Appendix C Management Plans

Appendix C1	Topsoil Management Plan (AARC 2018c)
Appendix C2	Rehabilitation and Void Investigation Report (AARC 2018b)
Appendix C3	Weed and Pest Management Plan (AARC 2018d)
Appendix C4	Chemical and Fuel Management Plan (AARC 2018a)
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ENVIRONMENTAL SOLUTIONS

JELLINBAH COAL MINE
TOPSOIL MANAGEMENT PLAN

PREPARED FOR

JELLINBAH MINING PTY LTD

JANUARY 2018

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JELLINBAH COAL MINE
TOPSOIL MANAGEMENT PLAN

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LIST OF ABBREVIATIONS

AARC	AARC Environmental Solutions Pty Ltd
cm	centimetre(s)
EA	Environmental Authority
ERD	effective rooting depth
ESCP	Erosion and Sediment Control Plan
GTES	GT Environmental Services Ltd
ha	hectare(s)
Ison	Ison Environmental Planners
Jellinbah	Jellinbah Mining Pty Ltd
km	kilometres
m	metre(s)
ML	Mining Lease
mm	millimetre(s)
mS/cm	milliSiemens per centimetre
Mtpa	million tonnes per annum
PAWC	plant available water capacity
Plan	Plan of Operations
t	tonne(s)
µs/cm	micro-Siemen(s) per centimetre
%	per cent

1.0 INTRODUCTION

The Jellinbah Coal Mine (the Project) is an open-cut coal operation, mining shallow, low stripping ratio coal reserves and producing approximately 4.5 – 5.0 million tonnes per annum (Mtpa) of pulverised coal injection and a minor amount of thermal coal, primarily for export. The Project is authorised by Environmental Authority (EA) EPML00516813 and operated by Jellinbah Mining Pty Ltd (Jellinbah) on behalf of the Jellinbah East Joint Venture. The participants of the Jellinbah East Joint Venture are: Jellinbah Group Pty Ltd, Tremell Pty Ltd, Marubeni Coal Pty Ltd and Sojitz Coal Resources Pty Ltd.

Jellinbah Coal Mine is located within the Bowen Basin in Central Queensland approximately 190 km west of Rockhampton. It is situated within both the Central Highlands Regional Council and the Isaac Regional Council and is approximately 24 km north of the township of Blackwater.

1.1 SCOPE OF DOCUMENT

This Topsoil Management Plan has been prepared by AARC Environmental Solutions Pty Ltd (AARC) to assist Jellinbah in managing the Project's environmental obligations and to provide supporting information to the Project's Plan of Operations (Plan). This document applies to the management of topsoil at the following operational areas at the Project site:

- Jellinbah Central – in operation;
- Jellinbah Plains – in operation (contractor-run operation);
- Mackenzie North – under development.

The scope of the Topsoil Management Plan is to provide:

- A description of each soil type identified on the Project site;
- Recommended methodology for the salvage and stockpiling of soil removed from disturbance areas during the term of the Plan; and
- A methodology for the application of topsoil in the rehabilitation of Project disturbance areas.

2.0 DESCRIPTION OF SOILS

A review of the Department of Natural Resources database indicates that no detailed mapping of soils in the Project area has been carried out by the State Government. Detailed Soil and Land Suitability Surveys have been undertaken within each ML at the time of Application and during mine operations.

This section consolidates information from multiple sources to provide a summary of soil types known to occur on the Project site (within the planned mining footprints).

2.1 JELLINBAH CENTRAL

Soil management units within the Jellinbah Central Project area have been described and mapped based on the findings of the following soil assessment reports:

- *Soil and Land Capability Assessment – Jellinbah Central East: MLA80140* (Ison Environmental Planners (Ison) 2007); and
- *Jellinbah Coal Mine – Highwall Topsoil Stockpile Assessment* (GT Environmental Services Ltd (GTES) 2012).

The Soil and Land Capability Assessment (Ison 2007) provides mapping over all topsoil reserves remaining at Jellinbah Central. The Highwall Topsoil Stockpile Assessment (GTES 2012) was conducted on a smaller scale resulting in more accurate mapping of the boundaries of each soil management unit. However, this mapping describes only the western most portion of the Central proposed mining footprint. The topsoil management units described in this report have been mapped based on the findings of both reports with preference awarded to the finer scale topsoil mapping (GTES 2012), where the soil boundaries were inconsistent.

For those areas located east of the GTES (2012) assessment area, it is recommended that the existing topsoil mapping is ground-truthed at the time of pre-stripping to determine the exact boundaries of each soil type. Ground-truthing may be completed by suitably trained operators undertaking the pre-strip or in advance of stripping by expert consultants.

Three distinct soil types have been identified at Jellinbah Central including:

Soil Type A Good quality light to medium clay Brigalow soil;

Soil Type B Moderate quality sandy loam to clay Brigalow soil; and

Soil Type C Heavily melon holed country comprising either hardsetting sandy loam or crusting clay in melonhole depressions.

The locations and extents of each soil type are illustrated in Figure 1.

