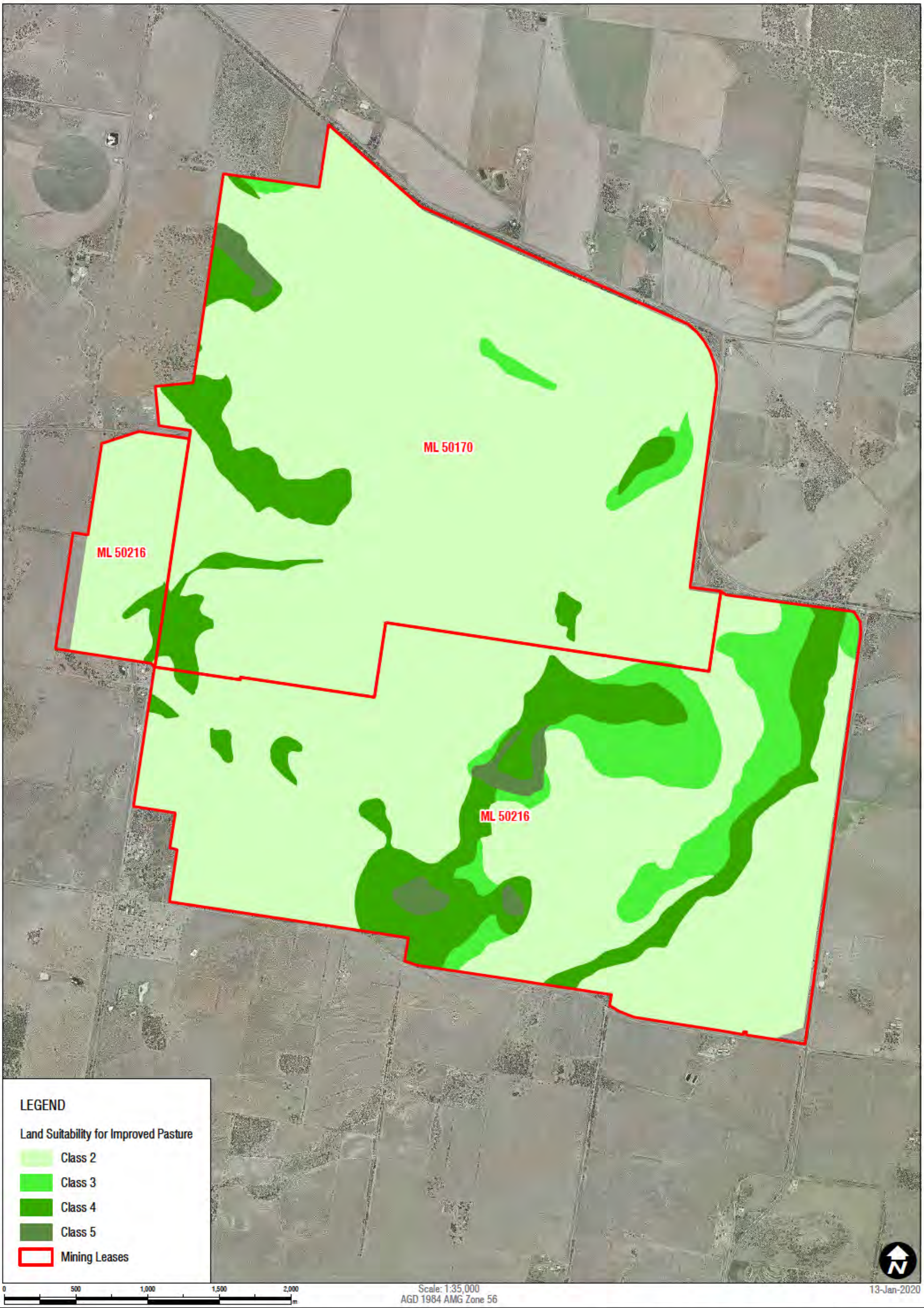
**Current Mine Pre-Mine Land Suitability Map For Dryland Cropping**

**FIGURE 6**

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**Current Mine Pre-Mine Land Suitability Map for Improved Pastures**

**FIGURE 7**

## 6.3 Current Mine Post Mine Land Suitability

This section outlines the implications of the activity on the suitability of areas for determined pre-mine land use (dryland cropping and cattle grazing) as mining activities are expected to change the physical, chemical and biological properties of soil, slope and slope length, and suitability of the land for intended post mine land use.

The suitability of the waste rock dumps for cropping and grazing is constrained by slope angle, soil cover, and altered moisture profile. These constraints would increase the risk of erosion significantly if cropping were undertaken.

The plateau of the final waste dump landforms is not considered suitable for rainfed cropping as it would require the replacement of a black cracking clay profile of approximately 900 millimetres depth and the installation of suitable soil conservation works, which is considered not practical.

The erosion stability of the waste rock dump may present a severe to extreme limitation to sustainable grazing. Moisture availability for a 30 centimetres deep topsoil would also be a severe limitation. Therefore, suitability on the waste rock dumps would be marginal land at best.

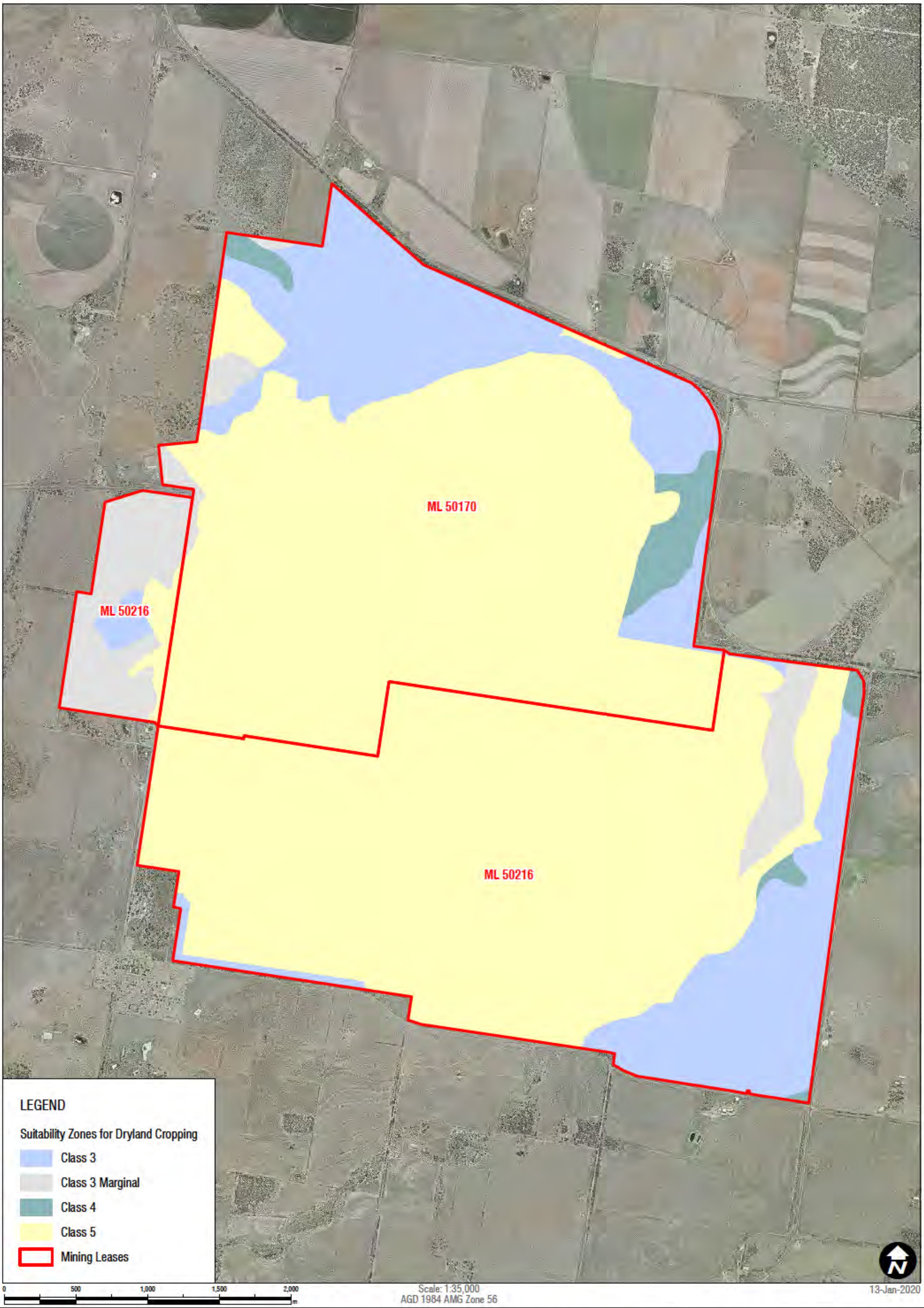
The extent of post-mine land suitability for Dryland Cropping is outlined on **Figure 8** and the extent of post-mine land suitability for Improved Pasture is outlined on **Figure 9**.

### 6.3.1 Dryland Cropping

Approximately 84% of the pre-mined area within ML 50170 (Stage 1) and 74% of the pre-mined area within ML 50216 (Stage 2) is suitability Class 3 and is suitable for rainfed cropping. This feature is consistent with existing land use, although some potential cropping land currently supports native pastures. The post-mining landscape suitable for rainfed cropping comprises approximately 24% of ML 50170 (Stage 1) and 25% of ML 50216 (Stage 2). Overall, the post-mine land suitability classes for dryland cropping of the area are unlikely to be suitable without extreme limitations. The pre-mine and proposed post-mine areas of land suitability for rainfed cropping is outlined in **Table 3**.

### Table 3 Current Mine Dryland Cropping Pre Mine and Post Mine Land Suitability

| Land Suitability Class | Area within ML50170 (ha) | | % of Total ML50170 Area | | Area within ML50216 (ha) | | % of Total ML50216 Area | |
|---|---|---|---|---|---|---|---|---|
| | Pre-Mining | Post-Mining | Pre- Mining | Post-Mining | Pre-Mining | Post-Mining | Pre- Mining | Post-Mining |
| 3 | 923 | 269 | 83.8 | 24.4 | 856 | 288 | 74.1 | 24.9 |
| 4 | 81 | 40 | 7.4 | 3.6 | 100 | 9 | 8.7 | 0.8 |
| 5 | 99 | 794 | 9.0 | 72.0 | 199 | 858 | 17.3 | 74.3 |
| **Total** | **1,103** | **1,103** | **100** | **100** | **1,155** | **1,155** | **100** | **100** |

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**Current Mine Post-Mine Land Suitability Map For Rainfed Cropping**

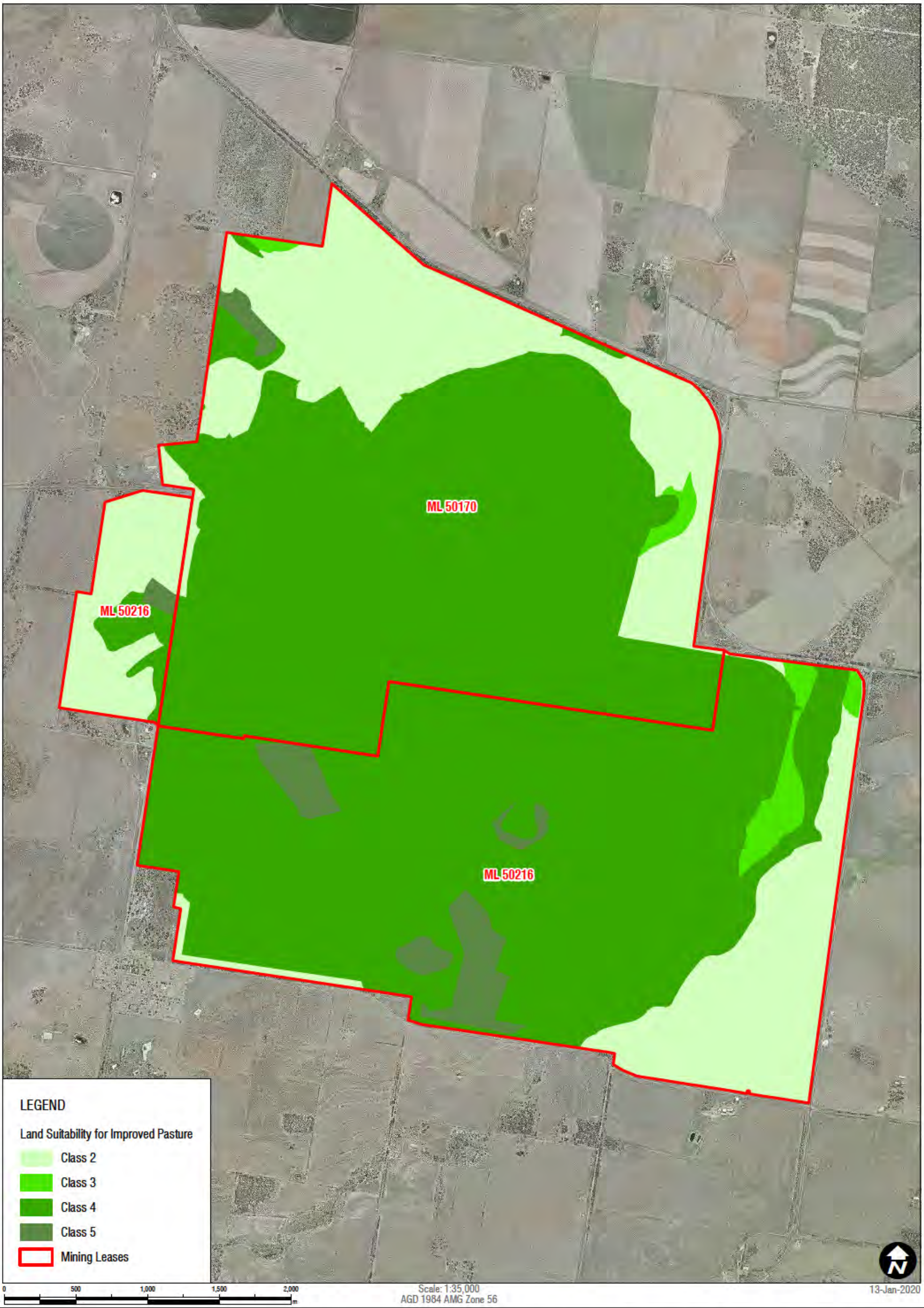
**FIGURE 8**

### 6.3.2 Grazing

The largest change in post-mining land suitability for cattle grazing occurs in Class 4 which increases from 8% to 71% within ML 50170 (Stage 1) and 15% to 71% within ML 50216 (Stage 2). Other land areas downgraded are mostly Class 2 and Class 3 land suitability. However, overall post-mine land suitability for grazing is substantially greater than that for dryland cropping. The pre-mine and proposed post-mine areas of land suitability for grazing are outlined in **Table 4**.

**Table 4 Current Mine Cattle Grazing Pre Mine and Post Mine Land Suitability Extents**

| Land Suitability Class | Area within ML50170 (hectares) | | % of Total ML50170 Area | | Area within ML50216 (hectares) | | % of Total ML50216 Area | |
|---|---|---|---|---|---|---|---|---|
| | Pre- Mining | Post-Mining | Pre-Mining | Post-Mining | Pre-Mining | Post-Mining | Pre-Mining | Post-Mining |
| **2** | 981 | 303 | 89 | 27 | 816 | 250 | 71 | 22 |
| **3** | 19 | 10 | 2 | 1 | 140 | 27 | 12 | 2 |
| **4** | 88 | 782 | 8 | 71 | 178 | 816 | 15 | 71 |
| **5** | 15 | 8 | 1 | 1 | 21 | 62 | 2 | 5 |
| **Total** | **1,103** | **1,103** | **100** | **100** | **1,155** | **1,155** | **100** | **100** |

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**Current Mine Post-Mine Land Suitability Map For Improved Pastures**

**FIGURE 9**

# 7 NAC03 Land Suitability Assessment

This Land Suitability assessment has been conducted in accordance with the Regional Land Suitability Frameworks for Queensland (DNRM, DSITIA, 2013) for the Eastern Downs Region. The suitability framework provides the detail for assessing which crops are suitable for individual mapped areas of land or soil.

Five land suitability classes are defined for use in Queensland, with land suitability decreasing progressively from Class 1 to Class 5. These classes are used to describe an area of land in terms of suitability for a particular land use which allows optimum, sustainable production with current technology while minimising degradation to the land resource in the short, medium or long-term.

Land is considered less suitable as the severity of limitations for a land use increases, reflecting either:

- reduced potential for production; and/or
- increased inputs required to achieve an acceptable level of production; and/or
- increased inputs required to prepare the land for successful production; and/or
- increased inputs required to prevent land degradation.

The five land suitability classes are defined as follows.

**Class 1** – Suitable land with negligible limitations. This is highly productive land requiring only simple management practices to maintain economic production.

**Class 2** – Suitable land with minor limitations which either reduce production or require more than the simple management practices of class 1 land to maintain economic production.

**Class 3** – Suitable land with moderate limitations which either further lower production or require more than those management practices of class 2 land to maintain economic production.

**Class 4** – Marginal land, which is presently considered unsuitable due to severe limitations. The long term significance of these limitations on the proposed land use is unknown or not quantified. The use of this land is dependent upon undertaking additional studies to determine whether the effect of the limitation(s) can be reduced to achieve sustained economic production.

**Class 5** – Unsuitable land with extreme limitations that preclude its use.

The first three classes of land are considered suitable for the specified land use, as the benefits from using the land for that land use in the long term should outweigh the inputs required to initiate and maintain production. Decreasing land suitability within a region often reflects the need for increased inputs rather than decreased potential production. There are many occasions where there is no land assessed as Class 1 (or other suitable classes) in a study area for a particular land use.

Class 4 land is regarded as marginal land, currently unsuitable for a particular land use due to the severity of one or a number of limiting factors. It is doubtful that the inputs required to achieve and maintain production outweigh the benefits in the long-term. This land may possibly be upgraded to a suitable class if future agronomic, soil or engineering studies show it to be economically viable and environmentally sustainable. Changes in climate, economic conditions, or technology may alter the level of management inputs required to achieve satisfactory productivity.

Six Soil Map Units (referred to as Unique Map Units within the Framework) and five Soil Map Unit variants were mapped with the NAC03 Study Area, with Vertosols comprising the dominant soil type. The Land Suitability Assessment for each Soil Map Unit has been completed on the soil and land properties identified from Analysed Sites.

The outcomes of the Land Suitability Assessment include:

- The entire Study Area has been assessed as either Land Suitability Class 3 or Class 4 for all Land Uses, including dryland cereal and grain crops (i.e. wheat, oats, barley and sorghum), sunflower and chickpeas (**Table 5**).
- The major limitations for Soil Map Units identified as Class 3 are Erosion Hazard (Es) and Surface Condition (Ps) (**Table 6)**.
- The major limitations for Soil Map Units identified as Class 4 are Soil Water Availability (M), Erosion Hazard (Es) and Rockiness (R) (**Table 6**).

### Table 5 NAC03 Overall Land Suitability Results

| Land Suitability Class | Major Limitation(s) | Area (Ha) |
|---|---|---|
| **3** | Es – Erosion Hazard<br>Ps – Surface Condition | 696 |
| **4** | Es – Erosion Hazard<br>M – Soil Water Availability<br>R - Rockiness | 316 |
| | **Total** | **1,012** |

### Table 6 Land Suitability Assessment Results Summary

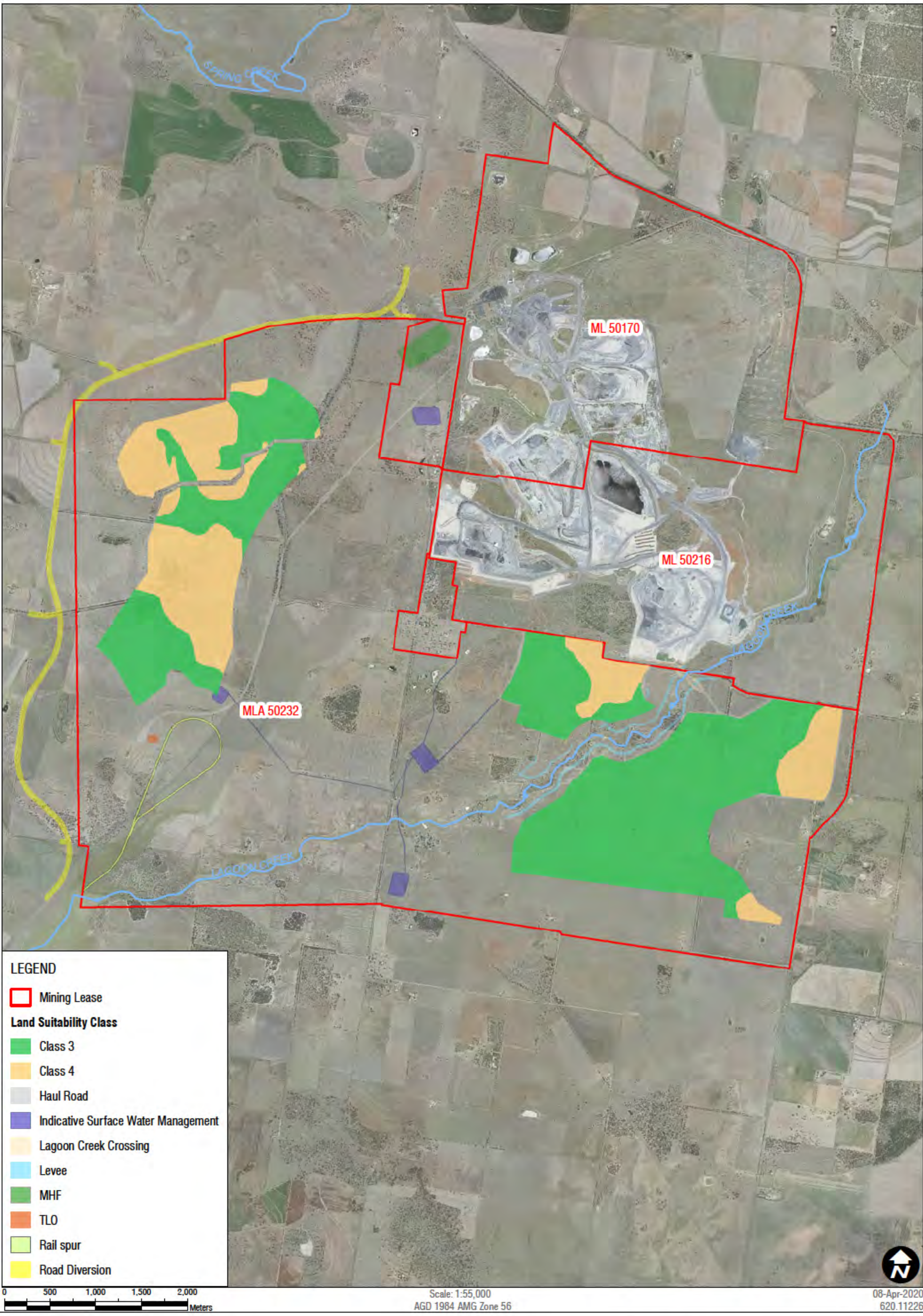
| Soil Map Unit | Major Limitation(s) | Overall Land Suitability Class |
|---|---|---|
| 1 | Es – Erosion Hazard, Ps – Surface Condition | Class 3 |
| 1A | Es – Erosion Hazard | Class 4 |
| 2 | Es – Erosion Hazard | Class 3 |
| 2A | R - Rockiness | Class 4 |
| 2B | Es – Erosion Hazard | Class 4 |
| 3 | Es – Erosion Hazard | Class 3 |
| 4 | M – Soil Water Availability | Class 4 |
| 4A | M – Soil Water Availability, R – Rockiness | Class 4 |
| 4B | M – Soil Water Availability, Es – Erosion Hazard | Class 4 |
| 5 | Es – Erosion Hazard | Class 3 |
| 6 | Es – Erosion Hazard, M – Soil Water Availability | Class 4 |

Full details of the NAC03 Land Suitability Assessment for each Soil Map Unit is provided in (SLR, 2015).

The post mining landforms and soil profiles are modified from pre mining classes, generally due to changes in slope steepness and length, soil profile depth and layering. These changes result in a modified land suitability for the site to that shown in **Figure 10**. The proposed post mining land suitability for the disturbance areas for NAC03 are as follows.

- Cropping Land Suitability Class 3 – 541 hectares, suitable for use as SCL with standard soil profile depths of 0.6 metres to 1.2 metres. These areas are located within the mining areas. However, they avoid the out-of-pit emplacements and final depressed areas.
- Grazing Land Suitability Class 4 – 471 hectares, suitable for use as grazing land with soil profile depths of 0.3 metres to 0.5 metres. These areas are located within the out-of-pit emplacements and final depressed areas, which are typically steeper slopes than the backfilled mining areas.

Where infrastructure areas are not required for the ongoing use by APC (i.e. water infrastructure such as dams or access tracks) they will be rehabilitated to a minimum of Grazing Suitability Class 4 (as per IC7). Prior to the commencement of any infrastructure works soil sampling will be undertaken to determine topsoil stripping depth, stockpiling requirements and rehabilitation requirements.

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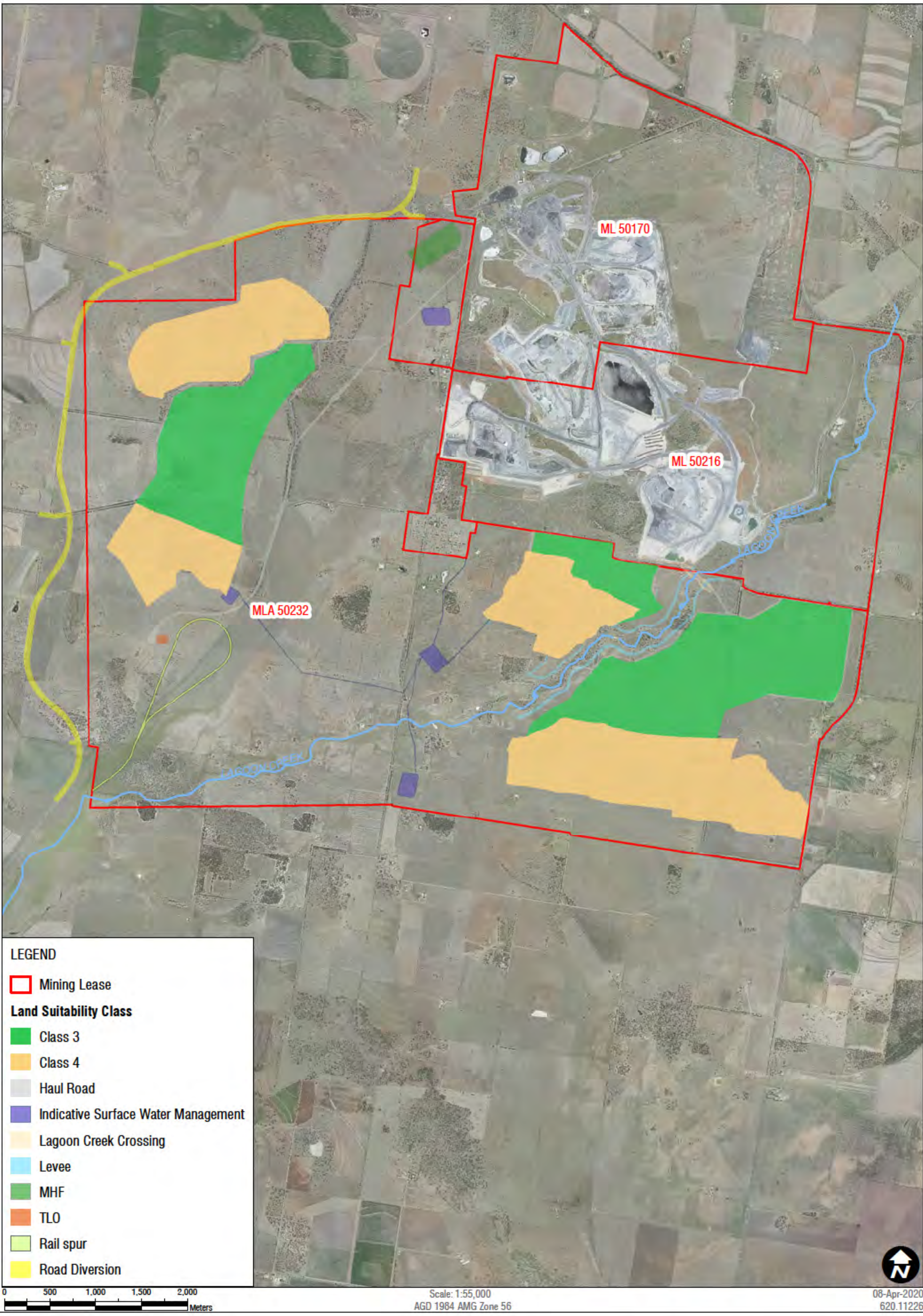
## NAC03 Pre-Mine Land Suitability Map For Improved Pastures

**FIGURE 10**

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NAC03 Post Mine Land Suitability Map

FIGURE 11

# 8 Erosion Potential and Control

## 8.1 Erosion Hazard

Open cut mining activities involve land disturbance that can pre-dispose an area to erosion risks. Typical mining activities that require use of erosion mitigation strategies include:

- topsoil stripping ahead of mining development and for infrastructure development such as haul roads, hard stands and access tracks;
- drainage line crossings for pipes and roads;
- spoil dump placement, as spoil is a fractured mix of earthen fines that possess a considerable erosion potential;
- newly rehabilitated areas prior to vegetation establishment; and
- topsoil stockpiles.

## 8.2 Erosion Control

Progressive rehabilitation will continue over the life of the Project until all areas disturbed by mining are safe, stable, non-polluting and able to support the proposed post-mining land use. In general, this approach will ensure disturbed areas are stabilised as quickly as practical to limit the risk of erosion.

Erosion and sediment control measures will be employed as per the practices described in the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland* (DME 1995).

The design parameters for the construction of erosion control work such as rock armoured or grass lined waterways will be in accordance with established principles for engineering and soil conservation earthworks. A number of variables are included such as time of concentration, rainfall intensity, erosivity, gradient, scour velocities and flow estimations.

The erosion control measures to be employed at the Project site are summarised in **Table 7**.

**Table 7 Erosion Causes and Control – Mining Activities**

| Area | Control Measure |
|---|---|
| Cleared Land | • restrict clearing to areas essential for the works<br>• windrow vegetation debris along the contour<br>• minimise length of time soil is exposed<br>• divert run-off from undisturbed areas away from the works<br>• direct run-off from cleared areas to sediment dam<br>• monitoring and/or inspection at an appropriate interval, and as required, prompt remediation actions based on risk |

| Area | Control Measure |
|---|---|
| Exposed Subsoils | • minimise length of time soil is exposed<br>• direct run-off from exposed areas to sediment dams<br>• monitoring and/or inspection at an appropriate interval, and as required, prompt remediation actions based on risk |
| Active Pit | • divert run-off from undisturbed areas away from the active pit(s)<br>• pump rainfall run-off capture within pit areas to the environmental dams for future water recycling purposes |
| Active Waste Rock Dump<br>(out-of-pit and in-pit) | • direct all run-off from dumps to sediment dams<br>• avoid placement of sodic waste material on final external batters<br>• control surface drainage to minimise the formation of active gullies<br>• commence rehabilitation activities as soon as operationally possible<br>• monitoring and/or inspection at an appropriate interval, and as required, prompt remediation actions based on risk |
| Rehabilitation | • re-contour waste rock dumps progressively to landform criteria<br>• install drainage control works<br>• replace topsoil, rip on the contour and seed<br>• direct run-off from rehabilitated areas to sediment dams<br>• revegetate rehabilitated areas as soon as practical<br>• monitoring and/or inspection at an appropriate interval, and as required, prompt remediation actions based on risk |
| Mine Infrastructure (including water) | • provide protection in drains where water velocity may cause scouring (e.g. rip rap, grass)<br>• confine traffic to maintained tracks and roads<br>• install sediment traps, silt fences, hay bales where necessary to control sediment<br>• rehabilitate disturbed areas no longer required for operational purposes as promptly as possible<br>• monitoring and/or inspection at an appropriate interval, and as required, prompt remediation actions based on risk |

# 9 Post Mining Land Use and Rehabilitation

## 9.1 Introduction

Rehabilitation studies at the existing Mine and for the Project have examined soils, landforms, the nature of waste materials, drainage and vegetation. These studies have demonstrated the successful use of conventional rehabilitation techniques on a range of materials excavated at the Mine and in the future for the Project. The knowledge gained from the existing Mine has been adapted and used in the progressive rehabilitation of the site and will continue throughout the Project.

Importantly, NAC has achieved a high standard of progressive rehabilitation at the existing Mine, which resulted in 349 hectares being ‘certified’ as progressive rehabilitation, under the EP Act, by DES on 1 November 2018. NAC will continue to build on the knowledge gained from this achievement to help its rehabilitation outcomes for the Project meet regulatory standards and community expectations.

Rehabilitation strategies at the site include all areas of disturbance and are reviewed on a regular basis in order to take into account any changes to mine operations, changes in legislative requirements and/or results of ongoing studies and monitoring.

The rehabilitation strategies have been developed after consideration of the Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland (DME, 1995), the Department of Environment and Heritage Protection (DEHP, now DES) Guideline: Rehabilitation Requirements for Mining Projects (DEHP 2014), the Mined Land Rehabilitation Policy (QLD Government 2018) and the Mineral and Energy Resources (Financial Provisioning Act (QLD Government 2019). Importantly, the following considerations have been applied:

- *Land Suitability Assessment Techniques* - which addresses the applicability and use of land suitability assessment techniques in determining pre-mining land capability and post-mining land use potential;
- *Determination of Post-Mining Land Use* - which describes the identification and selection of suitable post-mining land use options;
- *Progressive Rehabilitation* - which describes the advantages of and opportunities and strategies for progressive rehabilitation;
- *Assessment and Management of Acid Drainage* - which addresses the identification, evaluation and management of solid waste materials with potential to generate acid drainage and/or heavy metal toxicity;
- *Open Pit Rehabilitation* - discusses the criteria to be applied in the design and rehabilitation of open pits having regard to geophysical aspects, sealing of strata, water accumulation and safety issues;
- *Erosion Control* - which addresses the prediction, control and measurement of soil erosion on mining lease areas;
- *Growth Media Management* - which outlines the selection, handling, storage, treatment and replacement of soils and other media to be used for establishing and growing vegetation on land following mining;
- *Mine site Decommissioning* - which addresses the closure and decommissioning of areas, works and facilities used for mining, including the In-Pit Tailings Storage Facility;

- *Site Water Management* - which discusses the management of water on mine sites so as to reduce the amount of contaminated water that may need to be handled; and
- *Water Discharge Management* - which addresses the management of water discharged from mine sites to ensure compliance with statutory requirements and protection of downstream uses.

## 9.2 Rehabilitation Principles and Hierarchy

The overriding principle for the rehabilitation program at the Mine and for the Project is that the land should be returned to a post-mine land use that will be stable, self-sustaining and require minimal maintenance. The post-mine land use for areas disturbed by mining at the site will be a self-sustaining vegetation community using appropriate pasture grasses and scattered plantings of native tree and shrub species. The attainment of this land use will stabilise the landform and protect the downstream water quality.

In assessing the rehabilitation objectives and completion criteria, the Mine Rehabilitation Hierarchy outlined by the Guideline Rehabilitation Requirements for Mining Projects (DEHP 2014) have been considered as well as the Sustainable Final Land Use Outcomes outlined in the EA. The most practical, achievable and sustainable rehabilitation strategy for the site is to reinstate the dominant previous agricultural land use of grazing.