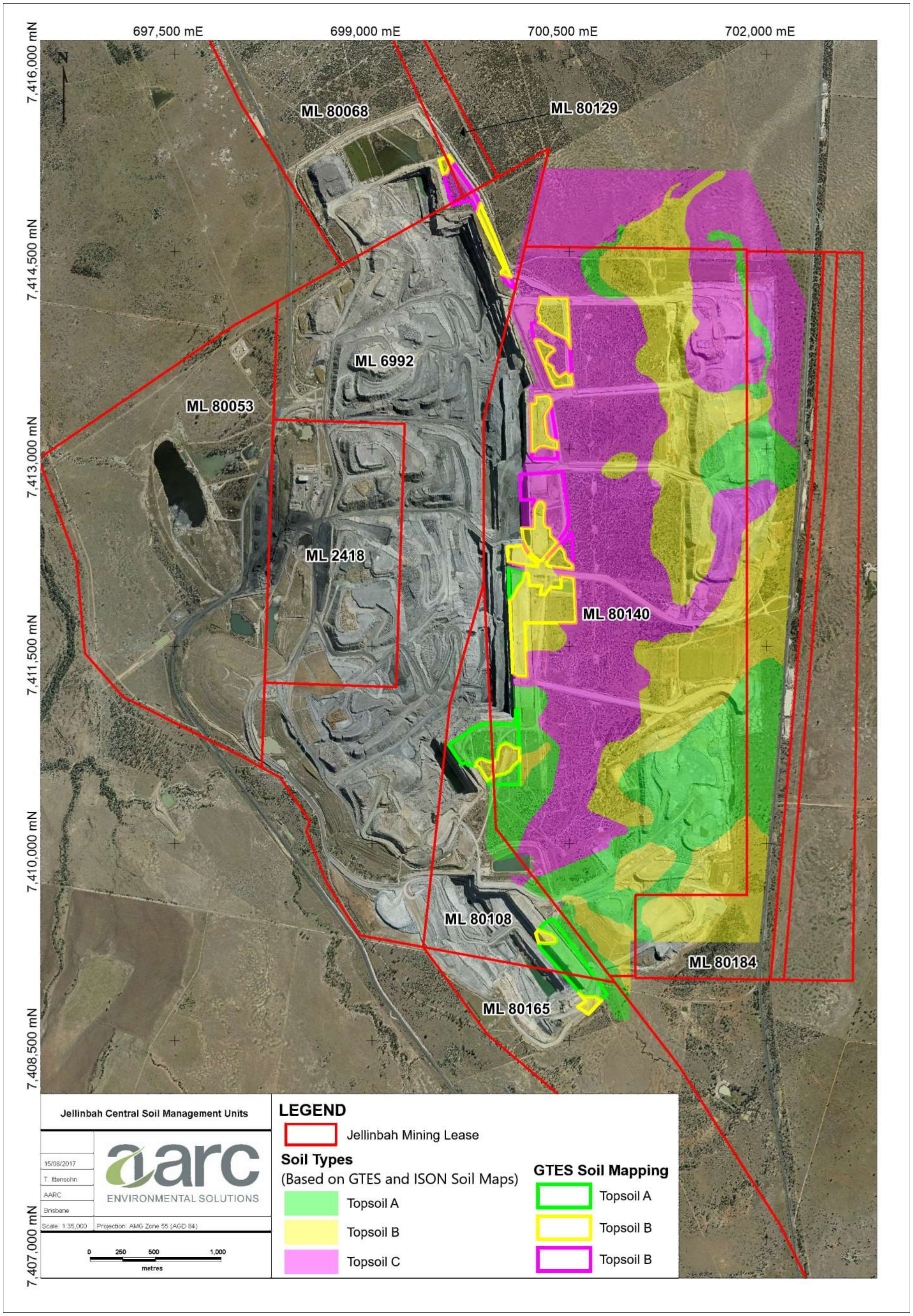

Figure 1 Jellinbah Central Soil Management Units

The assessment of highwall topsoil reserves at Jellinbah Central (GTES 2012) identified three Brigalow scrub soil types (A, B and C) of varying quality. These soil management unit descriptions were consistent with those mapped over the Central Eastern Expansion area (Ison 2007). Each of these soil types is described in Table 1 below.

Table 1 Soil Types at Jellinbah Central

Soil Type	Soil Description
A	• Good quality light to medium clay. • Subsoil (below 30 centimetres (cm)) is harder and coarse. • Non-saline at 40 cm. • Possibly sodic and saline below about 50 cm. • Further investigation may indicate some use for deeper subsoil but this is considered unlikely.
B	• Includes areas of melonholes but not to the extent of soil C. • Reasonable topsoil except for the crusting, hard clay melonholes. • Soil saline or almost saline by 30 – 40 cm depth. • Topsoil is of lower quality than soil A (but still useable), yellow clay which may be saline below 20 cm depth. • Avoid stripping melonhole depressions (see comment for soil C).
C	• Heavily melonholed country (>50 percent (%) of the surface is poor soil which is either hardsetting sandy loam or crusting clay in melonhole depressions). • Inter-melonhole areas are suitable for stripping to about 15 cm (possibly 20 cm). Stripping should not extend into harder, pale coloured subsoil. • Soil is saline by 30 cm. • Melonhole depressions consist of very coarse, sandy clays which are crusting and poorly structured. Stripping of melonhole clays is not recommended but may be undertaken to a depth of 10 cm where subsoil can be excluded. They are often acidic and saline close to the surface. The risk of contamination stripped topsoil is higher in the melonholes.

Source: GTES (2012)

The brown clay soils (Type A) consist of the highest quality and are recommended for use on steeper outer batters in rehabilitation areas. Soil type A can be stripped to a depth of 30 cm. Soil Type B is of moderate quality suitable for stripping to 20 cm deep.

Soil Type C is least suitable for rehabilitation. The high clay content reduces the ability of seeds to germinate making it difficult to establish a strong cover of grasses. These soils tend to be saline and sodic. Due to the dominant presence of deep melonholes, Soil Type C was found to have limited stripping value. Material between melonholes is of reasonable quality and can be stripped to a depth of 15 cm but subsoils should not be incorporated. A maximum stripping depth of 10 cm may be achieved in melonholes where subsoil can be excluded.

Although topsoil quality varies between the three soil types, all soils stripped to the prescribed depths would be beneficial for rehabilitation. The stripping depths nominated in Table 1 are considered a 'safe' average to maximise topsoil retrieval but avoid excessive contamination from unsuitable subsoils. Each soil type is reasonably fertile but would benefit from fertiliser application.

2.2 JELLINBAH PLAINS

A review of the *Mackenzie South – Soil and Land Suitability Survey* (AARC 2006) revealed the presence of three soil management units within the Plains Project area. These soils have been mapped as three distinct mapping units (refer to Figure 2). Soil types occurring at Jellinbah Plains include:

Soil Type 1 – Dee	Grey brown to brown self-mulching clays with a moderate to strong pedal structure with some calcareous inclusions.
Soil Type 2 – Callide	Light clay to clay loam A horizon (grey to dark reddish brown) graduating to medium to heavy clay subsoil. Moderately pedal structure is typical throughout the profile.
Soil Type 3 – Oombabeer	Loamy sand to clay loam A horizon (dark reddish grey to black) underlain by sandy loam to sandy clay loam horizons. Structure is typically moderate to strongly pedal and polyhedral in nature.

The locations and extent of each soil type at Jellinbah Plains are shown in Figure 2. The three soil types are described below.