In addition, the Project's rehabilitation requirements for mining disturbance on ML 50232 has been conditioned by the Coordinator-General to ensure:

1. rehabilitation is undertaken in a manner that does not allow unjustified mixing of soil material from different soil map units;
2. each rehabilitated land unit is capable of being assigned a specific post-disturbance land use suitability; and
3. a rehabilitation outcome that achieves at least 50 per cent of the total area of disturbed land originally meeting or exceeding the criteria for either Class 3 grazing land or Class 4 cropping land being able to still meet or exceed those classifications.

## 9.3 Post Mining Rehabilitation Goals

The core rehabilitation goal is to achieve the final land use of grazing at the Mine site and in the future for the Project site by:

- creating stable rehabilitated landforms that are safe to humans and wildlife and are non- polluting;
- ensuring rehabilitated landforms can support productive and sustainable grazing activities;
- implementing and monitoring measurable standards to assess the success of rehabilitated landforms to the agreed grazing post-mining land use;
- ensuring progressive rehabilitation of disturbed land over the life of the Project is incorporated into mine planning to minimise the amount of land disturbed at any one time and to reduce the rehabilitation burden prior to mine closure;

- undertaking rehabilitation within ML 50232 in a manner that establishes discrete land units in the disturbance areas, so that each rehabilitated land unit is capable of being assigned a specific post-disturbance land use suitability (i.e. to achieve the best possible post-disturbance land use);
- ensuring a rehabilitation outcome for ML 50232 that achieves at least 50 per cent of the total area of disturbed land originally meeting or exceeding the criteria for either Class 3 grazing land or Class 4 cropping land being able to still meet or exceed those classifications; and
- achieving a rehabilitation standard that will permit regulatory approval for surrender of MLs 50170, 50216, 50232 and 700002 to allow complete mine closure.

## 9.4 Strategies to achieve Rehabilitation Goals

The rehabilitation strategies for each of the four domains of solid waste disposal areas (spoil, waste dumps and reject dumps), tailings dams, infrastructure areas and depressed landforms at the Mine/Project site are summarised in **Table 8**. The rehabilitation acceptance criteria outlined under Section 9.2 relates to all four domains as they are classified as "disturbed by mining" and will receive the same rehabilitation treatment.

Infrastructure areas will generally not require spoil placement or capping. However, they will receive topsoil and seeding treatments similar to the solid waste disposal and capped tailings dams. Please note, by agreement some of the former mining infrastructure will remain for use by the New Hope Group subsidiary company, Acland Pastoral Company Pty Ltd (APC).

Each of the Project's depressed landforms (former voids) will require reshaping of its void's 'high' and 'low' walls to a maximum of 20 and 15 degrees, respectively. The reshaped slopes will receive a final layer of subsoil and topsoil suitable to promote re-vegetation to allow grazing to be conducted in a safe and sustainable manner.

## Table 8 Strategies to Achieve Rehabilitation Goals

| Domain | Rehabilitation Goals | | | |
|---|---|---|---|---|
| | Safe | Non-Polluting | Stable landform | Sustains Agreed Land Use |
| **Solid Waste Rock Disposal** | Appropriate geotechnical design will be used for solid waste disposal structures. | Only geochemically benign material will be placed at or near the surface of solid waste disposal structures.<br>Adequate vegetation cover will be established to minimise erosion.<br>Runoff and seepage associated with solid waste disposal structures will be controlled by water management (e.g. dams). | Appropriate geotechnical design will be used for solid waste disposal structures.<br>Adequate vegetation cover will be established to minimise erosion. | The re-establishment of vegetation will be monitored against the performance indicators for a successful grazing outcome.<br>As required, grazing trials will be conducted to evaluate grazing performance within rehabilitation areas. |
| **Tailings Dams** | Tailings dams will be decommissioned and rehabilitated as defined by the In-pit Tailings Storage Management Plan. | Tailings dams will be decommissioned and rehabilitated as defined by the In-pit Tailings Storage Management Plan.<br>Appropriate capping material will used for rehabilitation.<br>Adequate vegetation cover will be established to minimise erosion.<br>Runoff and seepage associated with tailings dams during rehabilitation will be controlled by water management (e.g. dams). | Tailings dams will be decommissioned and rehabilitated as defined by the In-pit Tailings Storage Management Plan.<br>Appropriate capping material will used for rehabilitation.<br>Adequate vegetation cover will be established to minimise erosion. | The re-establishment of vegetation will be monitored against the performance indicators for a successful grazing outcome. |

| Domain | Rehabilitation Goals | | | |
|---|---|---|---|---|
| | Safe | Non-Polluting | Stable landform | Sustains Agreed Land Use |
| **Mine Infrastructure Areas (including Linear Infrastructure Areas)** | Contaminated land investigations and remediation will be conducted as required.<br>All non-required infrastructure will be appropriately decommissioned and removed off site. | Contaminated land investigations and remediation will be conducted as required.<br>Runoff and seepage associated with Mine Infrastructure areas during rehabilitation will be controlled by water management (e.g. dams).<br>Adequate vegetation cover will be established to minimise erosion. | All non-required infrastructure will be appropriately decommissioned and removed off site.<br>By agreement some of the former mining infrastructure will remain for use by the New Hope Group subsidiary company, APC.<br>Adequate vegetation cover will be established to minimise erosion. | The re-establishment of vegetation will be monitored against the performance indicators for a successful grazing outcome. |
| **Depressed Landforms (Former Voids)** | Each final void will have its high and low walls reshaped to an appropriate geotechnical design that allows efficient rehabilitation activities, and longer term facilitates safe grazing of the internal slopes. | Adequate vegetation cover will be established to minimise erosion. | Appropriate geotechnical design will be used for depressed landforms.<br>Adequate vegetation cover will be established to minimise erosion. | The re-establishment of vegetation will be monitored against the performance indicators for a successful grazing outcome. |

To achieve the rehabilitation goals set by the Coordinator-General for the Project, NAC has completed a detailed soil survey of the proposed disturbance areas within ML 50232 and developed a Revised Soil Management Plan based on the detailed soil survey to ensure that the Project's topsoils and subsoils are selectively managed (stripped and returned) to minimise the risk of mixing soil types and to promote the opportunity to achieve the best possible rehabilitation outcome from an agricultural perspective.

## 9.5 Post Mining Land Use

The proposed post-mine land use for the existing Mine's and Project's disturbed areas will be grazing, using native and pasture (exotic) grass species combined with smaller areas of local native tree and shrub species. This nominated land use will ensure that the land remains agriculturally productive, is consistent with the surrounding land uses, and can be re-incorporated into the New Hope Group's agribusiness through its subsidiary company, APC.

To help satisfy community expectations, the Coordinator-General has conditioned the Project to ensure that all efforts are made by NAC to return the Project's disturbed areas to a high standard of agricultural production.

## 9.6 Post Mining Landform

The existing Mine and its continuation under the Project will change the land use and land suitability of the site. From a regulatory perspective, the Project's disturbed areas (including the existing Mine) will be rehabilitated in accordance with:

- Agency Interest: Land and Rehabilitation – Table H1 and Table H2 of the EA for the existing Mine;
- Table H4: Rehabilitation Requirements Stage 3 New Acland Mine Project, Table H5: Rehabilitation Acceptance Criteria — Grazing Lands Stage 3 New Acland Mine Project and Table H6: Rehabilitation Acceptance Criteria — Treed Areas Stage 3 New Acland Mine Project of the EA for the Project; and
- the requirements of Imposed Conditions 6 and 7 of the 'New Acland Coal Mine Stage 3 project Coordinator-General's evaluation report on the environmental impact statement (December 2014)'.

The primary design objective is the creation of a stable final landform that is compatible with the proposed final agricultural land use. NAC will use experience gained at the current Mine and other mines in the region, specialist consultants and relevant research findings to meet this objective and the requirements specified in the EA's *Agency Interest: Land and Rehabilitation* and the Coordinator-General's evaluation report.

Stable landforms will continue to be progressively established as part of the mining process using integrated mine planning, proven earthmoving techniques and appropriate water management design. The final slopes will be engineered to ensure geotechnical stability and designed to incorporate the required water management structures to manage storm runoff.

Established topsoil and revegetation techniques will be applied to create a self-sustaining vegetation community capable of supporting grazing. Advanced soil management (topsoil and subsoil) will be used within the Project's disturbance areas to help achieve an even higher standard of rehabilitation outcome.

Rehabilitation monitoring and grazing trials (as required) will be conducted to establish rehabilitation success and to capture the required data for further progressive rehabilitation certification and/or eventual surrender of the mining tenure.

## 9.7 Rehabilitation Strategy

A rehabilitation strategy has been developed to restore and re-establish disturbed areas resulting from mining operations. The rehabilitation strategy for the current Mine and the Project comprise the following integrated measures.

- Appropriate pre-disturbance preparation will be conducted, such as topsoil recovery and management plans, and integrated mine planning to efficiently coordinate mining activities.
- Practical landform designs will be developed and implemented to prevent erosion and establish final landform stability.
- Development of the proposed post-mine agricultural land use will consider local environmental constraints.
- All efforts will be made to ensure sodic/dispersive materials are not placed near the surface of the dumps or within the plant root zone.
- Tailing dams will be managed in accordance with the current in-pit tailings dam management plan and all other applicable statutory requirements.
- As required, revegetation trials will be conducted to assist the selection of appropriate revegetation species and methodologies.
- Progressive rehabilitation of disturbed areas will continue using appropriate rehabilitation procedures.
- A rehabilitation monitoring program to assess rehabilitation success will continue.
- A corrective action program to address identified areas of unsatisfactory rehabilitation will continue.
- Progressive rehabilitation, monitoring and remediation activities will be focussed on increasing the amount certified progressive rehabilitation over time.
- Advanced soil management activities through the Revised Soil Management Plan will be integrated into the Project's mine planning and operations.

### 9.7.1 Progressive Rehabilitation

A program of progressive rehabilitation is conducted at the current Mine and will continue over the life of the Project, and eventually will become a statutory requirement of a PRCP for the site (i.e. upon implementation of the process by DES). The main features of NAC's progressive rehabilitation process are as follows.

Final shaping of slopes and landforms involving a variety of topographical features are designed to complement the post mined land use. Landforms may be designed in a variety of ways, including but not limited to:

- reshaped landforms – reshaped areas of previously mined land supporting vegetative cover on a grade that does not promote erosion;
- basin catchment – reshaped areas of previously mined land that are designed in a way to capture and direct rainfall runoff;
- depressed landform (former residual void);

- drainage pathways to water management structures;
- contour banks – contour banks may be used on final landforms to reduce catchment areas and slope lengths, increase water infiltration and direct water; and
- leeward aspects – provide protection from the dominant wind direction and enhances vegetation growth.

Establishment of final landforms, spreading of topsoil and subsoil, seeding with appropriate pasture species, and livestock activity are progressively conducted on rehabilitation areas.

### 9.7.2 Soil Management

For the current Mine, soil is recovered prior to disturbance from all planned disturbance areas for eventual use in rehabilitation. Recovered soil is either purposefully stockpiled until suitable re-contoured areas are available for re-spreading or is directly returned to re-contoured areas to achieve a sustainable final landform. Currently, stockpile recovery processes are implemented per site-based Work Instruction documents (i.e. NAC documents: WI-ENV-11 Topsoil and Rehabilitation Work).

The soil resources present at the current Mine and to be recovered for the Project are adequate for the rehabilitation of current and proposed disturbed areas, and to achieve the proposed post- mining land suitability classes and post mining land uses. The soil resources allocated for rehabilitation at the current Mine are adequate to provide a soil profile depth of approximately 250-300mm.

The Project's soil resources (topsoil and subsoil) have been thoroughly assessed to ensure adequate post mining soil profiles and depths are achieved to establish the required amount of targeted land suitability classes and the planned post mining land uses.

### 9.7.3 Revegetation

The revegetation methods for disturbed areas generally comprise the following actions:

- respreading of stockpiled or freshly stripped soil;
- contour ripping;
- application of appropriate fertiliser for plant establishment (after soil chemical analysis, if required); and
- seeding with an appropriate seed mix to establish a post mining agricultural land use.

Where available, competent materials such as basalt are placed on steeper slopes to aid stability. Contour ripping is used as an erosion control measure immediately after surface preparation and before revegetation to improve infiltration. A seed mix containing a sterile cover crop for fast establishment, pasture grass and local native shrub and tree species is used to establish a sustainable vegetation cover in a one pass operation. The revegetation of disturbed areas normally occurs prior to the commencement of the wet season (October-December) to maximise the benefits of subsequent rainfall or following the heat of Summer (February-March). This practice occurs at the existing Mine and will continue as part of the Project's mining operations.

### 9.7.4 Rehabilitation Maintenance

Rehabilitated areas are monitored in order to identify any areas in need of maintenance and to capture data to confirm the success of rehabilitation against key performance indicators (i.e. for future rehabilitation certification and tenure surrender applications). Rehabilitated areas that have not achieved the designated acceptance criteria will be repaired. Supplementary plantings or seeding may be used to increase species diversity and/or groundcover. Maintenance work will be performed to repair any areas exhibiting excessive soil erosion. Excessive erosion will be investigated to identify appropriate methods for repair. As required, weed control activities are conducted.

### 9.7.5 Maintenance of Non-Mined Areas

*Non-Mined Areas – Grazing Activities*

APC will continue to manage those non-mining areas where grazing can be conducted (i.e. where access allows, and safety requirements can be met). APC is responsible for the management of these areas and will continue to liaise with NAC in relation to the management of this land.

*Non-Mined Areas – No Grazing Activities*

NAC will continue to manage non-mining areas where grazing cannot be conducted by APC in accordance with the most current version of its Pest and Weed Management Plan. Periodic site inspections of non-mining areas will also continue, and as required, any damage to the land from erosion or feral animals (e.g. wild pigs) will be repaired in accordance with the principles of Section 9.7.4.

NAC believes the maintenance of an appropriate vegetation cover, the control of feral animals and significant weed species, the management of erosion, and avoidance of unauthorised disturbance are the key drivers to preventing land degradation and ensuring that the pre-mined land capability of non-mining areas is retained for the life of the Project.

*Non-Mined Areas – Lease Arrangements*

NAC will also continue to lease by agreement certain non-mining areas to near neighbours for farming purposes (i.e. mainly within ML 50170 – Stage 1). Under the agreement, the neighbour leasing the land from NAC/APC is responsible for its proper management.

*Non-Mined Areas – Unauthorised Disturbance Control*

NAC possess a ‘permit-to-disturb’ system to minimise the risk of unauthorised land disturbance. NAC also continuously undertakes detailed short-medium mine planning to control disturbance on-site, which also defines its current ERC (and eventually its PRCP requirements). These practices will continue for the Project. For the Project, NAC intends to erect signage to delineate conservation zones, no disturbance areas and non-access areas (i.e. for safety reasons).

### 9.7.6 Grazing Trials

NAC has been undertaking a formal grazing trial within the eastern extent of the rehabilitation area of the North Pit's Elevated Landform within the Stage 1 area of the current Mine. The grazing trail program ceased in 2018 and has demonstrated the effectiveness of rehabilitation at the site. Details of the grazing trial are outlined under **Appendix C**.

### 9.7.7 Groundwater

During 2018, NAC produced an updated groundwater model to support the Project's Associated Water Licence application. The outputs from the groundwater modelling have been combined with other relevant variables (e.g. climatic inputs) to generate preliminary pit lake water balance models and preliminary contaminant modelling within the pit lakes of each depressed landform (former void) (SLR, 2018).

The coupled groundwater/surface water model for the final voids was also used to assess the salt balance associated with the voids as a means of assessing any long-term water quality (salinity) risks. As reported in SLR (2018), the results indicate as follows.

- Salinities in the void lakes are predicted to generally increase over time primarily as a result of evaporation from the void lakes, with cyclical fluctuations in the longer term due to the effect of rainfall (and therefore runoff) variability based off the historic rainfall record.
- The Manning Vale East void lake salinity stabilises at approximately 10,000 to 12,000 mg/L in the long term.
- The Manning Vale West and Willeroo void lake salinities reach approximately 20,000 to 25,000 mg/L in the long term.

The lower predicted lake salinity in the Manning Vale East void as compared to the Manning Vale West and Willeroo void lakes is considered to be a result of the reduced groundwater inflow volume to the Manning Vale East void in comparison to the other two voids. This leads to the predicted salinity in the Manning Vale East void lake increasing in concentration at a lower rate than the Manning Vale West or Willeroo void lakes (SLR, 2018).

Since all three void lakes are predicted to form groundwater sinks in the long term at rates of between 0.01 and 0.11 ML/day, the voids will continue to collect groundwater post-mining, and therefore, any local changes to the quality of groundwater that might occur as a result of mining are unlikely to migrate away from the residual voids (SLR, 2018).

From an acid rock drainage perspective, it is unlikely that any water captured in the Project's final voids will become acidic from oxidation of pyrites in the Walloon Coal Measures aquifer because of the neutralising effect of the surrounding sediments which are naturally alkaline. To date, NAC has not experienced any occurrences of acid rock drainage at the Mine (SLR, 2018).

As a requirement of specific State and Commonwealth approvals for the Project, the pit lake water balance models and contaminant modelling will continue to be refined over time with each mandatory update of the Project's groundwater model. NAC will be able to improve its predictions for the 'pit lake' scenarios for each of the three depressed landforms (former voids) and further investigate final landform design, which will eventually be incorporated into the Project's mine closure process at the cessation of mining.

NAC has recommended regarding post-mining modelling within SLR (2018), which formed part of the Project's Associated Water Licence application, that during future detailed mine closure planning, as a minimum the following matters should be considered as a priority.

- The incorporation of diversion bunds adjacent the eastern sides of the Manning Vale West void and the Manning Vale East void should be considered as part of the final landform design to divert surface water runoff away from the voids.
- Groundwater model grid discretisation revisions adjacent the voids should be considered to allow better representation of the detail of the final land surface in the groundwater model.
- The simulation of long-term void lake levels for both the base case climate scenario and the climate change scenario should be undertaken.
- Redesign of the land surface should be considered to have a minimum elevation between 405 mAHD and 410 mAHD at Manning Vale East.
- The incorporation of the groundwater modelling results into a feedback loop with the final landform design should be undertaken to provide the most optimum solution with regards to limiting potential long-term groundwater quantity and quality impacts (i.e. via ensuring the floor of the depressed landforms are above the final predicted groundwater level).

### 9.7.8 Decommissioning

A Life of Mine (LoM) Plan will be developed for the Mine to allow eventual surrender the EA. This LoM Plan will inform the mine closure planning process and establish a basis for final landform design and management. The LoM Plan will be based on economic, geological and engineering factors. As a result of the planning process a competent Mine Closure Plan will be prepared and will ultimately be incorporated into a PRCP for the Project.

A Mine Closure Plan will be submitted to the Administering Authority at least five years prior to the surrender of the EA. The decommissioning and final rehabilitation of the site will occur on a staged basis over several years. A contaminated land assessment will be carried out as part of the Final Rehabilitation Report. On completion of the Project's mining, infrastructure will be treated as follows.

- Under an agreement with APC, certain mine roads and other infrastructure will be left behind for use as farm roads, or if not required, they will be rehabilitated.
- Under an agreement with APC, specific dams will remain and approved by regulators. Otherwise, the dams will be rehabilitated.
- Most buildings, plant and equipment will be removed and the surface rehabilitated, including the Coal Handling and Preparation Plant, certain hard stands and coal handling facilities (e.g. conveyors, bins, etc.).
- Concrete pads will be covered with benign waste rock, topsoiled and revegetated or removed and disposed to the nearest landfill or in-pit (depending on the timing of the activities).
- Contaminated land management will be completed as required under the EP Act.
- All TSFs will be capped with a competently engineered final cover system, topsoiled and grassed.

- The final voids remaining at the end of the mine life will be re-shaped into depressed landforms so that all their slopes are safe, stable and able to be revegetated to facilitate grazing activities.

A Final Rehabilitation Report and Compliance Statement will be produced as a statutory requirement under the EP Act for the surrender process for environmental authorities and their associated mining tenures.

## 9.8 Rehabilitation Timetable

Scheduling and reporting of the Project's (including the current Mine's) rehabilitation will be outlined in each subsequent ERC/PRCP. Changes and updates to the Project's mine plan and rehabilitation schedule must be capture by amendment of the ERC/PRCP or during submission of a new ERC/PRCP. These new processes once fully implemented for the Project will make the FLURP a redundant document.

In general, over the life of the existing Mine, NAC has rehabilitated on average 40 hectares per year. This amount of completed rehabilitation is influenced by a range of operational, climatic and other factors, and therefore, may vary from year to year. This annual quantum of completed rehabilitation is likely to remain consistent for the Project.

The Department of Environment and Science 'certified' 349 hectares of progressive rehabilitation during November 2018. At the time, the area certified was the largest single area of certified rehabilitation on an open cut mine in Queensland. NAC will continue to seek certification of its rehabilitated land for the Project.

# 10 Selection and Description of Analogue Sites

## 10.1 Methodology for Selecting Analogue Sites for the current Mine

Analogue sites were selected to represent Grazing Land Suitability Classes 2, 3, 4 and 5. Analogue sites are used as a means of providing baseline data against which future land use rehabilitation can be measured. Analogue sites are intended to represent a typical example of that Land Suitability Class within the Project area and provide an opportunity for meaningful monitoring to occur.

Based on the substantial body of information available in relation to soil properties and landscapes, land classes and productivity, no replication of previous survey work was required. The information provided in the NAC FLURP (2008) and the Mine Rehabilitation Monitoring report (Jacobs, 2017) has been utilised to update this section. The locations of the analogue sites are illustrated in **Figure 12**.


0 500 1,000 1,500 2,000 m

Scale: 1:35,000
AGD 1984 AMG Zone 56

13-Jan-2020

Sheet Size : A4

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**Current Mine Analogue Site Locations**

**FIGURE 12**

## 10.2 Description of Analogue Sites

### 10.2.1 Class 2 Analogue Site

The analogue site chosen for Land Suitability Class 2 has been updated since the NAC FLURP (2008) due to access issues. As a result, the Mine Rehabilitation Monitoring report (Jacobs, 2017) surveyed an updated analogue site for Land Suitability Class 2. The 2008 FLURP Class 2 analogue site vegetation cover has been retained as the basis for the vegetation cover targets discussed in **Section 11**. The 2008 FLURP vegetation cover at the original Class 2 analogue is outlined in **Table 9**.

**Table 9 2008 Class 2 Analogue Site Description**

| Class 2 | | | | | | |
|---|---|---|---|---|---|---|
| **Location: 375262, 6981253** | | | | | | |
| **Sub plot** | **1** | **2** | **3** | **4** | **5** | **Average** |
| % Grass Cover | 5 | 10 | 10 | 40 | 20 | 17 |
| % Herb/forb Cover | 25 | 40 | 10 | 10 | 30 | 23 |
| % Total Cover | 30 | 50 | 20 | 50 | 50 | **40** |

The updated Class 2 analogue site is located on a plain (slope gradient <1%), is moderately well- drained, possesses no rock outcrop, and has no evidence of erosion (stable). The soil is a medium heavy clay (0- 350 mm depth) gradually increasing to heavy clay (350-900+ mm depth). The soil has a strong sub-angular or polyhedral throughout. Soil consistence is firm (moist) (0-100 mm), grading to very firm (moderately moist) (100-700 mm). The vegetation cover at the updated Class 2 analogue site is described in **Table 10** and demonstrated in **Photo 1**.

**Table 10 Class 2 Analogue Site Description**

| Class 2 | | | | | | |
|---|---|---|---|---|---|---|
| **Location: 374121, 6978662 (Site ID: *R06_2016*)** | | | | | | |
| **Sub plot** | **1** | **2** | **3** | **4** | **5** | **Average** |
| % Vegetation Cover (Grasses only) | 95 | 95 | 95 | 95 | 95 | **95** |

Notably, the vegetation cover at the Class 2 analogue site in the Jacobs (2017) survey (95%) is significantly higher than that of the original survey of the Class 2 analogue site (40%). This difference is likely due to seasonal variability and/or survey technique changes and is not considered a reasonable vegetation cover target for rehabilitation.

Photo 1 Typical Vegetation at Class 2 Analogue Site

### 10.2.2 Class 3 Analogue Site

The analogue site chosen for Land Suitability Class 3 is located at a mid-slope (slope gradient 3%), which is well-drained and has no visible rock outcrop or erosion. The soil profile consists of a clay loam (sandy) (0-100 mm depth) abruptly increasing to medium clay (350-800 mm depth). Light clay (sandy) from 800+ mm. The soil has weak to moderate sub-angular or polyhedral structure between 0-600 mm depth, and is apedal from 600+ mm. The current vegetation cover across the Class 3 analogue site is outlined in **Table 11**, and the typical vegetation found across at the site is a *Eucalyptus populnea* (Poplar Box) woodland with a grassy understorey (**Photo 2).**

Table 11 Class 3 Analogue Site Description

| Class 3 | | | | | | |
|---|---|---|---|---|---|---|
| Location: 375271, 6980962 (Site ID: *R02_2013*) | | | | | | |
| **Sub plot** | **1** | **2** | **3** | **4** | **5** | **Average** |
| % Grass Cover | 0 | 5 | 5 | 5 | 30 | 9 |
| % Herb/forb Cover | 40 | 25 | 45 | 20 | 40 | 34 |
| % Total Cover | 40 | 30 | 50 | 25 | 70 | **43** |

Photo 2 Typical Vegetation at Class 3 Analogue Site

### 10.2.3 Class 4 Analogue Site

The analogue site chosen for Land Suitability Class 4 has been updated since the FLURP (2008) as the original location was mined through by the current Mine's Centre Pit. The Mine Rehabilitation Monitoring report (Jacobs, 2017) outlines the updated analogue site for Land Suitability Class 4. The 2008 FLURP Class 4 analogue site vegetation cover has been retained as the basis for the vegetation cover targets discussed in **Section 11**. The 2008 FLURP vegetation cover at the original Class 4 analogue is outlined under **Table 12**.

Table 12 2008 Class 4 Analogue Site Description

| Class 4 | | | | | | |
|---|---|---|---|---|---|---|
| **Location: 372169, 6979878** | | | | | | |
| **Sub plot** | **1** | **2** | **3** | **4** | **5** | **Average** |
| % Grass Cover | 50 | 65 | 15 | 80 | 70 | 56 |
| % Herb/forb Cover | 0 | 0 | 0 | 0 | 0 | 0 |
| % Total Cover | 50 | 65 | 15 | 80 | 70 | **56** |

The analogue site chosen for Land Suitability Class 4 is located on the crest of a tributary bank (slope gradient 0%), is moderately well-drained and possesses no visible rock outcrop or erosion (stable). The soil profile consists of light clay (0-50 mm depth) abruptly increasing to light medium clay (50-900 mm). Refusal at 900 mm. The soil has strong to moderate polyhedral structure grading. Notably, the vegetation cover at the Class 4 analogue site in the Jacobs (2017) survey (67%) is higher than that of the original survey of the analogue site (56%). This difference is likely due to seasonal variability and/or differences between survey methods. The current vegetation cover across the Class 4 analogue site is outlined in **Table 13** and the typical vegetation found at the site is a Poplar Box woodland with a grassy understorey (**Photo 3**).

Photo 3 Typical Vegetation at Class 4 Analogue Site

### Table 13 Class 4 Analogue Site Description

| Class 4 | | | | | | |
|---|---|---|---|---|---|---|
| Location: 375142, 6980991 (Site ID: *R01_2013*) | | | | | | |
| **Sub plot** | **1** | **2** | **3** | **4** | **5** | **Average** |
| % Vegetation Cover (Woody vegetation and grasses) | 90 | 70 | 25 | 80 | 70 | **67** |

### 10.2.4 Class 5 Analogue Site

The analogue site chosen for Land Suitability Class 5 was located in an area of Shallow basaltic soils (clay loam and non-cracking clay, outcrop soils). The current vegetation cover across the Class 5 analogue site is outlined in **Table 14** and the typical vegetation found across the transect was *Eucalyptus orgadophila* (Mountain Coolibah) woodland with *Brachychiton rupestris* (Narrow-Leaved Bottletree) (**Photo 4**).

### Table 14 Class 5 Analogue Site Description

| Class 5 | | | | | | |
|---|---|---|---|---|---|---|
| Location: 372231, 6979083 (Site ID: *R04_2013*) | | | | | | |
| **Sub plot** | **1** | **2** | **3** | **4** | **5** | **Average** |
| % Grass Cover | 1 | 15 | 30 | 15 | 5 | 13.2 |
| %Herb/forb Cover | 59 | 35 | 5 | 15 | 45 | 31.8 |
| % Total Cover | 60 | 50 | 35 | 30 | 50 | **45** |

Photo 4 Typical Vegetation at Class 5 Analogue Site

Current analogue sites are being used to determine composition of the desired rehabilitation outcomes i.e. groundcover, species diversity and nil declared weeds. Analogue site methodology and monitoring results are detailed in the *New Acland Coal Mine Rehabilitation Monitoring Program – April 2019* (SLR, 2019a).

# 11 Proposed Rehabilitation Acceptance Criteria

## 11.1 Review of Major Research Project

### 11.1.1 Sustainability Indicators for Coal Mine Rehabilitation

The Research Project Sustainability Indicators for Coal Mine Rehabilitation (DNRM, 2001) was completed under the Australian Coal Association Research Program (ACARP). The Research Project's objectives were to:

- monitor the long-term impact of open cut mine rehabilitation on erosion and water quality under natural rainfall conditions;
- evaluate physical and biophysical indicators for sustainable rehabilitation; and
- use the monitoring sites as an educational resource to promote the outcomes from the study to the industry and the wider community.

In particular, this research assessed runoff, erosion and water quality from rehabilitated land at Curragh, Goonyella Riverside and Oaky Creek mines at two scales - plot (0.01 ha) and catchment (0.4ha to 0.9ha) - and three slope gradients – 10 percent, 20 percent and 30 percent. Pasture and tree vegetation treatments were imposed on topsoil and spoil materials and a number of topsoil and spoil plots at each site were left bare to compare with the vegetative treatments.

Pasture establishment on spoil was poor at all mine sites, especially where the spoil was hard setting and dispersive. Annual erosion rates from spoil remained unacceptably high throughout the study.

The key findings of this research were as follows.

- Rainfall is the major limiting factor associated with successful rehabilitation. It is critical that pasture cover is established rapidly in order to maximise rainfall infiltration.
- A rehabilitated landscape is at greatest risk of erosion before grass cover is established. The window-of-erosion risk occurs before vegetative growth reaches 50 percent ground cover.
- Pasture establishment to 50 percent cover should be a minimum target indicator for coal mine rehabilitation. Further increases in pasture cover (greater than 80 percent) and biomass are required to reduce erosion rates on 30 percent slopes to negligible levels.
- Topsoil erosion rates declined between slopes once a dense sward of grass cover established (greater than 80 percent cover).
- Vegetative cover reduces the risk of salt movement on-site and off-site through runoff.
- The development of a hard-dispersive crust on the spoil material reduced infiltration, produced very poor pasture and tree establishment and resulted in unacceptably high runoff and erosion.
- Surface ripping of slopes greater than 20 percent should be used to improve infiltration and reduce runoff and erosion losses.
- Supplementary irrigation should be used to assist rapid pasture establishment during periods of low rainfall.

## 11.2 Rehabilitation Acceptance Criteria for the Project

### 11.2.1 Grazing Land

Proposed rehabilitation acceptance criteria have been developed to monitoring the progress of rehabilitation efforts for the Project. Drawing on the findings of Grigg, Emmerton and McCallum (2007) it is considered appropriate to focus on several key criteria to determine rehabilitation success, namely:

- 'Vegetation Cover', measured as a percentage;
- 'Species Diversity', determined from analogue sites;
- 'Slope';
- 'Erosion';
- 'Absence of Declared Weeds';
- 'Exchangeable Sodium Percentage (ESP)' (as a measure of soil dispersion);
- 'Cation Exchange Capacity (CEC)' (as a measure of nutrient availability); and
- 'Root Zone Salinity (RZS)'.

Exchangeable Sodium Percentage (ESP), Cation Exchange Capacity (CEC) and Root Zone Salinity (RZS) have been incorporated into the monitoring and reporting framework outlined in **Section 10**. Vegetation cover, species diversity, slope angle, erosion and the absence of declared weeds have been incorporated into the acceptance criteria for land suitability class. The acceptance criteria do not apply to conservation areas at the Project as these are considered in the Project's Conservation Zone Management Plan. Proposed rehabilitation acceptance criteria for disturbed areas is outlined under **Tables 15** and **16**.

## Table 15 Rehabilitation Acceptance Criteria – Grazing Land

| Indicator | Acceptance Criteria |
|---|---|
| **Ecological** | |
| Vegetation cover | ≥70% |
| Grass species diversity | ≥4 pasture species |
| Prohibited or Restrictive invasive plants (Qld) | Absent |
| **Geomorphological** | |
| Slope[1] | 17° (maximum) |
| Active rill/gully erosion[2] | Rill/gully erosion will be managed to be consistent with surrounding in-situ landforms.<br>Identification and repair of areas of concern (e.g. large scale rill/gully erosion) |
| Geotechnical stability | Stable surface, no subsidence |
| **Physical** | |
| Field texture | Sandy loam to light clay (rigid soils i.e. duplex soils)<br>Clay loam to heavy clay (non-rigid soils i.e. Vertosols) |
| Bulk density (BD) | 1.1 – 1.8 gm/cm3 |
| Emerson dispersion test | Class 2, 3, 4, 5 or 6 |
| Depth of effective root zone (ERZ) | 250 – 1000 millimetres |
| **Chemical** | |
| $pH_{Ca}$ | $pH_w$ 6.5 – 9.5, $pH_{ca}$ 6.0 – 8.0 |
| Electrical Conductivity (EC/se) | **$EC1{:}5_w$**<br>120 – 240 µS/cm for low salinity in sandy soils<br>90 – 300 µS /cm for low salinity in clay soils<br>**$EC_{se}$** 950-1900 µS/cm for low – moderate salinity in all soils |
| Cation Exchange Capacity (CEC) | 9 – 45 meq/100 gm |
| Exchangeable Sodium Percentage (ESP) | <10 |
| Total metals –Cu, Zn | *Risk Based Ecological Levels*<br>Zn – 190 mg/kg, Cu – 90 mg/kg<br>*Typical Background Levels*<br>Cu – 3-412 mg/kg, Zn – 5-92mg/kg, |
| Total Organic Carbon (TOC) | >1% for total organic carbon |

1. This criterion has been developed to meet the standards set in the EA (*Schedule H Table H5*). Maximum slope will be 17° as authorised but consideration will be given to the lower slope angles.
2. Should active rill/gully erosion be identified, erosive soil loss will be estimated using RULSE.

A further 22 reference (analogue) sites have been assessed in the *New Acland Stage 3 Project Land Resource Survey Establishment of Soil Reference Sites* (SLR,2019b) to satisfy IC 6(c)(i)(ii), 6(e)(i)(ii), and 7(c)(i)(ii) of the Coordinator-General's Report. This includes reference sites for rehabilitation that are required to be established under two conditions, 6(c) and 7(c), within areas of land that have not, and will not, be disturbed by mining activities. Condition 6(c) requires three reference sites be established for each soil map unit identified in the land resource survey, including detailed soil profile descriptions and laboratory analysis.