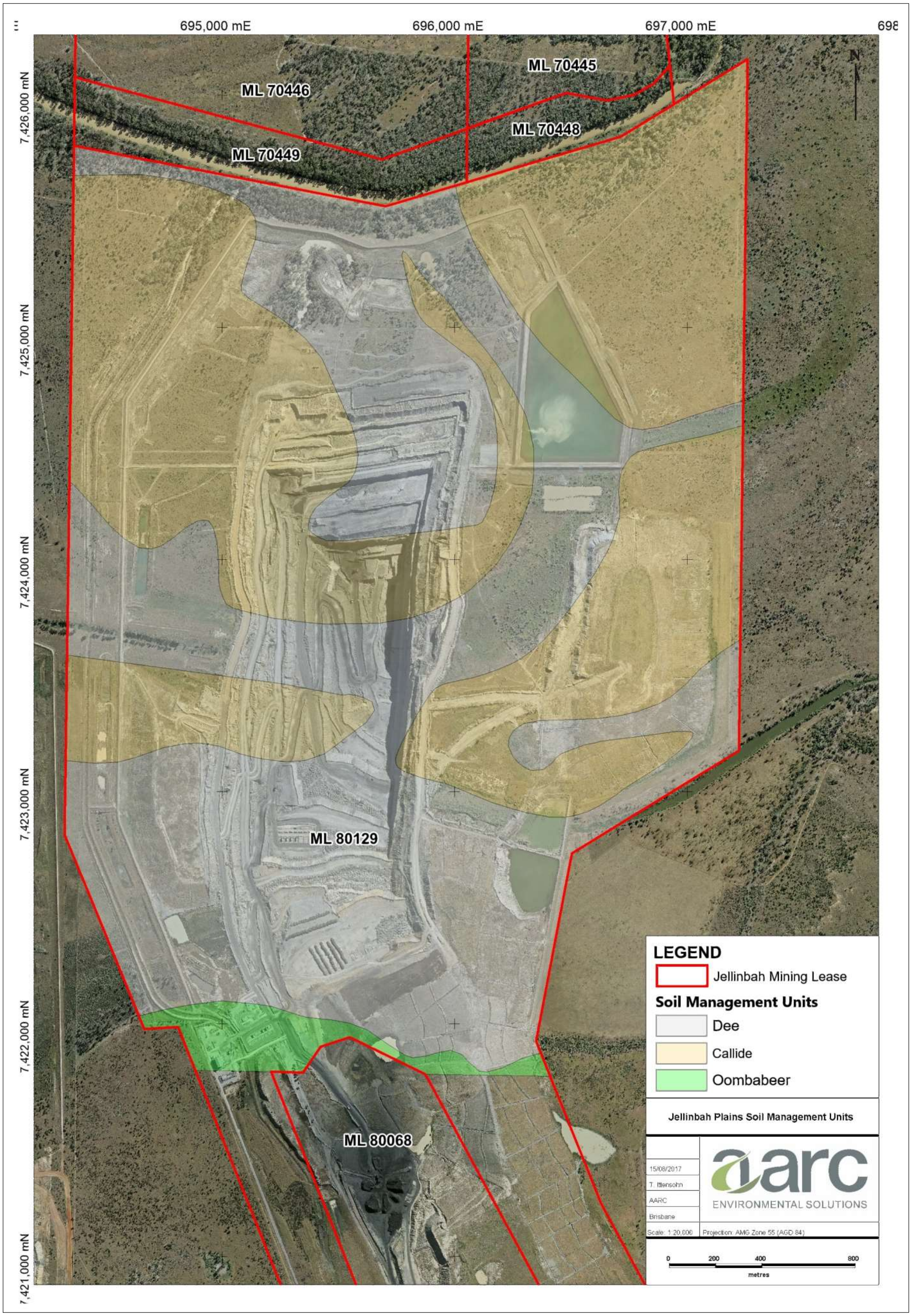

Figure 2 Jellinbah Plains Soil Management Units

Dee Soil Management Unit

The Dee Soil Management Unit at Jellinbah Plains comprises grey brown to brown self-mulching clays with a moderate to strong pedal structure with some calcareous inclusions.

This soil type covers approximately 500 hectares (ha) of the Mackenzie South area. The majority of this area has been cleared for low intensity grazing on improved pastures. The topography is of low relief with slopes tending to be less than 2%.

The surface of this soil type is characterised by grey to reddish brown self-mulching clays with a moderate to strong polyhedral structure. Structure changes with depth to become massive typically at a depth of approximately 30 cm. The soil is alkaline to strongly alkaline, non-saline, of low sodicity and a high cation exchange capacity. Calcareous inclusions occur at depths below approximately 30 cm. This soil type constitutes the Dee soil management unit.

This soil type is suitable for topsoil stripping down to a depth of approximately 30 cm.

Callide Soil Management Unit

The Callide Soil Management Unit at Jellinbah Plains comprises light clay to clay loam A horizon (grey to dark reddish brown) graduating to medium to heavy clay subsoil. Moderately pedal structure is typical throughout the profile.

This soil type covers approximately 500 ha of the Mackenzie South area. The area has previously been cleared for low intensity grazing. The topography is generally of low relief with slopes tending to be less than 2%.

The area is characterised by grey to dark reddish brown clay loam to light clay with occasional cracking. The surface is firm and is typically moderately pedal. Peds are less than 20 millimetres (mm) in size. The A horizon is approximately 30 cm in depth, below which a sharp texture and colour change of the lower horizon can be found. Colour becomes darker and texture increases to medium to heavy clays.

The soil surface is typically slightly acid to neutral with pH increasing with depth. The soils are non-sodic and are of moderate to high cation exchange capacity. This soil constitutes the Callide soil management unit.

Topsoil stripping is recommended to a depth of approximately 30 cm to exclude the heavier clay soils.

Oombabeer Soil Management Unit

The Oombabeer Soil Management Unit at Jellinbah Plains comprises light yellowish brown to reddish black loamy sand to sandy loam A horizon of weak to moderate pedality overlying loamy sand to silty loam horizons.

This soil management unit covers approximately 25 ha of the proposed Mackenzie South area. It has been cleared of native vegetation for low intensity cattle grazing. Occurring on the upper ridges and steeper slopes of the proposed mining lease area, this soil type is found on gently to moderately inclined relief.

A loamy sand to sandy loam A horizon typifies this soil type. This horizon is generally light yellowish brown to reddish black in colour. The A horizon is of weak to moderate pedality. Underlying the A horizon is a horizon of slightly higher clay content (loamy sand to silty loam). The underlying horizon is also darker in colour and is only weakly pedal or apedal (granular) in structure. The boundary between these horizons is abrupt.

These soils are slightly alkaline in the A horizon, with alkalinity increasing with depth. These soils are slightly to moderately sodic in the surface horizon with exchangeable sodium percent generally increasing with depth. Excessive salinity does not occur in these soils. This soil constitutes the Oombabeer soil management unit.

Topsoil stripping is recommended to a depth of approximately 30 cm to exclude the darker higher clay content subsoil.

2.3 MACKENZIE NORTH

Soil management units within the Mackenzie North area have been described and mapped based on the findings of the *Mackenzie North – Soil and Land Suitability Assessment* (AARC 2013). Two soil management units were delineated over the Mackenzie North area:

Emerald Hardsetting, pedal grey, brown, black Vertosols and Dermosols on active levees, flats and scroll plains adjacent to floodplain channels.

Ruby Self-mulching clay alluvial black / brown Vertosols on level clay plains and low lying black plains.

The locations and extent of each soil type at Mackenzie North are shown in Figure 3. The two soil types are described below.