### Table 16 Rehabilitation Acceptance Criteria – Treed Areas

| Land Suitability Class | Acceptance Criteria | | | | | | |
|---|---|---|---|---|---|---|---|
| | Non-Polluting | Stability and Sustainable Land Use | | | | | |
| | Active Rill/Gully Erosion | Vegetation Cover | Native & Exotic Grass Species[1] | Slope[2] | Geotechnical Stability | Active Rill/Gully Erosion | Prohibited or Restrictive Invasive Plants (Qld) |
| 2-5 | Absence (<10t/ha/yr) | ≥50% | *Eucalyptus sp.* ≥2;<br>*Acacia sp.* =≥2;<br>Other tree/shrub sp. ≥2;<br>Grass= ≥ 3 | Maximum 17° | Stable | Rill/gully erosion will be managed to be consistent with surrounding in-situ landforms. Identification and repair of areas of concern (e.g. large scale rill/gully) | Absence |

1. The majority of the rehabilitated land will be returned to grazing with exotic pastures established. Where pockets of trees/shrubs have been established the diversity criteria will apply taking into account the limited diversity of some remnant communities near the Mine.
2. This criterion has been developed to meet the standards set in the EA (*Schedule H Table H6*). Maximum slope will be 17° as authorised but consideration will be given to the lower slope angles

### 11.2.2 Agricultural Production

The Project has been strictly conditioned to ensure that the rehabilitated mined land achieves a higher standard of rehabilitation from an agricultural perspective. As explained earlier, the Queensland Coordinator-General has conditioned the Project to achieve the following rehabilitation outcome.

*"The rehabilitation of disturbed land is to result in the affected land units being able to support the best post-disturbance land use possible. The post-disturbance land suitability of each land unit is to:*

*(i) represent that achievable on an ongoing basis;*

*(ii) be obtainable without the use of irrigation; and*

*(iii) be such that collectively at least 50 per cent of the total area of disturbed land originally meeting or exceeding the criteria for either Class 3 grazing land or Class 4 cropping land still meet or exceed those classifications."*

To achieve the Project's agricultural based rehabilitation outcome, the Queensland Coordinator-General has also conditioned the Stage 3 Project to undertake selective handling and return of topsoils and sub-soils within the proposed mining areas.

In addition prior to the commencement of the Project, an extensive land resource (soil) survey has been completed to establish the soil types and soil profiles for future soil management purposes and to refine land suitability classifications within the proposed mining areas. Reference sites have also been established for each of the identified soil types to assist with future monitoring of rehabilitation performance.

## 11.3 Seed Mix

Seed mixes for the Grazing Lands used for rehabilitation have been refined and will continue to be applied to the rehabilitation works for the Project. The seed mix and seed rates applied since 2014 are outlined in **Table 17**.

### Table 17 Seed Mix – Grazing Lands from 2014-2017

| Common Name | 2014 Seed rate (kg/ha) | 2015 Seed rate (kg/ha) | 2016 Seed rate (kg/ha) | 2017 Seed rate (kg/ha) |
|---|---|---|---|---|
| Japanese Millet | 4 | 6 | 5 | 5 |
| Bisset Creeping Blue Grass (Coated) | 4 | 2 | 3 | 3 |
| Qld Blue Grass (Coated) | 2 | 2 | 3 | 3 |
| Katambora Rhodes Grass (Coated) | 6.5 | 4 | 4 | 4 |
| Gatton Panic (Coated) | 4.5 | 4 | 4 | 4 |
| Woolly Pod Vetch | 5 | 4 | 3 | 3 |

# 12 Reporting Framework

## 12.1 Monitoring Rehabilitation Works

Monitoring activities for the Project will involve the continuation of the methodology applied to the current Mine's monitoring program, which was developed using reference site data to establish rehabilitation targets to monitor changes over time at monitoring sites. Ongoing monitoring of reference sites serves as a control for environmental variability in the assessment and allows rehabilitation success to be determined over time against success criteria.

In terms of establishing permanent rehabilitation monitoring points, at the commencement of rehabilitation works in a new area, permanent photograph points are established and delineated with a star picket or similar. The geographic location and bearing of the photograph are recorded using a GPS.

## 12.2 Revegetation Monitoring Program

In summary, formal revegetation monitoring will be conducted by a competent person, annually. New rehabilitation areas will be added as necessary and subject to establishment success which may be affected by rainfall, seedling establishment and other seasonal factors. This formal monitoring program will continue for the current Mine areas and will apply until all rehabilitated areas are deemed successful via the surrender of the associated mining tenure. During this monitoring the revegetation will be compared against the rehabilitation success criteria proposed in **Tables 15** and **16**. The following information will be collected for rehabilitation areas during the biennial monitoring surveys at the end of the wet season:

1. a minimum of 8 permanent monitoring sites, plus any additional analogue sites;
2. photographs of existing and new rehabilitation areas from permanent photographic points;
3. record of treatments used for each new rehabilitation, including seeding rates, soil treatment, topsoil source;
4. botanical description of the rehabilitation area, including percentage cover and species diversity;
5. selective measurement of pH, ESP, CEC and RZS;
6. Emerson Aggregate Test, soil texture or particle size analysis, and bulk density or penetrometer resistance;
7. presence and abundance of weed species;
8. landform monitoring, including slope angle, contour bank spacing, waterways, presence/absence of active rill/gully erosion; and
9. any failure of rehabilitation works and maintenance conducted or proposed to be conducted for these areas.

Full details of the revegetation monitoring program are provided in the *New Acland Coal Mine Rehabilitation Monitoring Program – April 2019* (SLR, 2019a).

## 12.3 Identification of Remediation Works

Remedial works may be required during the rehabilitation process, including the following actions.

- Soil remediation may be required prior to the seeding/planting of rehabilitation areas. This requirement will be based on the soil type, stripping depths applied, and if applicable, the residence time in storage;
- Failure to achieve the desired levels of vegetation cover and species diversity will require supplementary seeding and/or planting;
- Weed infestation will require treatment to an appropriate standard or as defined by legislation; and
- Erosion damage may require repair depending on the level of severity. The potential for erosion will be controlled by the establishment of a good ground cover (i.e. ≥50%) and through the correct design of water management structures.

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# APPENDIX A

## Current Mine

## Soil Assessment Details and Description of Soil Mapping Units

## Background

During previous investigations for NAC01 and NAC02, sampling and profile inspection points spread across the Project area to characterise all landform elements and geological units were undertaken. The surveys were designed to provide sufficient information on land resources to allow the determination of land suitability, soil erosion, rehabilitation potential and storm water runoff quality consistent with the methods set out by the following documents:

- Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques (DME, 1995); and
- Shields and Williams (1991).

In addition, information regarding local production systems, land suitability and flooding was obtained from the Department of Natural Resources and Mines (DNRM) through direct communications and soil mapping data.

In summary, soil profile descriptions were consistent with the Australian Soil and Land Survey Field Handbook (McDonald et al, 1998), the Australian Soil Classification (Isbell, 1996) and Munsell Soil Colour Charts.

## Methodology of Previous Assessments

The land resource information presented is based on two previous surveys. The first study was conducted in 1996 and involved 13 samples on MDL 244 over the areas currently overlayed by NAC01 and NAC02. The following study was conducted in 1999 as part of an Impact Assessment for a proposed coal mine and power station for Shell Coal Australia Ltd. The 1999 survey was carried out using a 1:1000 map of the area and a 1:1000 digitised photo mosaic (1998) of the area. The survey was carried out using the map and aerial photograph provided and marking investigation sites and soil boundaries according to surface features and vehicle odometer readings. The 1999 investigation involved an additional 96 holes and included detailed profiles and samples to determine soil boundaries and provided:

- Delineation and mapping of soil types present on the site;
- Broad descriptions of soil profiles;
- Data on the chemical and physical properties of soils for use in topsoil stripping and rehabilitation;
- A brief land contamination study; and

- A land suitability assessment of soils for dryland cropping and grazing

The 1999 survey contained over 750 samples that were tested for pH and electrical conductivity on a 1:5 (soil:water) basis. The soils were categorised into 11 soil groups. From these soil groups, samples were selected from a total of 35 profiles for analysis. Profiles were analysed to characterise their physical and chemical conditions with additional fertility environment analyses for surface samples. Analyses undertaken on all samples included:

- pH, electrical conductivity, chloride and sulphate;
- Exchangeable calcium, magnesium, potassium and sodium;
- Cation exchange capacity;
- Particle size analysis and RI dispersion index; and
- 15 bar moisture content.

Additional analyses on surface samples from the soil profiles included:

- Organic carbon;
- Nitrate and total nitrogen;
- Extractable and total phosphorous; and
- Copper, manganese and zinc.

Plant available water was assessed for 29 profiles as a guide to land suitability, in terms of moisture retention for cropping.

## Soil Characteristics

The soils described in this section are those that occur within the NAC01 and NAC02 area. Topsoil was examined using soil and chemical properties including pH, electrical conductivity, phosphorus and exchangeable sodium percentage (ESP). Physical properties such as permeability and drainage characteristics were inferred from profile morphological characteristics such as concretions, depth to rock, observed root depth, colour and mottling.

Typical depths of primary and secondary topsoil were determined using the DME (1995) guideline, site data and experience with similar soil types used in rehabilitation by the Project.

Primary topsoil is the uppermost layer of soil used in site rehabilitation. It is salvaged from the surface horizons of areas to be disturbed, is relatively fertile and contains seeds and micro-organisms. Secondary topsoil (subsoil), if used is placed directly in contact with waste rock and may be obtained from subsurface soil horizons, including weathered rock

## Soils on Upper and Midslope

Soils in mid and upper slope positions are either associated with basalt or are formed purely on sediments. Soils formed on or associated with basalt, range from: 'Shallow basaltic soils' on upper slopes and steeper basaltic outcrops; through 'Shallow and mid depth cracking clays on basalt' on less steep slopes (<6%) through to 'Red and black clays' which are deeper soils influenced by basalt from above but are formed on colluvium or on in-situ sediments.

Soils formed on sediments are primarily cracking clay soils. They are mainly comprised of closely associated and often intermixed areas of 'Reddish non cracking and lesser cracking clays on sediments' and 'Dark cracking clays on sediments'. These soil types were originally vegetated by brigalow and softwood scrubs with minor eucalypt vegetation but have been extensively cleared for farming (Ison Environmental Planners, 1999). The soil descriptions are as follows, and have been sourced from Ison Environmental Planners (1999).

## Soils in Upslope and Midslope Positions associated with Basalt Shallow Basaltic Soils (clay loam and non-cracking clay, outcrop soils)

This soil type is present in association with elevated ridges and caps and basalt outcrops throughout the area. These soils have been partially cleared and are generally grazing lands. Limited pasture improvement has taken place in less steep areas.

A range of soil types are present ranging from silty clay loams to medium clays over basalt (which may contain substantial rock on steeper basalt slopes), to skeletal non- cracking soils. All soils are shallow with the skeletal cracking soils less than 10 cm deep on steep slopes up to 15%.

Natural vegetation tends to be mountain coolibah, wilga and softwood scrub remnants. Slope is generally in the order of 2 to 5%, but may be up to 15% on some rocky outcrop areas. Rock exposure may be up to 70% in some steeper outcrop areas. The soil surface is friable and appears to be non-cracking. The thin soil surface is immediately underlain by weak to friable silty clay loam to medium clay that is dark reddish brown to dark brown (5YR to 7.5YR3/2) in colour. Broken decomposed basalt is found increasing down the profile below 10 cm to 25 cm, depending on slope and the amount of basalt.

Salinity (EC and chloride) is generally low throughout the profile, and the soil reaction trend is generally neutral.

Sodicity (Exchangeable sodium percentage -ESP) is low throughout the profile. Calcium magnesium ratios are high down the profile and are considered favourable to the maintenance of good structure. The low ESP's and favourable Ca/Mg ratios are reflected in the low RI dispersion indices throughout the profile which indicates good stable structure (although sometimes reaching higher RI levels in the decomposed basalt under the soil proper). The clay content of the soil is moderate to high and the clay activity ratio indicates some activity, although no cracking was observed in the field.

The soil generally has good levels of organic carbon in the surface. Cation exchange capacity is good down the profile (although probably slightly overestimated) indicating a good ability to hold nutrients. The levels of extractable phosphorus and total phosphorus present are high. Nitrate nitrogen levels are high in the surface while the levels of total nitrogen present are also generally high, indicating good nitrogen reserves.

Sulphate levels are low to medium while levels of other major nutrients would be considered adequate. Levels of micronutrients are also adequate.

In the profiles analysed, plant available water capacity (PAWC) would be approximately 40 to 50 mm for a soil 30 cm deep over parent rock. In isolated areas where the soil is deeper, PA WC levels may reach around 90 mm.

## Shallow and Mid Depth Cracking Clays on Basalt

This soil type occurs extensively on slightly elevated areas in association with and below the 'shallow basaltic soils'. These soils are mainly cleared and are either cropped or for forage production. Boundaries between these soils and the 'Red and black cracking clays (basaltic influenced soils on colluvium or in situ sediments)' should be regarded as indicative.

Natural vegetation is scattered mountain coolibah bloodwood and wilga with mid height grassland below, but much of the area has been cleared and cultivated. Slope is generally, approximately 2%, but extending up to 4% in some isolated areas. Occasional basalt floaters may be present on the surface in the darker soil types, however are generally minor in occurrence.

The soil surface is a light to medium clay in the more reddish soil types and heavy clay in the darker soil types. The soil is strongly cracking and self-mulching with the mulch (1 to 3 cm) being fine to medium in the redder soil types and becoming coarser and deeper in the darker soil types. Colour is dark reddish brown to black (5YR3/2 to 10YR2/1).

In areas where surface colour is darker, colour tends to be maintained down the profile and texture increases slightly. Where the soils are lighter (redder), colour lightens below 10 to 30 cm and texture becomes slightly heavier. Below 30 to 50 cm some hard calcium carbonate ($CaCO_3$) may be encountered. Soil depth is generally between 45 to 80 cm below which parent material is encountered. Parent material may be hard basalt, decomposed basalt, calcareous basaltic material or on some occasions basaltic clays. Site 54 is a darker heavier profile and shows decomposed basaltic material under 80 cm, which is deeper than average for this soil type.

Salinity is low in the soil surface and may increases slightly down the profile, still maintaining low levels at depth. The soil has a neutral to alkaline soil reaction trend. Sodicity is low in the surface and usually remains low with depth. Calcium to magnesium ratios are high throughout the profile (they may decline in the underlying basalt) and are considered favourable to the maintenance of good structure.

The generally low ESP's and favourable Ca/Mg ratios are reflected in the low RI dispersion indices indicate good, stable structure throughout the profile. In some cases there may be slight elevation in some surface soils and the dispersion indices may also be elevated in underlying basaltic materials. The clay content of the soil is high and the clay activity ratio indicates the presence of active clays. The soil generally has moderate levels of organic carbon in the surface. Although organic carbon may be lower in some of the more marginal cropped sites, possibly leading to the higher levels of dispersion.

Cation exchange capacity is medium-high down the profile indicating a good ability to hold nutrients. The levels of extractable phosphorus and total phosphorus are high. Nitrate nitrogen levels are moderate to high, while the levels of total nitrogen are only moderate, thus indicating moderate nitrogen reserves with some nutrient run-down from cropping. Levels of major nutrients are adequate, except for sulphate sulphur levels which are low. Levels of micronutrients also appear adequate with the exception of zinc which may be marginal in some areas.

In the profiles analysed, PAWC would be considered to be 80 to 120 mm for a soil 50 to 80 cm deep over decomposed basalt parent rock. In areas where basaltic clays are present, PAWC levels may be higher.

## Red and Black Clays (basaltic influenced soils on colluvium or in situ sediments)

This soil type occurs in association with the basaltic soils and occurs below those soils, which are present on slightly elevated areas. The soils have been cleared and are either cropped or utilised for forage production. In most instances the soil type is only distinguishable from the 'Shallow and mid depth cracking clays on basalt' by more intense survey.

The natural vegetation was probably occasional mountain coolibah and poplar box woodlands. These soils have been extensively cleared for agriculture. Slope is generally low between 1 to 3% and occasionally increasing to over 8%. Occasional basalt floaters may exist on the soil surface and occasional silcrete may also be present. But, in general, deeper soils such as these have only minor stone occurrence, being predominantly confined to the steeper areas on and below the basalt outcrops.

The soil surface tends to be a heavy clay which is strongly cracking and self-mulching. The surface colour is dark reddish brown to black (5YR3/2 to 10YR2/1). The surface 2 to 5 cm has a strong generally medium self-mulch. Below 5 cm, the soil is firm to the base of the plough zone, below which it is a hard, coarse blocky structure. Colour generally lightens below 20 to 50 cm and texture increases slightly.

Some slight hard CaC03 may exist throughout the profile and occasionally high concentrations of soft CaC03 may exist below 30 to 60 cm where the colluvial material is from basaltic origin. Parent colluvium or decomposed sediments may be encountered anywhere below 50 to 190 cm and where colluvium is encountered at relatively shallow depths, sediments are often encountered at deeper depths below this. Plant rooting depths are generally considered to be deep.

Salinity levels are variable at depth but are low in the surface soil. In some profiles, salinity increases down the profile, in some instances reaching high levels which may restrict crop rooting depth by 80 to 90 cm. Other profiles still have low salinity levels at depth. The soil generally has an alkaline soil reaction trend, however it is occasionally neutral.

The pH of the profiles analysed tend to be alkaline in the surface and become increasingly alkaline with depth. Exchangeable sodium percentage is low in the surface becomes sodic with depth (generally below 50 to 90 cm). The subsoil clays although sodic are not considered highly sodic (>15%). Calcium to magnesium ratios are reasonable in the soil surface and decline with depth to levels which are unfavourable to the maintenance of structure below 30 to 60 cm. The low surface ESP's and favourable Ca/Mg ratios are reflected in the low RI dispersion indices, while dispersion indices tend to increase to elevated levels below 30 to 60 cm. The clay content of the soil is high and the clay activity ratio indicates the presence of clays with some activity.