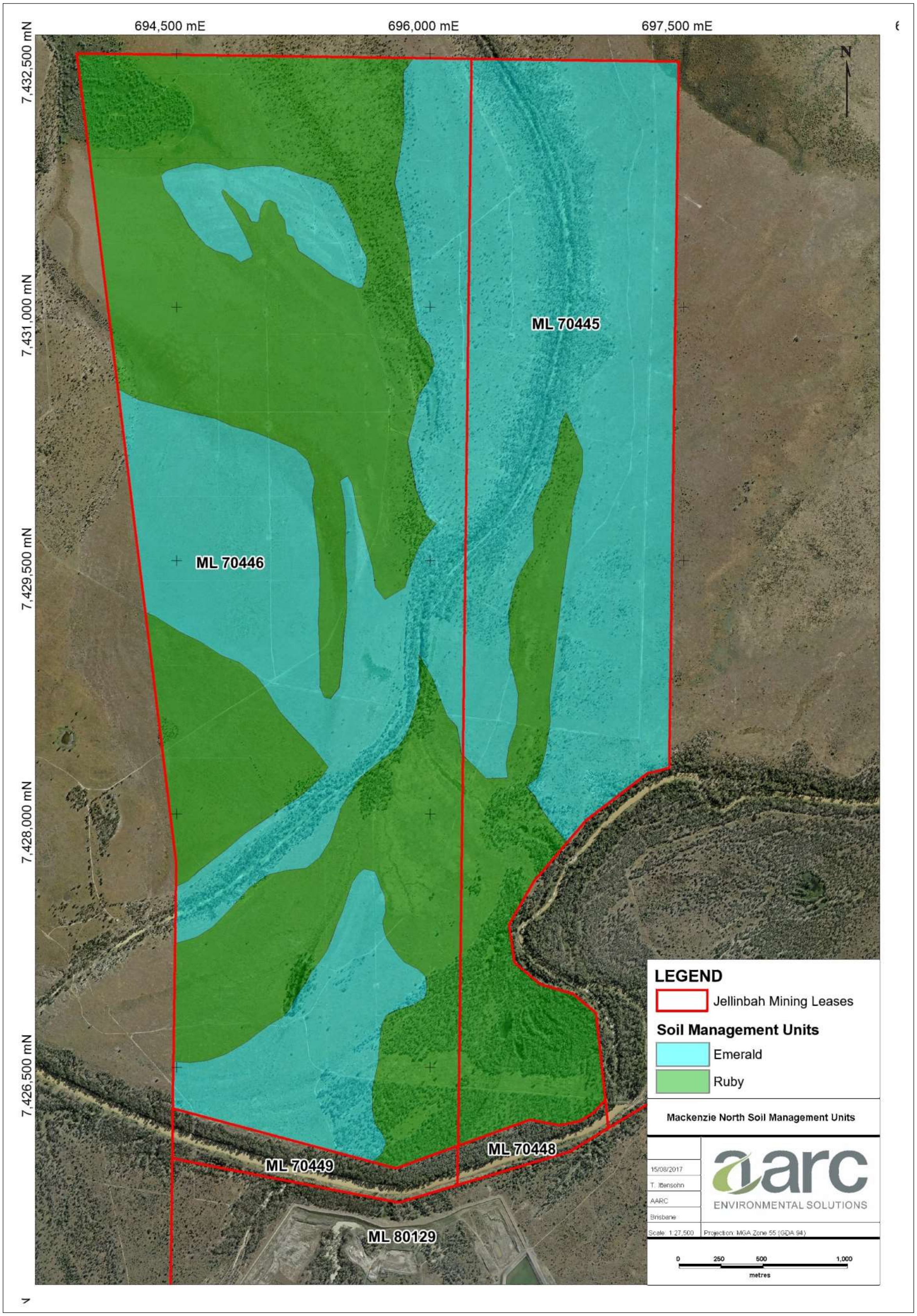

Figure 3 Mackenzie North Soil Management Units

Ruby Soil Management Unit

The Ruby Soil Management Unit consists of self-mulching and cracking brown or black non-rigid clay soils. These soils possess vertical properties with cracking surfaces, medium to heavy clay textures, slickensides and lenticular structure. These soils are derived from fine alluvial sediments developed from basaltic parent material. These soils are deep with many meters of sediment having been deposited over time. However, plant available water capacity (PAWC) and effective rooting depth (ERD) may be limited by subsoil constraints.

Useable soil resources are mainly confined to the surficial horizons and locally in the upper part of the subsurface horizons which contain seed-stock, micro-organisms and nutrients necessary for plant growth. The quality of topsoil resource and recommended stripping depths for Ruby soils is 400 mm.

Emerald Soil Management Unit

The Emerald Soil Management Unit consists of hardsetting, pedal, clay soils with occasional bleached surface horizons. These soils possess weakly structured or massive topsoils over moderately to strongly structured subsoils. These soils are differentiated from the Ruby soils by the absence of a self-mulching surface and by the coarser nature of the solum. Some of these soils exhibit vertic properties whilst others lack this feature. These soils are derived from a mixture of coarse and finely textured parent material inherited from sedimentary and basaltic lithologies. Hardsetting surface soil may restrict permeability and drainage, whilst subsoil constraints may affect the effective rooting depth and hence PAWC available to vegetation.

Useable soil resources are mainly confined to the surficial horizons and locally in the upper part of the subsurface horizons which contain seed-stock, micro-organisms and nutrients necessary for plant growth. The quality of topsoil resource and recommended stripping depths for Emerald soils is 400 mm.

3.0 TOPSOIL MANAGEMENT

The aim of the rehabilitation program at Jellinbah is to rehabilitate disturbed areas as soon as practicable. Topsoil will therefore be preferentially used by direct application in rehabilitation, where possible. Extensions to the mine pits provide greater opportunity to strip topsoil and apply it directly to re-contoured areas, thereby eliminating the need to stockpile the topsoil.

Topsoil that is stripped and directly placed in rehabilitation areas retains more viable seed stock, micro-organisms and nutrients than stockpiled soil. The direct application of topsoil improves the establishment of vegetation and the overall rehabilitation cost and success.

3.1 TOPSOIL STRIPPING

Topsoil stripping is to be conducted prior to the disturbance of land required for mining activities. The surface soils available on site and proposed for recovery are generally satisfactory for use as a plant growth medium, although some of the sandy surface horizons have low plant available water capacity and low fertility.

For each of the soil types identified on the Project site, the recommended depth to which topsoil should be stripped is provided in Table 2. The proposed stripping depth and the soil features distinguishing the suitable topsoil horizons from the underlying unsuitable horizons are summarised in Table 2.

Stockpiles should be placed away from drainage areas, roads, machinery, and stock grazing areas. If the period of stockpiling is greater than one growing season or six months, the stockpiles may need to be ripped and seeded to limit erosion, and maintain seed viability. It is recommended that topsoil stockpiles do not exceed 2 metres (m) in height.