The soil generally has moderate levels of organic carbon in the surface, indicative of cropped sites. Cation exchange capacity is high down the profile indicating a good ability to hold nutrients. The levels of extractable phosphorus and total phosphorus are moderate to high. Nitrate nitrogen levels are generally moderate (sometimes low) in the surface while the levels of total nitrogen present are only medium indicating moderate nitrogen reserves and some nutrient run-down from cropping. Sulphate levels are relatively low in the surface while levels of other major nutrients would be considered adequate. Levels of micronutrients also appear adequate with the exception of zinc which may be marginal in some areas

In the profiles analysed, PAWC would be considered to be around 170-180 mm for an analysed rooting depth of 120 cm which appears to be available in most cases (or around 150 mm where salinity restricts rooting depth to around 90 cm).

## Soils in Upslope and Midslope Positions Formed on Sediments Reddish Non Cracking and Lesser Cracking Clays on Sediments

This soil type occurs in close association with and on similar materials to the 'Dark cracking clays on sediments'. The soils have mainly been cleared and are usually cropped or to a lesser degree utilised for forage production. These soils were originally poplar box and softwood scrub with lesser brigalow vegetation.

Slopes are generally low, 2 to 3%, but occasionally increase above 5%. No large stones are present in these soils. The soil surface tends to be a light clay (or occasionally a clay loam) which is normally non cracking or very slightly cracking. Colour is dusky red to dark reddish brown (2.5YR3/3 to 5YR3/4). Significant surface ironstone is present and the surface forms a slight crust with occasional surface structural problems indicated. Colour may darken slightly down the profile before lightening below 20 to 50 cm to dark reddish brown to yellowish red (5YR3/4 to 4/6), while texture generally increases down the profile to a heavy clay by around 50 cm.

Some soft $CaCO_3$ may be present below 30 to 60 cm. Parent sediments or less commonly deeper colluvium may be encountered below 70 to 130 cm and ironstone or limestone bands may be encountered in the parent material. Site 16, considered to be a deeper profile, shows parent material under 120 cm.

Salinity is generally low in the soil surface and increases to varying degrees down the profile, but does not reach high levels which would be considered to restrict crop rooting depth. The soil has an alkaline soil reaction trend.

Structural characteristics are variable and exchangeable sodium percentage is low in the surface and may increase only slightly with depth to levels which are still non- sodic in the parent material, or may increase to levels which are considered to be highly sodic (ESP> 15%) below 60 cm.

Calcium to magnesium ratios are good for the maintenance of soil structure in the surface and may be maintained at good levels with depth or may decline to unfavourable levels below 60 to 80 cm. The RI dispersion indices in the surface layers vary between 0.30 and 0.55 and this indicates that in some profiles slight surface structural problems are evident. Depending on the sodicity trend, dispersion may remain relatively low down the profile, increasing only slightly at depth or may rise to relatively high levels with depth. The clay content of the soil is high and the clay activity ratio indicates the presence of clays with low activity.

The soil generally has slightly low levels of organic carbon in the surface, indicative of cropped sites. Cation exchange capacity is moderate throughout the profile indicating a reasonable ability to hold nutrients. The levels of extractable phosphorus are moderate to high and the levels of total phosphorus are relatively high. Nitrate nitrogen levels are generally moderate (sometimes low) in the surface while the levels of total nitrogen present are slightly less than medium indicating moderate nitrogen reserves and some nutrient run-down from cropping. Sulphate levels are relatively low in the surface (sometimes higher at depth) while levels of other major nutrients would be considered adequate. Levels of micronutrients appear adequate.

In the profiles analysed, PAWC is approximately 130-150 mm for an estimated rooting depth of 100 to 110 cm.

## Dark Cracking Clays on Sediments (upper slopes)

This soil type occurs in close association with, and on similar materials to the 'Reddish non cracking and lesser cracking clays on sediments'. These soils have mainly been cleared and are usually cropped or to a lesser degree utilised for forage production. This soil type was originally vegetated with brigalow and softwood scrub with lesser poplar box emergents. The two soil types are closely associated and often form a mosaic, however for the purposes of this study an attempt has been made to map them separately.

Slopes are generally 2 to 3% and occasionally increasing to above 5%. No large stones are present in these soils apart from a small steep area where metamorphosed siltstone is present.

The soil surface tends to be a medium clay which is cracking and has a weak medium self-mulch. Colour is dark brown to very dark grey (7.5YR3/2 to 10YR3/1). Significant surface ironstone is present and some silcrete. The soil becomes very tight and hard below the plough zone and texture generally increases to a heavy clay. Colour is generally maintained down the profile before lightening and becoming slightly mottled below 20 to 40 cm. Subsoil colours range widely from dark reddish brown to yellowish brown (5YR3/3 to 10YRS/4). Soft $CaCO_3$ may be present below 30 to 60 cm, decreasing where parent material is encountered generally by 90 to 120 cm. Salinity levels are variable at depth but are low in the soil surface. In some soil profiles salinity increases with depth, reaching high levels, which could be considered to restrict crop rooting depth by 80 to 90 cm. Some soil profiles still have low salinity levels at depth. The soil normally has an alkaline reaction trend, however, occasionally acidic sediments may be encountered at depth.

The pH of the profiles analysed tend to be alkaline in the surface and become increasingly alkaline with depth, although in one instance acidic parent sediments are encountered at depth.

Structural characteristics are variable. Sodicity levels are variable with some non-sodic soils, others that are sodic in the parent material, or others that are highly sodic below 60 cm. Calcium to magnesium ratios are favourable for the maintenance of soil structure in the surface and may be maintained at good levels with depth or may decline to unfavourable levels below 50 to 80 cm.

The R1 dispersion indices in the surface layers vary between 0.35 and 0.54 and this indicates that in some profiles slight surface structural problems are evident. Dispersion generally increases down the profile rising to relatively high levels with depth. The clay content of the soil is high and the clay activity ratio indicates the presence of clays with low to moderate activity.

The soil has low to moderate levels of organic carbon in the surface, common of cropped sites. Cation exchange capacity is moderate to high in the surface and down the profile indicating a good ability to hold nutrients. The levels of extractable phosphorus are moderate to high and the levels of total phosphorus are relatively high. Nitrate nitrogen levels are moderate to high in the surface while the levels of total nitrogen present are medium to high indicating reasonable nitrogen reserves. Sulphate levels are relatively low in the surface (often higher at depth) while levels of other major nutrients would be considered adequate. Levels of micronutrients also appear adequate.

In the profiles analysed, PAWC is approximately 130 mm in some areas where crop rooting depth is restricted to 90 cm. However, PAWC is more common approximately 160 mm where crop rooting depth is around 120 cm.

## Soils on Mid and Lower Slope

Soils in mid and lower slope positions are formed mainly on colluvium and to a lesser degree on alluvium. In the south eastern portion and also in the northern area, two relatively small areas of 'Dark cracking clays on in situ sediments or colluvium' are present below the other mixed cracking and non-cracking clays on sediments which previously supported softwood scrub. An area of 'Tight shallow surfaced duplex soils on deep colluvial material' in the south east also occurs below the scrub soils. In the northwest an area of 'Deep heavy clays on clay colluvium' occurs, while small areas of 'Alluvial clays in drainage ways' occur in drainage lines that drain or cross the site (Ison Environmental Planners, 1999). The soil types mapped follow.

## Dark Cracking Clays on In Situ Sediments or Colluvium (lower slopes)

This soil type occurs at lower slope angles below the 'Dark cracking clays on sediments' upper slopes' in relatively confined areas in the south east and north of the study area. The soils have mainly been cleared and are cropped. The original vegetation was brigalow. Slopes are generally less than 2%. No large stones are present in these soils apart from minor small ironstone and silcrete pebbles on the surface.

The soil surface tends to be a medium to heavy clay which is cracking and has a well-developed medium to coarse self-mulch. Colour is very dark grey to very dark greyish brown (10YR3/l to 3/2). Slight surface ironstone is present and some silcrete. Colour is maintained down the profile and texture increases slightly with some soft CaCO3 being present below 20 to 50 cm. Below 50 to 60 cm some colour lightening and slight mottling may occur with colour becoming reddish brown to brown (5YR4/4 to 7.5YR5/4) by 90 to 100 cm. Below 100 to 130 cm parent colluvial clays are present.

Salinity is relatively low in the soil surface and increases down the profile, sometimes remaining relatively low down the profile but occasionally reaching high levels, which could be considered to restrict crop rooting depth below 120 to 150 cm. The soil has an alkaline reaction trend.

The pH of the profiles analysed tend to be alkaline in the surface and become increasingly alkaline with depth. Exchangeable sodium percentage is low in the surface and with depth soils becoming sodic by 50 cm and highly sodic by 80 to 110 cm.

Calcium to magnesium ratios are generally favourable for the maintenance of soil structure in the surface and may be maintained at good levels with depth to below 30 cm or may decline more rapidly. The dispersion indices in the surface layers vary between 0.35 and 0.56 and this indicates that in some profiles slight surface structural problems are evident. Dispersion generally increases down the profile rising to high to extreme levels at depth (below 60 cm). The clay content of the soil is high and the clay activity ratio indicates the presence of clays with low to moderate activity.

The soil has low to moderate levels of organic carbon in the surface, common of cropped sites. Cation exchange capacity is moderate to high in the surface and down the profile indicating a good ability to hold nutrients. The levels of extractable phosphorus are moderate to high and the levels of total phosphorus are medium. Nitrate nitrogen levels are moderate to high in the surface while the levels of total nitrogen present are relatively low to medium indicating some nutrient run-down. Sulphate levels are relatively low in the surface (higher at depth) while levels of other major nutrients would be considered adequate. Levels of micronutrients also appear adequate, except zinc, which may be deficient at some sites.

In the profiles analysed, PAWC is often restricted at depth by high sodicity (rather than chloride) and would be around 130 to 150mm at a rooting depth of 100 to 110 mm or occasionally reaching 160 mm where sodicity is lower.

## Tight Shallow Surfaced Duplex Soils on Deep Colluvial Material

This soil type occurs in only one location in the south east of the investigation area. The soils have been largely cleared and some areas out of drainage lines are cropped. The remnant vegetation that exists is predominantly poplar box. Slopes are low and generally between 1 to 2%.

The soil surface tends to be hardset loam (massive where not cultivated), fine sandy and surface structural problems are indicated. Some silcrete and ironstone gravel is present. The surface is very dark greyish brown (10YR3/2) in colour. There is an abrupt boundary to the B horizon at around 10 cm and this is a tight medium to heavy clay which is very dark grey to very dark greyish brown (10YR3/1 to 3/2) in colour and becomes mottled below 20 to 30 cm. Hard and soft CaCO3 may be present below 40 to 50 cm down the profile and below 50 to 60 cm colour lightens to yellowish brown (10YR5/6). The material then becomes light to heavy clay parent colluvium some 20 to 30 cm after the colour lightening. The parent colluvium contains some ironstone and hard limestone material.

Salinity (EC and chloride) is relatively low in the soil surface and increases down the profile, sometimes remaining relatively low down the profile but can reach high levels which may restrict crop rooting depth below 60 cm. The pH of the profiles analysed tend to be acidic or neutral in the surface and become increasingly alkaline with depth. Exchangeable sodium percentage is low to slightly elevated in the surface and sodic in the upper B horizon and becoming highly sodic below 50 to 80 cm. Calcium to magnesium ratios are favourable for the maintenance of soil structure in the immediate surface and decline quite rapidly under the surface.

The dispersion indices in the surface layers vary between 0.59 and 0.66 and this indicates poor surface structural aspects. In addition, silt contents are 15 to 17% and quite severe crusting would be anticipated (as observed in the field). Dispersion generally rises rapidly down the profile and in some areas is extreme in the B horizon clays and colluvial material below.

The soil has low levels of organic carbon in the surface, indicative of nm-down of organic content and structure. Cation exchange capacity is only moderate in the surface indicating a limited ability to hold applied nutrients. The levels of extractable phosphorus and total phosphorus are moderate. Nitrate nitrogen levels are moderate to high in the surface while the levels of total nitrogen present are low and indicate low reserves and nutrient run-down. Sulphate levels are relatively low in the surface (higher at depth) while levels of other major nutrients would be considered adequate with the exception of magnesium which may be low in the immediate surface in some cases. Levels of micronutrients also appear adequate with the exception of zinc which appears to be deficient.

In the profiles analysed, PAWC is approximately 130 mm for a 90 cm rooting depth. However, it is considered that this does not account for poor surface structural characteristics, low moisture infiltration and impermeable subsoil clays. For a 60 cm rooting depth which is considered more likely when these soils are cropped in conjunction with the clay soils the PAWC would be in the order of 100 cm.

## Alluvial Clays in Drainage Ways

This soil type occurs in three positions in drainage ways that drain the area. The majority of the area has been semi cleared, and remnant vegetation is poplar box, wilga, myall and belah. Minor areas are cropped. Slopes are generally less than 1 %. No stones are present in these soils.

The soil surface tends to be a light to medium clay (lighter from alluvial deposition), becoming heavy soon under the surface. The surface has a weak medium self-mulch. Colour is dark brown to very dark grey (7.5 YR3.2 to 10YR3/1) to around 50 cm, below which some colour lightening occurs and soft $CaCO_3$ is present. Below 80 to 120 cm further lightening occurs to brown to yellowish brown (7.5YR4/4 to 10YR5/6) and some gypsum may be present at this depth in some profiles. Below 100 to 150 cm parent alluvial clays are present.

Salinity (EC and chloride) is relatively low in the soil surface and increases down the profile, sometimes rising to only moderate levels but sometimes reaching high levels which could be considered to restrict crop rooting depth below 50 to 60 cm. The soil has an alkaline reaction trend. The pH of the profiles analysed tend to be alkaline in the surface and more alkaline at depth.

Exchangeable sodium percentage is very slightly elevated in the surface becoming sodic below 20 to 30 cm and highly sodic by 60 to 80 cm. Calcium to magnesium ratios are favourable for the maintenance of soil structure in the immediate surface and decline down the profile.

The dispersion indices in the surface layers vary between 0.49 and 0.62 and this indicates that in some profiles surface structural problems are evident. Dispersion increases at depth, with some of the material below 60 to 120 cm having high to extreme dispersion. The clay content of the soil is high and the clay activity ratio indicates the presence of clays with moderate activity. The soil has low to high levels of organic carbon in the surface, (low in the cropped site where some erosion appears to have taken place). Cation exchange capacity is moderate in the surface and high immediately below, indicating a good ability to hold nutrients.

The levels of extractable phosphorus are moderate to high and the levels of total phosphorus are moderate. Nitrate nitrogen levels are low to moderate in the surface, while the levels of total nitrogen present are low to high (low where erosion has taken place in the cropped site). Sulphate levels are relatively low in the surface (higher at depth) while levels of other major nutrients would be considered adequate. Levels of micronutrients are adequate, except zinc, which appears to be deficient in some sites.

In the profiles analysed, PAWC varies depending on the presence or absence of salinity at depth. PAWC is approximately 120 to 140 mm.

# APPENDIX B

## Current Mine

## Limitations for Dryland Cropping

## Land Suitability Classes for Dryland Cropping – Pre-Mining

| Soil Group | Limitations | Suitability |
|---|---|---|
| **Soils in upslope and mid slope associated with basalt** | | |
| Shallow basaltic soils (clay loam and non-cracking clay, outcrop soils) | m5, n2, r2-5, e2-5 | 5 |
| Shallow and mid depth cracking clays on basalt | m3-4, n2, p2, k2, r1-2, e3 | 3-4 |
| Red and black clays (basaltic influenced soils on colluvium or in situ sediments) | n2, p2, k2, r1-2, e3-4 | 3-4 |
| **Soils in upslope and mid slope formed on sediments** | | |
| Reddish non-cracking and lesser cracking clays on sediments | m2, n2-3, p2-3, k2, e3-4 | 3-4 |
| Dark cracking clays on sediments (upper slopes) | m1-2, n2, p2, k2, sa1-2, e3-4 | 3-4 |
| **Soils in mid and lower slope** | | |
| Dark cracking clays on in situ sediments or colluvium (lower slopes) | m1-2, n2, p2, k2, w2, e3 | 3 |
| Tight shallow surfaced duplex soils on deep colluvial material | m3, n3, p3-4, k3, w3, e3, f1-5 | 3, some 5 |
| Alluvial clays in drainage ways | m2, n2, p2, k2, sa1-2, w2, e2, f4-5 | 5, some 4 |

## Limitations for Dryland Cropping

This classification evaluates the broad acre potential for growing a range of dry land crops normally grown in the area. Ten limitations were identified that significantly affect rainfed cropping in the Project area as outlined below:

- water availability (m);
- nutrient deficiency (n);
- soil physical factors (p);
- soil workability (k);
- salinity (s);
- rockiness (r);

- microrelief (g-gilgai);
- wetness (w);
- water erosion (e); and
- flooding (f).

The major limitations to cropping use are water availability, slope and the potential for erosion.

## Water Availability (m)

Plant available water capacity (PAWC) cut off levels were obtained from the DME (1995) Guideline and Vandersee and Mullins' (1977). The PAWC cut off levels assigned are as follows:

- M1-> 150 mm;
- m2 -125-150 mm;
- m3 -90-125 mm;
- m4 --70-90 mm; and
- m5 -< 70 mm.

Vandersee and Mullins (1977) analyses crop failures at certain levels of PAWC and recommends a PAWC level of 75mm as the cut off for land suitable for cropping (i.e. the cut off between Class 3 and 4). The economics of cropping have declined over the past twenty years, with much of the more marginal land which was developed in the 1970's having reverted to pasture. It is considered by the author of this assessment that the cut off level of 75 mm is not appropriate and a level of 90 mm may be more suitable for sustainable agricultural practices.