Table 2 Depth of Topsoil Recovery for Rehabilitation at Jellinbah Coal Mine

Soil Management Unit	Stripping Depth (mm)	Distinguishing Features	
		Suitable Topsoil	Unsuitable or Subsoil Material
Jellinbah Central			
A	300	Red or brown light to medium heavy clay, non-saline, well-structured, no mottles.	Increasing mottles with hard coarse structure. Coarse concretions and minor gravels on top of B horizon.
B	200	Red brown sandy clay loam to yellow medium clay, weak, coarse structure, no mottles.	Hard, saline, mottled clay with coarse structure. Coarse concretions and minor gravels lie along top of B horizon.
C	0 – 100 (in melonhole) 150 (between melonholes)	Brown sandy clay loam, hard and massively structured.	Hard, coarse and saline clay.
Jellinbah Plains			
Dee	300	Grey to reddish brown self-mulching clays	Massive clay
Callide	300	Grey to dark reddish brown clay loam to light clay with occasional cracking	Darker medium to heavy clays

Soil Management Unit	Stripping Depth (mm)	Distinguishing Features	
		Suitable Topsoil	Unsuitable or Subsoil Material
Oombabeer	300	Light yellowish brown to reddish black, loamy sand to sandy loam	Darker loamy sand to silty loam (slightly higher clay content)
Mackenzie North			
Emerald	400	Grey, Brown or Black, hardsetting, pedal clay soil with occasional bleached surface horizon	Below 600mm, soil potentially contains higher salinity, sodicity and more alkaline pH
Ruby	400	Self-mulching and cracking brown or black non-rigid clay soil	Below 600mm, soil potentially contains higher salinity, sodicity and more alkaline pH

Source: AARC (2006); AARC (2013).

It should be noted that the accuracy of mapped soil units is limited by scale of the mapping. Recommended stripping depths should be cross checked against the physical appearance of the soil (as compared to Table 2) during stripping. Corrections to stripping height can be made where physical appearance of the soil differs to recommended stripping depths.

Subsoil materials on the Project are considered unsuitable for use as topsoil. However, subsoil materials may act as a supplementary, underlying growing and stabilising medium, minimising the volumes of topsoil required. Subsoils are to be stripped and stockpiled separately to topsoil materials. Subsoil material can be spread prior to the application of topsoil.

3.1.1 Topsoil Stripping Procedure

Topsoil should be stripped and handled in a manner that optimises the retention of soil characteristics favourable to plant growth and natural regeneration. The following topsoil stripping procedure is recommended.

- Existing vegetation is to be cleared prior to topsoil recovery. Cleared vegetation will be pushed first and windrowed alongside the area where topsoil will later be stockpiled. Smaller ground layer vegetation (e.g. grasses, herbs, forbs) may be recovered with the topsoil as a source of organic matter and plant propagules, unless the existing plant species are a potential weed problem.

- Appropriate equipment such as scrapers, graders or preferably dozers, should be used to recover topsoil. While scrapers are efficient and minimise the risk of stripping below the required depth, stockpiles may be degraded due to compaction. Topsoil should be transported to stockpile or rehabilitation areas using scrapers or rear dump trucks. Deep ripping may be required to maximise topsoil recovery in heavily compacted areas.

- Care should be taken at all times to avoid mixing topsoil with sodic subsoils. Topsoil stripping depth may change unexpectedly. Poorer quality underlying material such as subsoil clays or stone dominant material is to be avoided.

- Any machinery being introduced to site for topsoil stripping should be presented in a weed-free condition.

- Topsoil should be stripped in a progressive manner to reduce erosion and sediment generation, minimise the stockpile volumes and enable direct use in rehabilitation works.

- Where possible direct placement of topsoil onto rehabilitation areas is recommended. Otherwise topsoil should be stockpiled.

3.2 TOPSOIL STOCKPILING

Where it cannot be directly placed onto rehabilitation sites, topsoil should be stockpiled. This section outlines topsoil stockpile management measures which are designed to maintain the pre-disturbance condition of topsoils on the Project site.

3.2.1 Stockpile Location

Stockpile locations should be determined in accordance with the following management considerations:

- Grazing stock, machinery and vehicles should be excluded;

- Stockpiles should be located outside proposed mine disturbance areas;

- Overland water flow onto or across a stockpile site shall be kept to a minimum. Appropriated erosion and sediment control including runoff collection drains and dams should be constructed as required in accordance with the Erosion and Sediment Control Plan (ESCP) for the Project;

- Stockpiles should be located to maximise protection from prevailing winds and the threat of wind erosion. This may be achieved by locating stockpiles adjacent to cleared vegetation stockpiles and existing vegetation buffers; and

- To avoid erosion and sedimentation impacts on the receiving environment, stockpiles should not be located in the vicinity of natural watercourses or drainage lines.

3.2.2 Stockpile Design

Separate stockpiles should be formed for topsoil and subsoil, where both types of material are deemed suitable to be used in rehabilitation works. Stockpiles should be established in windrows with maximum flat surface area and a maximum height of 2 m. Restricting stockpiles to a height of 2 m will permit oxygen to diffuse through the topsoil stockpile, thereby maintaining the viability of the seed and microorganisms it contains.

Where topsoil stockpiles are to remain in place for an extended period due to operational requirements, vegetation growth will be encouraged. Topsoil stockpiles will be ripped, seeded and fertilised with pasture grass species. Revegetating stockpiles will facilitate water infiltration, maintain soil organic matter levels, maintain soil structure and microbial activity, minimise weed infestations and prevent erosion.

A seed mix for stabilising topsoil stockpiles includes:

1. Rhodes Grass (*Chloris gayana*),
2. Forest Bluegrass (*Bothriochloa decipiens*),
3. Queensland Blue Grass (*Dichanthium sericeum*),
4. Barb Wire Grass (*Cymbopogon refractus*),
5. Black Speargrass (*Heteropogon contortus)* and
6. Curly Windmill Grass (*Enteropogon acicularis*) and other species endemic to the area.

Varying rates will be applied depending on rehabilitation species sensitivity, growth media and post mining land use, but rates will range from 6.0 to 10.3 kg/ha. These should be used with other endemic species in the area.

Topsoil stockpiles should be clearly demarcated for easy identification and to avoid inadvertent losses or disturbance.

3.2.3 Stockpile Management

Topsoil stockpiles should be managed in accordance with the following recommendations:

- Topsoil should be stockpiled for a minimal length of time;
- Topsoil stockpiles should be clearly demarcated to avoid disturbance or removal;
- All long-term topsoil material stockpiles will be located outside the active mine path and away from drainage lines;
- Subsoils should be stockpiled separately if they are deemed suitable to be used as a base layer in rehabilitation works and appropriately demarcated;
- Stockpiles shall be constructed with suitable embankment grades to limit the potential for erosion of the outer pile face;
- The surface of any stockpiled soil dump that will not be used within three months will be allowed to revegetate with a suitable grass cover to prevent erosion, increase soil organic matter levels and to maintain soil structure and microbial activity;
- Stockpiles should be located outside proposed mine disturbance areas;
- Topsoil stockpile locations will be strategically located to assist the sequence of future rehabilitation.
- In accordance with the Project’s ESCP, stockpiles will have appropriate erosion and sediment control measures installed and will be located within the catchment of sediment control dams; and
- Develop and maintain a stockpile register or inventory; stockpile locations should be accurately surveyed and recorded along with details relating to soil type, date created and volume. Data should be stored in a database on site and updated as required. This register will enable site to determine what soils should be used first. This register can be found with the Technical Services department.

3.3 TOPSOIL APPLICATION

Topsoil application and rehabilitation will either occur progressively on disturbance areas or upon cessation of mining, depending on the mining requirements. Topsoil is to be applied once each section of spoil reaches final landform design (profiling of slopes) and suitable drainage works are completed. Ideally topsoil spreading should occur just prior to the wet season to encourage timely plant growth.

Where suitable material is available for a subsoil layer, subsoil will be placed and spread to a depth of 75 – 200 mm. Topsoil will then be placed and spread to a depth of 75 – 200 mm with greater depths applied in critical areas. The application of soils in rehabilitation should provide a minimum total thickness of 250 mm to provide sufficient depth for plant root establishment and re-ripping in the event that maintenance is required.

In order to minimise the loss of topsoil material available during placement and thereby maximise rehabilitation potential, the following application procedures / measures are recommended:

- Topsoil / subsoil should be placed by scraper or truck at the top of the profiled slope and pushed by dozer or grader to achieve the desired thickness. The equipment used should be mixing the topsoil/subsoil together to allow for seed mixing.

- Following final spreading of topsoil, the dump surface should be ripped (dozer or grader) to the depth of the topsoil to encourage infiltration of water required for plant growth.

- Seeding of topsoil should occur as soon as possible to encourage plant growth and prevent soil loss to erosion;

Monitoring of erosion should be undertaken in accordance with the Project's ESCP.

3.4 CURRENT TOPSOIL REQUIREMENTS & ESTIMATED AREAS

The Current topsoil requirements estimated in the Financial Assurance for rehabilitation purposes amount to approximately 4,135,447 m^3 (Table 3). The estimated surface area of topsoil stockpiles currently onsite is 151.91 ha (Table 4). Based on an average depth of 2 m, this equates to a total of 3,038,200m^3. In addition to this, topsoil will be progressively taken from the mining footprint as the final void is developed. When added to the current stockpile amount, this should ensure that adequate reserves are available to satisfy all final rehabilitation requirements.

Table 3 Jellinbah Topsoil Rehabilitation Requirements

Management Precinct	Predicted Rehabilitation Requirements (m^3)
Domain 1	304,026.3
Domain 2	34,960
Domain 3	2,277,000
Domain 4	46,100
Domain 5	1,399,800
Domain 7	71,961
Domain 9	1,600
Total	**4,135,447.3**

Table 4 Jellinbah Estimated Stockpile Reserves

Management Precinct	Estimated Area of Topsoil Stockpile (ha)	Estimated Volume of Topsoil (m^3)
ML 2418	8.37	167,400
ML 6992	15.92	318,400
ML 80140	57.67	1,153,400
ML 80184	8.36	167,200
ML 80068	10.50	210,000
ML 80129	30.63	612,600
ML 80018	3.13	62,600
ML 80053	11.41	228,200
ML 80108	2.64	52,800
ML 80165	3.28	65,600
Total	151.91	**3,038,200**

4.0 REFERENCES

AARC Environmental Solutions Pty Ltd (AARC) 2006, *Mackenzie South – Soil and Land Suitability Survey*, prepared for Jellinbah Resources Pty Ltd, March 2006.

AARC Environmental Solutions Pty Ltd (AARC) 2016, *Final Landform and Rehabilitation Management Plan*, prepared for Jellinbah Resources Pty Ltd, November 2016.

AARC Environmental Solutions Pty Ltd (AARC) 2013, *Mackenzie North – Soil and Land Suitability Assessment*, prepared for Jellinbah Group Pty Ltd, June 2013.

AARC Environmental Solutions Pty Ltd (AARC) 2016, *Jellinbah Coal Mine – Erosion and Sediment Control Plan*, prepared for Jellinbah Mining Pty Ltd, November 2016.

GT Environmental Services Ltd (GTES) 2012, *Jellinbah Coal Mine – Highwall Topsoil and Stockpile Assessment*, June 2012.

Ison Environmental Planners (Ison) 1989a, *Preliminary Environmental Report, Mining Lease Application 2866 – Clermont, Jellinbah East Project*, March 1989.

Ison Environmental Planners (Ison) 1989b, *Environmental Impact Assessment Study, Mining Lease Application 2866 – Clermont, Jellinbah East Project*, August 1989.

Ison Environmental Planners (Ison) 1992, *Environmental Impact Study, Mining Lease Application 6992, Jellinbah Central Project*, March 1992.

Ison Environmental Planners (Ison) 1993, *Soil and Land Capability Survey and Topsoil Evaluation, Jellinbah South Project, ML Extension*, January 1993.

Ison Environmental Planners (Ison) 1998a, *Soil and Land Capability Assessment, Jellinbah West Extension Project*, January 1998.

Ison Environmental Planners (Ison) 1998b, *Soil and Land Capability Assessment, Jellinbah Plains Extension Project*, June 1998.

Ison Environmental Planners 2005, *Assessment of Overburden Characteristics, especially Acid Drainage, Mackenzie South Project*, December 2005.

Ison Environmental Planners 2007, *Soil and Land Capability Assessment – Jellinbah Central East: MLA80140*, July 2007.

Shields, P.G. and Williams, B.M. 1991, *Land resource survey and evaluation of the Kilcummin area, Queensland*, Land Resource Bulletin QV91001, Queensland Department of Primary Industries, Brisbane.

AARC ENVIRONMENTAL SOLUTIONS

JELLINBAH COAL MINE
REHABILITATION & VOID INVESTIGATION REPORT

PREPARED FOR

JELLINBAH GROUP PTY LTD

NOVEMBER 2018

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Document History and Status

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Name of Project:	Jellinbah Coal Mine
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Opinions and judgments expressed herein, which are based on our understanding and interpretation of current regulatory standards, should not be construed as legal opinions. Information obtained from interviews and contained in the documentation has been assumed to be correct and complete. AARC Environmental Solutions Pty Ltd does not accept any liability for misrepresentation of information or for items not visible, accessible, nor able to be inspected at the sites at the time of the site visits.

JELLINBAH COAL MINE REHABILITAION & VOID INVESTIGATION REPORT

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AARC	AARC Environmental Solutions Pty Ltd
AGE	Australasian Groundwater and Environmental Consultants Pty Ltd
AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment and Conservation Council
CPP	Central Processing Plant
DES	Department of Environment and Science
EA	Environmental Authority
EC	Electrical Conductivity
EPP	*Environmental Protection (Water) Policy 2009*
ESD	Ecologically Sustainable Development
GAB	Great Artesian Basin
GL	Giga Litre(s)
JBT	JBT Consulting Ptd Ltd
km	kilometre(s)
km^2	square kilometre(s)
L/s	Litres per second
ML	Mining Lease
ML/Day	Mega Litres per Day
NAF	Non-Acid Forming (Waste)
NUMA	Non-Use Management Area
REMP	Receiving Environment Monitoring Program
RL	Relative Level
ROM	Run of Mine
µS/cm	microSiemens per centimetre

1.0 INTRODUCTION

AARC Environmental Solutions Pty Ltd (AARC) has prepared this Rehabilitation and Final Void Investigation Report for the Jellinbah Group Pty Ltd (Jellinbah). The report has been prepared in accordance with the Jellinbah Mine Environmental Authority (EA), conditions G7 and G12.