The 'Shallow basaltic soils' are considered to generally have an extreme limitation (m5) apart from isolated deeper pockets, while the 'Shallow and mid depth cracking clays on basalt' generally have a moderate (m3) moisture limitation, with some shallower areas within the general soil type having a severe (m4) limitation. As such, the soil type is considered to be a marginal soil type for long term cropping. The other basaltic soil 'Red and black clays (basaltic influenced soils on colluvium or in situ sediments' generally has good moisture availability and has a negligible (ml) limitation.

## Nutrient Deficiency (n)

The DME (1995) guideline have largely been used in the assessment (apart from pH characteristics of the subsoil). In addition, some soils appear to suffer from nutrient rundown over time with lower than desirable levels of organic carbon and total nitrogen and these soils are given a minor to moderate (n2-3) limitation (depending on the severity of the decline) while soils which may have marginal sulphate or zinc are given a minor (n2) limitation.

## Soil Physical Factors (p)

The DME (1995) guideline have been largely used in the assessment. The cracking clay soils are generally given a minor (p2) limitation while the 'Reddish non- cracking and lesser cracking clays on sediments' have some crusting tendencies under cultivation and are given a minor to moderate (p2- 3) limitation.

The 'Shallow basaltic soils (clay loam and non-cracking clay outcrop soils)' generally have a friable surface and are given a negligible limitation. 'Tight shallow surfaced duplex soils on deep colluvial material' have relatively severe surface structural problems for continued cropping and are assigned a moderate to severe (p3-4) limitation.

## Soil Workability (k)

The DME (1995) guideline have been largely used in the assessment. The 'Shallow basaltic soils (clay loam and non-cracking clay outcrop soils)' are considered to have a negligible limitation (kl). All clay soils are cracking to a degree and are given a minor (k2) limitation. The hard-set duplex 'Tight shallow surfaced duplex soils on deep colluvial material' would have a narrower moisture range for working and have a moderate limitation (k3).

## Salinity (s)

The DME (1995) guideline are largely used, however, they do not take into account the potential for dryland salting to occur with increased leaching through fallowing for cropping. The 'Dark cracking clays on sediments (upper slopes)' and the 'Alluvial clays in drainage ways' all have some incidence of increased salinity in the root zone in some profiles and have a negligible to minor (sal-2) limitation.

## Rockiness (r)

Rockiness refers to rock outcrop and coarse fragments within the plough zone that impede cultivation and damage machinery, and the only soils which this occurs on are the soils associated with basalt. For the 'Shallow basaltic soils (clay loam and non-cracking clay outcrop soils)' rock content is variable and the limitation to cultivation ranges from minor to extreme (r2-5.). The other two soils associated with basalt have a negligible to minor (rl-2) limitation depending on how close they are to basalt outcrop material.

## Microrelief (g)

This limitation covers the effect microrelief has on uneven cultivation and impeding trafficability of machinery. Only slight linear gilgai are present and all soils have a negligible limitation.

## Wetness (w)

This limitation covers the adverse effects of excess water on crop production through reduction in plant growth and yield and restrictions on the use of machinery following rain. The heavier clay soils and soils in low lying areas 'Dark cracking clays on in situ sediments or colluvium (lower slopes)', and' Alluvial clays in drainage ways' are all assigned a minor (w2) limitation. The rigid duplex soil 'Tight shallow surfaced duplex soils on deep colluvial material' reach high sodicity levels within 60 cm of the surface and are considered to have impeded drainage. They are assigned a moderate (w3) limitation. All other soils have a negligible limitation.

## Water Erosion (e)

This limitation covers accelerated soil loss which results in declining productivity, increasing difficulty to cultivate and eventually an inability to produce a crop in most years. DME guidelines are generally used but have been modified on advice from the DNRM. On the

Darling Downs, the clay soils formed on sediments are considered to be croppable up to 5% slope, while the basaltic soils are considered to be croppable up to 8% slope.

No soils have a negligible erosion limitation. The' Alluvial clays in drainage ways' have a minor limitation (e2) based on slope only. The 'Shallow basaltic soils' have a minor to extreme (e2-5) limitation because of the large variation in slope.

A moderate limitation (e3) is assigned to the soils with lower slope, being the 'Shallow and mid depth cracking clays on basalt', 'Dark cracking clays on in situ sediments or colluvium' and 'Tight shallow surfaced duplex soils on deep colluvial material'.

The other soils which are slightly steeper in some areas 'Red and black clays', Reddish non- cracking and lesser cracking clays on sediments', and 'Dark cracking clays on sediments' generally have a moderate limitation but in steeper areas where slopes rise above those discussed above, have a severe limitation (e3-.4).

## Flooding (f)

This limitation accounts for periodic inundation with damage caused by fast flowing water or submersion. This limitation is negligible as it relies heavily on local knowledge and severe to extreme (f4-5) limitation has been imposed on the' Alluvial clays in drainage ways' depending on their proximity to drainage ways. A negligible to extreme (f4-5) limitation is assigned to the 'Tight shallow surfaced duplex soils on deep colluvial material' depending on their proximity to drainage lines.

# APPENDIX C

## Current Mine

## Limitations for Grazing

## Land Suitability Classes for Grazing – Pre-Mining

| Soil Group | Limitations | Suitability |
|---|---|---|
| **Soils in upslope and mid slope associated with basalt** | | |
| Shallow basaltic soils (clay loam and non-cracking clay, outcrop soils) | m4-5, r1-5, e2-3 | 4-5 |
| Shallow and mid depth cracking clays on basalt | m2-3, n2, p2, e1-2 | 2-3 |
| Red and black clays (basaltic influenced soils on colluvium or in situ sediments) | n2, p2, e1-3 | 2-3 |
| **Soils in upslope and mid slope formed on sediments** | | |
| Reddish non-cracking and lesser cracking clays on sediments | n2, p2, e1-3 | 2-3 |
| Dark cracking clays on sediments (upper slopes) | n2, p2, e1-3 | 2-3 |
| **Soils in mid and lower slope positions** | | |
| Dark cracking clays on in situ sediments or colluvium (lower slopes) | n2, p2 | 2 |
| Tight shallow surfaced duplex soils on deep colluvial material | m2, n3, p2-3, w2, e2-4, f1-2 | 3-4 |
| Alluvial clays in drainage ways | n2, p2, w2, e1-4, f1-2 | 2, some 4 |

## Limitations for Beef Cattle Grazing

This classification evaluates the beef cattle grazing potential on improved pastures. Eight limitations to grazing improved pasture were considered in relation to the lands of the mining leases. These limitations are the same as those for rainfed cropping except for the removal of soil workability (k) and microrelief (g-gilgai ) (Shields and Williams, 1991 ).

## Water Availability (m)

Pasture production occurs in a shallower root zone than cropping systems and 60 cm of rooting depth in clay soils is considered to be adequate for pastures to achieve maximum production (Shields and Williams, 1991).

The better and deeper clay cropping soils have the highest PAWC' s and have a negligible limitation. These are the 'Red and black clays (basaltic influenced soils on colluvium or in situ sediments)', 'Reddish non-cracking and lesser cracking clays on sediments', 'Dark cracking clays on sediments (upper slopes)', 'Dark cracking clays on in situ sediments or colluvium (lower slopes)' and the 'Alluvial clays in drainage ways'.

A minor limitation (m2) is assigned to the 'Deep heavy clays on clay colluvium' and the 'Tight shallow surfaced duplex soils on deep colluvial material'. The 'Cracking clays with linear gilgai supporting poplar box and scrub understorey species' also generally have a minor (m2) limitation, but this may be moderate (m3) where the rooting depth is restricted by salinity.

The 'Shallow and mid depth cracking clays on basalt also have a minor to moderate (m2-3) limitation depending on the depth to parent material.

The shallow basaltic soils (clay loam and non-cracking clay outcrop soils)' have a severe to extreme (m4-5) limitation, depending on the depth to parent basalt.

## Nutrient Deficiency (n)

The DME (1995) guideline have been modified in the assessment. Some soils appear to suffer from nutrient run-down over time with lower than desirable levels of organic carbon and total nitrogen and these soils are given a minor to moderate (n2-3) limitation depending on the severity of the decline, while soils which may have marginal sulphate or zinc are given a minor (n2) limitation. Soil Physical Factors

Physical factors limit pasture establishment and spread. They are typically related to size of surface aggregates, hard setting or cracking. Small seeded species such as buffel and Rhodes grass are difficult to establish on cracking clays as the seeds are lost down large airspaces or rapidly dry out after germination in the porous soil. Spread of most species is restricted on hard setting surface soils such as sandy loam to clay loam textures. Larger seeded species such as sorghum and bambatsi are more suited to the clay surface textures (Lambert and Graham, 1996).

The DME (1995) guideline have been largely used in the assessment. The 'Shallow basaltic soils (clay loam and non-cracking clay outcrop soils)' are given a negligible limitation. All other soils are given a minor limitation (p2) with the exception of the 'Tight shallow surfaced duplex soils on deep colluvial material' where structural problems appear to be quite severe (p2-3).

## Salinity (sa)

The DME (1995) guideline are largely used, however, effective rootzones for pastures are generally considered to be shallower than for crops and so milder limitations exist. The assessment is made on a 60 cm rootzone, resulting in all soils having a negligible limitation.

## Rockiness (r)

Rockiness refers to rock outcrop and coarse fragments that may impede cultivation. Cultivation is occasionally required for pasture improvement and the same limitations apply as for cropping. The 'Shallow basaltic soils (clay loam and non-cracking clay outcrop soils)' have variable rock content and the limitation ranges from negligible to extreme (rl-5) where areas of rock outcrop may occur. All other soils are considered to have a negligible limitation.

## Wetness (w)

This limitation covers the adverse effects of excess water on pasture production through reduced persistence of a range of introduced species and restrictions on use of machinery following rain. The 'Alluvial clays in drainage ways' are given a minor limitation (w2) as are the rigid soils with strongly sodic subsoils ('Tight shallow surfaced duplex soils on deep colluvial material').

## Water Erosion (e)

This limitation covers accelerated soil loss which results in declining productivity. Grazing generally increases the potential for soil loss during rainfall, compared to land with little disturbance. Clearing and increased grazing pressure can reduce cover. Occasional cultivation for preparation for seeding or renovation results in temporary exposure. Erosion will result in declining productivity.

Limitations are similar to the cropping limitations but are less severe and DME guidelines  are generally used. The clay soils with low slope ('Dark cracking clays on in situ sediments or colluvium') are considered to have a negligible limitation.

The 'Shallow and mid depth cracking clays on basalt' have a negligible to minor (el-2) limitation depending on slope, while the 'Red and black clays (basaltic influenced soils on colluvium or in situ sediments)', 'Reddish non- cracking and lesser cracking clays on sediments' and 'Dark cracking clays on sediments (upper slopes)' have a negligible to moderate (el-3) limitation.

The 'Shallow basaltic soils (clay loam and non-cracking clay, outcrop soils)' have a minor to moderate (e2-3) limitation.

The 'Tight shallow surfaced duplex soils on deep colluvial material' generally have a minor limitation (e2) but within drainage lines that traverse the soil is given a severe limitation (e4). The 'Alluvial clays in drainage ways' have either a negligible or severe limitation (el-4) depending on their proximity to drainage lines and the risk or erosion with soil disturbance.

This limitation covers the adverse effects of excess water on pasture production through reduced persistence of a range of introduced species and restrictions on use of machinery following rain. The 'Alluvial clays in drainage ways' are given a minor limitation (w2) as are the rigid soils with strongly sodic subsoils ('Tight shallow surfaced duplex soils on deep colluvial material').

## Flooding (f)

This limitation accounts for periodic inundation with damage caused by fast flowing water or submersion. The limitation is largely ignored as it relies heavily on local knowledge and only a minor limitation has been imposed in and close to drainage channels where they are present on the 'Tight shallow surfaced duplex soils on deep colluvial material' and 'Alluvial clays in drainage ways'.

# APPENDIX D

## Grazing Trial Program

The grazing trial included slope areas and involved a comparison process with an analogue site. The grazing trial program was managed by the New Hope Group subsidiary APC and included a formal study and report by a professional third party agricultural consultancy and local university. The grazing trial expanded to include the progressively rehabilitated areas designated for grazing as the mine progressed.

NAC believes the grazing trial is a critical assessment tool for demonstrating long term success of its grazing based rehabilitation for future mine closure and mining lease surrender requirements. From an operational perspective, NAC will use the grazing trial:

- To assess the success of the current rehabilitated area in relation to the performance of cattle growth (beef production);
- To evaluate current rehabilitation practices from a final land use perspective; and
- As required, to develop new rehabilitation strategies to improve rehabilitation and long- term grazing performance.

Longer term, the APC will also use this information to develop appropriate land management plans for NAC's former mined land at the site. The grazing trial has provided clarity and confidence in NACs rehabilitation processes and demonstrates with full scientific rigor that proposed post landforms will be able to support grazing (beef production) in a long term sustainable manner.

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**NAC Attachment 14 - EPBC Approval**

**Approval**

**Stage 3 Expansion of New Acland Coal Mine, Queensland (EPBC 2007/3423)**

This decision is made under sections 130(1) and 133 of the *Environment Protection and Biodiversity Conservation Act 1999*.

**Proposed action**

| | |
|---|---|
| **person to whom the approval is granted** | New Acland Coal Pty Ltd |
| **proponent's ABN** | 90 081 022 380 |
| **proposed action** | The Stage 3 expansion of an existing coal mine by New Acland Coal Pty Ltd on Mineral Development Lease 244 located on the Darling Downs in Southern Queensland, approximately 35 km north-north-west of Toowoomba. (See EPBC Act referral 2007/3423 received on 23 April 2007 and the variations accepted on 25 November 2008 and 26 October 2012). |

**Approval decision**

| **Controlling Provision** | **Decision** |
|---|---|
| Section 18 & 18A (listed threatened species and ecological communities) | Approved |
| Section 24D & 24E (water resources) | Approved |

**conditions of approval**

This approval is subject to the conditions specified below.

**expiry date of approval**

This approval has effect until 31 January 2042.

**Decision-maker**

| | |
|---|---|
| **name and position** | The Hon Josh Frydenberg MP<br>Minister for the Environment and Energy |
| **signature** | |
| **date of decision** | 18 January 2017 |

**Conditions of approval**

**Disturbance Limits**

1. The **approval holder** must not take the proposed action outside the **project area**.

2. The **approval holder** must not clear more than 70.8 hectares of Belson's Panic (*Homopholis belsonii*) from the **project area**.

**Adaptive Management and Offsets**

3. The **approval holder** must provide environmental offsets for the **impact** to 70.8 hectares of Belson's Panic (*Homopholis belsonii*).

4. The **approval holder** must prepare and submit an Offset Management Plan for the written approval of the **Minister**. The action must not **commence** until the Offset Management Plan has been approved by the **Minister** in writing. The approved Offset Management Plan must be implemented. The Offset Management Plan must include:

   i. a survey and description of the current condition (before any management activities) of each offset area proposed, including existing vegetation (the baseline condition). This must include a shapefile of each offset property boundary;
   ii. information about how the offset areas provide connectivity with other relevant habitats and biodiversity corridors, including a map depicting the offset areas in relation to other habitats and biodiversity corridors;
   iii. performance and completion criteria for evaluating the management of the offset area, and criteria for triggering remedial action (if necessary), including any **impacts** to the offset area/s associated with altered hydrogeology as a result of the action;
   iv. a description of the management measures that will be implemented for the protection of Belson's Panic, including a discussion of how measures outlined take into account the approved **conservation advice** for *Homopholis belsonii*;
   v. a program to monitor and report on the effectiveness of these measures, and progress against the performance and completion criteria;
   vi. a description of potential risks to the successful implementation of the plan, and a description of the contingency measures that would be implemented to mitigate against these risks;
   vii. a timeline for when actions identified in the Offset Management Plan will be implemented for the offset area/s; and
   viii. the proposed legal mechanism for securing the offset area/s.

5. The **approval holder** must register and **legally secure**, in accordance with Queensland legislation, offsets for authorised unavoidable **impacts** to Belson's Panic within two years of the **commencement** of the action.

6. The **approval holder** must ensure that environmental offsets comply with the principles of the **EPBC Act Environmental Offsets Policy (2012)**.

7. If additional areas of **EPBC Act listed threatened species** not previously identified and reported to the **Department** are found in the **project area** during pre-clearance surveys required for the Environmental Authority issued for the project under the *Environmental Protection Act 1994* (Qld), the **approval holder** must:

   i. notify the **Department** within five business days of finding the **EPBC Act listed threatened species**;

ii. submit to the **Minister** for written approval a Species Management Plan (SMP) for how **impacts** to **EPBC Act listed threatened species** will be avoided, mitigated and offset if a significant **impact** is considered likely.

8. The **approval holder** must not **commence** the action until the SMP, if required, has been approved by the **Minister** in writing. The **approval holder** must implement the approved SMP.

**Water management and monitoring**

9. The **approval holder** must undertake management and monitoring of water resources in accordance with:

   i. the Environmental Authority issued for the project under the *Environmental Protection Act 1994* (Qld); and

   ii. the requirements of any conditions regarding groundwater to be imposed by the authority responsible for administering the *Water Act 2000* (Qld).

10. The **approval holder** must submit the Receiving Environment Monitoring Plan (REMP) to the **Minister** for written approval. **Mining activities** must not **commence** until the REMP has been approved by the **Minister** in writing. The **approval holder** must implement the approved REMP.