> ***G7*** *Complete an investigation into the rehabilitation of disturbed areas and submit a report to the administering authority proposing acceptance criteria to meet the outcomes in tables G2, G3 and G4 by 31 September 2010.*
>
> ***G12*** *Complete an investigation into residual voids and submit a report to the administering authority proposing acceptance criteria to meet the outcomes in condition G10 and landform design criteria in Table G5 by 31 September 2010.*

This document compiles information from a range of sources including previous approval documents, monitoring reports and technical studies completed as part of Jellinbah Coal Mine's closure planning. This document has been updated to reflect current authorised mine plans and is intended to replace previous versions.

The scope of the Rehabilitation and Void Investigation Report includes:

- An investigation of rehabilitation of disturbed areas on the mining leases including;
    - A description of pre-mining land uses and Environmental Values;
    - A description of mine Domains at closure;
    - Definition of post mining land outcomes (land uses);
    - Determination of rehabilitation goals, objectives, indicators and acceptance criteria designed to achieve the rehabilitation design parameters detailed in the Jellinbah Mine EA and ultimate rehabilitation success.
- An investigation of residual voids defined in the Project EA including:
    - Planned residual void locations and boundaries;
    - A description of the residual void design parameters;
    - Assessment of residual void hydrology and hydrogeology;
    - Assessment of the long-term risk of environmental harm associated with final voids;

2.0 JELLINBAH MINE PROFILE

2.1 OPERATION NAME AND LOCATION

Operation Name: Jellinbah Coal Mine

Operation Location: The Jellinbah Coal Mine is located in the Bowen Basin in Central Queensland. The operational area of the existing mine is located approximately 24 kilometres (km) north-north-east of Blackwater and 190 km west of Rockhampton, within the Central Highlands and Isaac Regional Council areas (Figure 1).

2.2 THE ENVIRONMENTAL AUTHORITY

Environmental Authority (EA) Number:
EPML00516813

Relevant Mining Lease Numbers:
ML 2418, ML 6992, ML 80140, ML 80184, ML 80068, ML 80129, ML 80018, ML 80053, ML 80108, ML 80165, ML 70445, ML 70448, ML 70449, ML 70446, ML 700011, ML 700012 and ML 700013.

Environmental Authority Holder(s):

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Level 7 Comalco Place
12 Creek Street
BRISBANE CITY QLD 4000

Tremell Group Pty Ltd
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Marubeni Coal Pty Ltd
Level 7 Comalco Place
12 Creek Street
BRISBANE CITY QLD 4000

Sojitz Coal Resources Pty Ltd
Level 34 ANZ Centre
324 Queen Street
BRISBANE CITY QLD 4000

2.3 BACKGROUND

The Jellinbah Coal Mine commenced operations in March 1989 and is an open-cut coal operation, mining shallow, low stripping ratio coal reserves, with the mine predominantly producing pulverised coal injection and a minor amount of thermal coal, primarily for export.

Land underlying the Jellinbah Coal Mine MLs includes existing mining related disturbance and infrastructure at various stages of operation or rehabilitation. Associated disturbance includes: open cut pits, spoil dumps at various stages of rehabilitation, areas cleared of vegetation and/or topsoil, in-pit tailings disposal, ROM pads, CPP, workshops and laydown areas, roads and tracks, dams, administration area and buildings, levee banks, topsoil stockpiles, and other mine related disturbance.

The Project currently incorporated two active mining areas: Jellinbah Central, operated by Jellinbah Mining Pty Ltd, and Jellinbah Plains, a contractor-run operation. Jellinbah South is currently inactive and Mackenzie North is in the construction stage.

The mine is situated on the mining leases (MLs) depicted in Figure 2.