11. In addition to the requirements for an REMP as identified in an Environmental Authority issued for the project under the *Environmental Protection Act 1994* (Qld), the **approval holder** must:

   i. identify the location of all discharge points and include monitoring locations downstream of each discharge point and environmental dams;

   ii. identify the locations of all sampling points and review these for adequacy to ensure these are representative of upstream, downstream, control and reference sites;

   iii. include field observations such as weather and flow conditions during each sampling event;

   iv. increase the frequency of sampling and expand the range of analytes (e.g. metals, nutrients, ionic composition and polycyclic aromatic hydrocarbons) to be sampled at each sampling event;

   v. use *Australian and New Zealand Environment and Conservation Council* (ANZECC) water quality guidelines for 95 per cent species protection in slightly to moderately disturbed systems until such time as site-specific water quality objectives can be derived based on data gathered during at least the first two years of the project;

   vi. include measures to report and verify any exceedance of triggers to the **Department**;

   vii. include mitigation and management measures to be implemented in the event a threshold is exceeded;

   viii. include additional flow gauges on Spring Creek, including automatic samplers to collect water samples during first flush and high flow events; and

   ix. address all the surface water management measures outlined in the **IESC advice**.

12. The **approval holder** must submit a Groundwater Management and Monitoring Plan (GMMP) to the **Minister** for written approval. **Mining activities** must not **commence** until the GMMP has been approved by the **Minister** in writing. The **approval holder** must implement the approved GMMP.

13. The GMMP must include:

    i. details of a groundwater monitoring network to measure **impacts** to groundwater quality and drawdown as a result of the action, including:

        a. **control monitoring sites**;

        b. details of the physical groundwater conditions, analytes, contaminants and physico-chemical properties to be monitored;

        c. sufficient bores to determine the lateral extent of groundwater drawdown and flow direction and monitor potential **impacts** on **groundwater resources** and the effect of faulting on groundwater drawdown; and

        d. a rationale for the design of the monitoring network with respect to the nature of potential **impacts**;

    ii. baseline monitoring to determine existing groundwater quality within the **project area**, particularly adjacent to the location of the proposed pits;

    iii. baseline monitoring data including a detailed bore census and investigation of bores in the area likely to be **impacted**;

    iv. details of the location of monitoring bores to use as early warning indicators of groundwater drawdown propagation;

    v. **threshold triggers** for **early warning monitoring bores** based on modelled **impacts** to water resources;

    vi. groundwater **drawdown limits** for **impacts** to the Oakey Creek Alluvium and Tertiary Basalt Aquifers;

    vii. measures and timeframes to report and verify any exceedance of **threshold triggers** or **drawdown limits** to the **Department**;

    viii. a process to submit additional mitigation measures including a review of the appropriateness of the existing **threshold triggers** to the **Department** for approval in the event a **threshold trigger** is exceeded;

    ix. an outline of the proposed methodology to assess groundwater connectivity between each hydrogeological unit using nested bore arrays;

    x. mechanisms for addressing the **impacts** of the action to **groundwater resources**, including details of measures for **impacts** to water bores and **offsets for the Oakey Creek Alluvium and Tertiary Basalt Aquifers**;

    xi. a timeframe for when the measures and offsets for **impacts** to **groundwater resources** will be implemented;

    xii. a timeframe for a regular review of the GMMP in accordance with the requirements of the conditions to be imposed by the authority responsible for administering the *Water Act 2000*, and subsequent updates of the GMMP, including to incorporate the outcomes of the groundwater model reviews (condition 16 of this notice); and

    xiii. address the groundwater management measures outlined in the **IESC advice**.

13A. If monitoring reports, based on **threshold triggers** for **early warning monitoring bores**, indicate that a groundwater **drawdown limit** will be substantially exceeded, the **Minister** may:

i. require the **approval holder** to suspend mining operations; or

ii. suspend or revoke an approval under section 144 and section 145 of the **EPBC Act**.

To avoid any doubt, this condition does not limit the application of section 144 or section 145 of the **EPBC Act**, if the **Minister** believes that the action will have a significant **impact** that was not identified in assessing the action.

14. The **Minister** may submit the GMMP to the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (**IESC**) or other independent expert for review before making a decision on whether to approve it under condition 12.

15. The GMMP, including any revisions of the GMMP, must be peer reviewed by a **suitably qualified expert** before the GMMP is submitted for approval. A peer review must be submitted to the **Minister** together with the GMMP and a statement from the **suitably qualified expert** stating that they carried out the peer review and accept the findings and the content of the GMMP.

16. The **approval holder** must undertake groundwater model reviews in accordance with the requirements of the conditions imposed by the Queensland Coordinator-General under section 54B of the *State Development and Public Works Organisation Act 1971*. The reviews must address all matters raised in the December 2015 and 2016 **IESC advice** in regards to groundwater modelling. In addition, groundwater model reviews must be undertaken by a **suitably qualified expert** and must include:

i. validation of the existence and nature of faulting and its potential effect on the predicted lateral extent of groundwater drawdown;

ii. updated **groundwater resource** user abstraction data;

iii. a review of predicted volumetric **impacts** to a **groundwater resource**; and

iv. ongoing model evaluation including comparison between observed and modelled heads for each formation, across pre-mining, operations, post-mining and **long term phases**.

17. The **approval holder** must make groundwater monitoring and modelling data available to the **Department** and **Queensland Government authorities** (if requested) for inclusion in any cumulative **impact** assessment, regional water balance model and/or bioregional assessment.

**Final Landform and voids**

18. Within six years of **commencement**, the **approval holder** must prepare and submit a Final Land Use and Rehabilitation Plan to the **Minister** for written approval. The Final Land Use and Rehabilitation Plan must include:

i. revised predictions of final void water levels for each proposed pit using pit lake water balance models in conjunction with the groundwater model;

ii. pit lake water balance models based on inflow data gathered during mining;

iii. long-term contaminant (e.g. metals and salinity) modelling within pit lakes of each final void;

iv. a monitoring network suitable to identify any contaminant seepage from the final voids;

v. final void geometries which will be implemented to minimise the risk of voids becoming contaminated or saline water sources or through-flow systems to the surrounding environment;

vi. incorporation of climate and rainfall variability into the assessment and management of final voids;

vii. a schedule for regular update and review of the Final Land Use Rehabilitation Plan.

viii. identify the timeframe in which rehabilitation works will be completed; and

ix. addressing the final landform and void management measures outlined in the **IESC advice.**

19. The approved Final Land Use and Rehabilitation Plan must be implemented.

**Note:** The **approval holder** may align a plan required under these conditions with the requirements of the Queensland Government, as long as the relevant matters under the conditions of this approval are clearly and adequately addressed.

**General**

20. Within 30 days after the **commencement** of the **action**, the **approval holder** must advise the **Department** in writing of the actual date of **commencement**.

21. The **approval holder** must maintain accurate records substantiating all activities associated with or relevant to the conditions of approval, including measures taken to implement the management plans required by this approval, and make them available upon request to the **Department**. Such records may be subject to audit by the **Department** or an independent auditor in accordance with section 458 of the **EPBC Act,** or used to verify compliance with the conditions of approval. Summaries of audits will be posted on the **Department's** website. The results of audits may also be publicised through the general media.

22. Within three months of every 12 month anniversary of the **commencement** of the **action**, the **approval holder** must publish a report on its website addressing compliance with each of the conditions of this approval. Documentary evidence providing proof of the date of publication must be provided to the **Department** at the same time as the compliance report is published. Reports must remain on the **approval holder's** website for the duration of this approval. Following completion of the action, the **approval holder** may seek the written agreement of the **Minister** to cease preparing and publishing compliance reports as required by this condition.

23. The **approval holder** must report any contravention of the conditions of this approval to the **Department** within two business days of the **approval holder** becoming aware of the contravention.

24. Upon the direction of the **Minister**, the **approval holder** must ensure that an independent audit of compliance with the conditions of approval is conducted and a report submitted to the **Minister**. The audit must not commence unless and until the **Minister** has approved the independent auditor and audit criteria. The audit report must address the criteria to the satisfaction of the **Minister.**

25. The **approval holder** may choose to revise a plan approved by the **Minister** under conditions 4, 7 and 9 without submitting it for approval under section 143A of the **EPBC Act**, if the taking of the action in accordance with the revised plan would not be likely to have a **new or increased impact**. If the **approval holder** makes this choice they must:

   i. notify the **Department** in writing that the approved plan has been revised and provide the **Department** with an electronic copy of the revised plan;

   ii. implement the revised plan from the date that the plan is submitted to the **Department**; and

   iii. for the life of this approval, maintain a record of the reasons the **approval holder** considers that taking the action in accordance with the revised plan would not be likely to have a **new or increased impact**.

26. The **approval holder** may revoke its choice under condition 25 at any time by notice to the **Department**. If the **approval holder** revokes the choice to implement a revised plan without approval under section 143A of the **EPBC Act**, the **approval holder** must implement the version of the plan most recently approved by the **Minister**.

26A. Condition 26 does not apply if the revisions to the approved plan include changes to environmental offsets provided under the plan in relation to a matter protected by a controlling provision for the action, unless otherwise agreed in writing by the **Minister**. This does not otherwise limit the circumstances in which the taking of the action in accordance with a revised plan would, or would not, be likely to have **new or increased impacts**.

26B. If the **Minister** gives a notice to the **approval holder** that the **Minister** is satisfied that the taking of the action in accordance with the revised plan would be likely to have a new or increased **impact**, then:

   i. condition 26 does not apply, or ceases to apply, in relation to the revised plan; and

   ii. the **approval holder** must implement the version of the plan most recently approved by the **Minister.**

   To avoid any doubt, this condition does not affect any operation of conditions 26 and 26A in the period before the day after the notice is given.

   At the time of giving a notice under condition 26, the **Minister** may also notify that for a specified period of time condition 26 does not apply for one or more specified plans required under the approval.

26C. Conditions 26, 26A, 26B and 26C are not intended to limit the operation of section 143A of the **EPBC Act** which allows the **approval holder** to submit a revised plan to the **Minister** for approval.

27. If, at any time after five years from the date of this approval, the **approval holder** has not **commenced** the **action**, then the **approval holder** must not **commence** the action without the written agreement of the **Minister.**

28. Unless otherwise agreed to in writing by the **Minister**, the **approval holder** must publish all management plans referred to in these conditions of approval on its website. Each management plan must be published on the website within one month of being approved by the **Minister** or updated and remain available on that website for the **life of the approval**.

**Definitions**

**Approval holder:** means the person to whom the approval is granted or any person acting on their behalf, or to whom the approval is transferred under section 145B of the EPBC Act.

**Commence/commencement:** is the first instance of any specified activity. Unless the activity is specifically defined for the purposes of these conditions, commencement of an activity includes any physical disturbance including clearing of vegetation, earthworks, new road works, construction of new camps, development of mining associated infrastructure and mining activities. Commencement does not include:

a) minor physical disturbance necessary to undertake pre-clearance surveys or establish monitoring programs; or

b) activities that

   i. are critical to commencement; and

   ii. are associated with mobilisation of plant and equipment, materials, machinery and personnel prior to the start of development;

   iii. but only if such activities will have no adverse impact on matters of national environmental significance, and the proponent has notified the Department in writing before an activity is undertaken.

**Conservation advice** means a conservation advice approved by the Minister under section 266B(2) of the EPBC Act.

**Control monitoring sites** means analogous monitoring points that are close to the project but outside of the project's likely impact zone for the purpose of comparison with impacted areas.

**Department** means the Australian Government Department administering the *Environment Protection and Biodiversity Conservation Act 1999*.

**Drawdown limit/s** means the reduction in groundwater head that must not be exceeded.

**Early warning monitoring bores** means monitoring bores which have been located to provide early indications of where and when threshold triggers are exceeded.

**EPBC/ EPBC Act** means the *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

**EPBC Act Environmental Offsets Policy (2012)** means the EPBC Act Environmental Offsets Policy (October 2012) including the Offsets Assessment Guide.

**EPBC Act listed threatened species** means a threatened flora or fauna species (other than a conservation dependent species) included in the relevant list under the EPBC Act at the time a decision was made under section 75 of the EPBC Act.

**Groundwater resource** includes but is not limited to the Oakey Creek alluvial aquifer, Tertiary Basalt aquifer, Walloon Coal Measures and Marburg Sandstone Aquifer.

**Impact/s/impacted:** as defined in section 527E of the EPBC Act.

**IESC** means the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development.

**IESC advice** means Advice to the decision maker on coal mining projects *IESC 2016-081: New Acland Coal Mine Stage 3 (EBC 2007/3423) – Expansion* (14 December 2016).

**Legally secure** means to secure a covenant or similar legal agreement in relation to a site, to provide enduring protection for the site against development incompatible with conservation.

**Long term phases** means the long term period post mining after a new groundwater equilibrium has been reached.

**Minister** means the Minister administering the *Environment Protection and Biodiversity Conservation Act 1999* and includes a delegate of the Minister.

**Mining activities** means mining coal from the coal measures including the removal of overburden.

**Offsets for the Oakey Creek Alluvium and Tertiary Basalt Aquifers** may comprise a retirement of part or all of an existing entitlement, or purchase and retirement of a new entitlement.

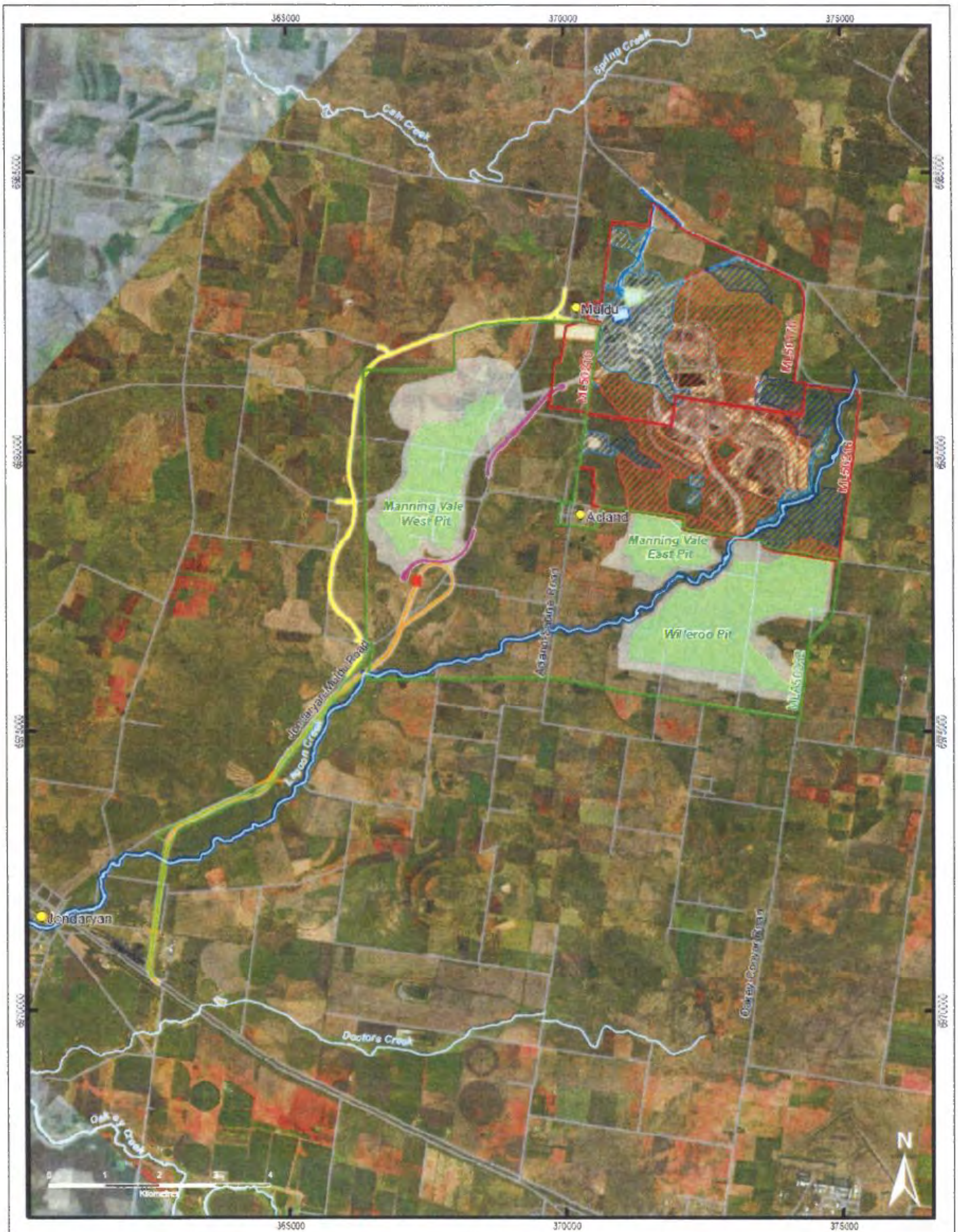
**Project area** means the area identified as the Stage 3 Tenements shown in Attachment A.

**Queensland Government authorities** means authorities who have a role in regulating activities relating to water resources.

**Suitably qualified expert** means a person who has professional qualifications, training or skills or experience relevant to the nominated subject matters and can give authoritative assessment, advice and analysis about performance relevant to the subject matter using relevant protocols, standards, methods and/or literature.

**Threshold triggers** means triggers in place for early warning monitoring bores that identify when further investigation and management responses are required.

## ATTACHMENT A




LEGEND

- Towns and Localities
- Train Loadout Facility

Revised Rail & Road Infrastructure

- Internal Haulage Road
- Revised Access to Mine
- Revised Jondaryan-Muldu Road Diversion
- Revised Rail Spur and Balloon Loop Alignment
- Roads
- Creeks
- Stage 2 Tenements
- Stage 3 Tenements

Disturbance Footprint Area

- Stage 3 Pit Areas
- Watercourse Buffer

Disturbance Areas - Stage 2

- Mining Areas
- Other Surface Infrastructure Areas
- Out of Pit Dumping Areas

NEW ACLAND COAL MINE
STAGE 3 PROJECT

Figure 1 - Revised Project Overview

Scale 1:90,000 on A4
Projection: Australian Geodetic Datum – Zone 56 (AGD84)