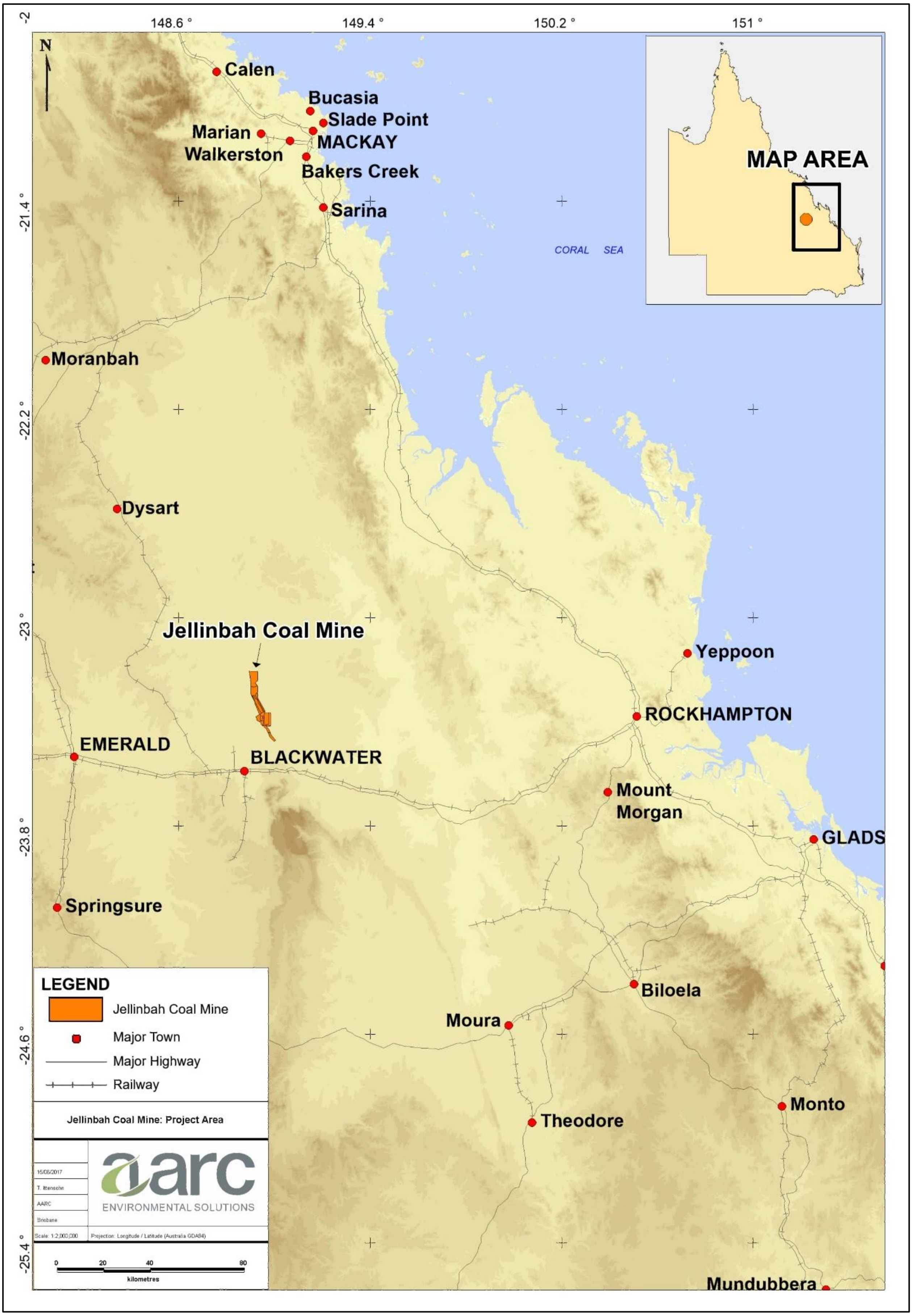

Figure 1 Project Locality

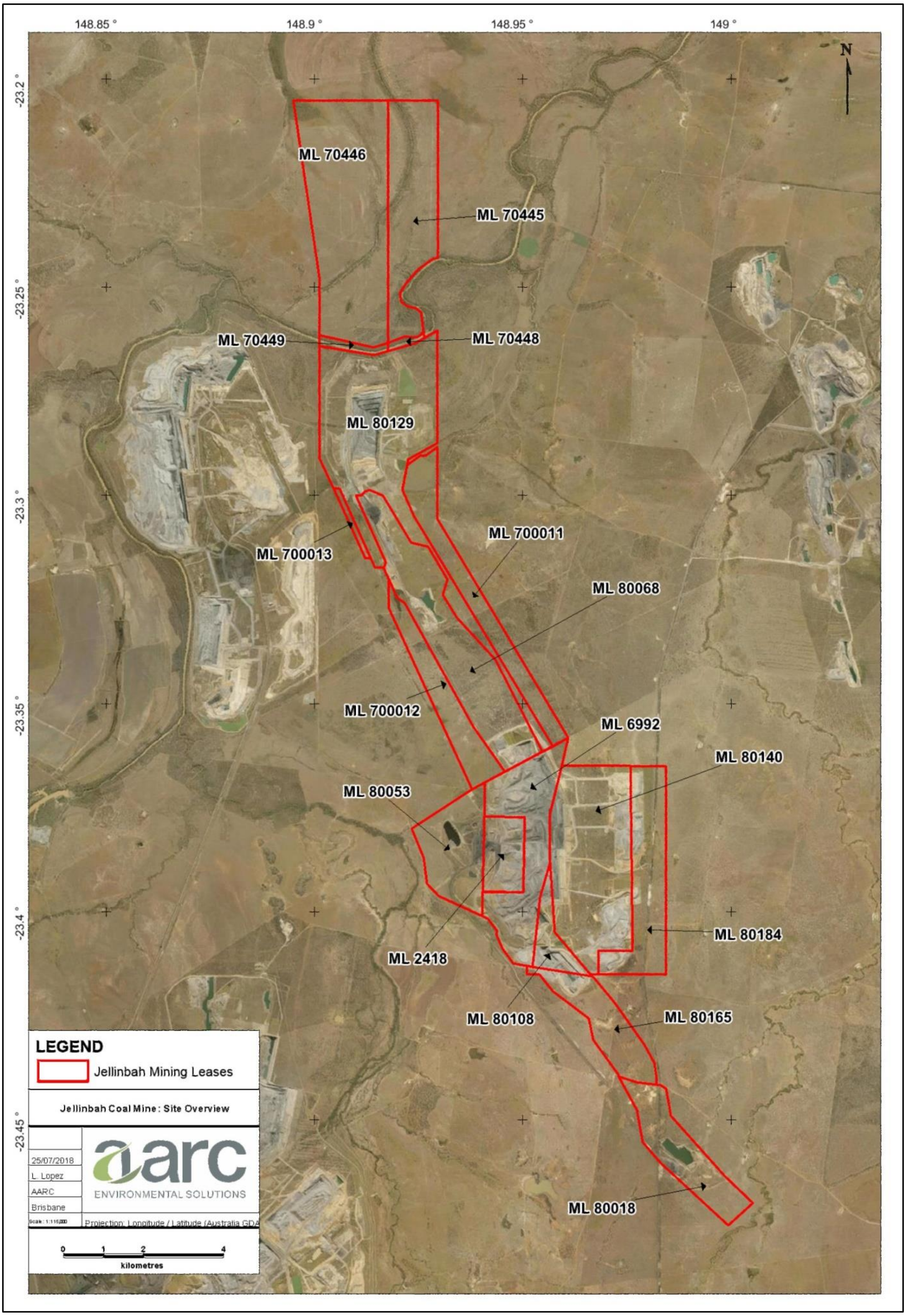

Figure 2 Jellinbah Mining Leases

3.0 PRE-MINING LAND USE & ENVIRONMENTAL VALUES

3.1 LAND

The existing mine is located approximately 24 km north-north-east of Blackwater and 190 km west of Rockhampton, within the Central Highlands and Isaac Regional Council areas.

The pre-mining land use of the site was cattle grazing on open pastures and woodlands.

As a basis for comparison with regional land systems, the pre-mining terrain within the Jellinbah area has been classified and described in terms of land systems. These land systems have been divided into six divisions based on physiographic and geomorphological attributes. These land systems are:

- Blackwater – Brigalow plains and cracking clay soils on weathered Tertiary clay and older rocks along the central axis of the area
- Highworth – Brigalow plains, commonly gilgaied, in the centre and north
- Humboldt – Blackbutt and brigalow on weathered clay plains occurring in most parts of the area; texture contrast and cracking clay soils
- Funnel – Flood plains with coolabah along major streams and in basalt areas; cracking clay soils
- Comet – Alluvial plains with brigalow and cracking clay soils, often flooded, along major streams
- Connors – Alluvial plains with box on texture-contrast soils throughout the area

Despite variation across the Project, soil types are primarily derived from three parent materials including (Ison 1998):

- Soils developed over Cainozoic unconsolidated materials of clay, silt and sand which overlie Permian sedimentary rocks;
- Soils developed directly over sedimentary rocks, mainly sandstone and siltstone of Permian and Tertiary age; and
- Soils developed in recent alluvium.

Generally, soils within the project area are structurally competent in their natural setting, such as strongly structured alluvial clays or soils of sandy texture on gentle slopes and are not considered at high risk of dispersion. A small proportion of the soils display characteristics identified as increasing the susceptibility of the soil to erosion and dispersion (high Exchangeable Sodium Percentage and low calcium to magnesium ratio).

3.2 GEOLOGY

The Project area falls within the central part of the Bowen Basin, which is predominantly known for its Permian-aged coal reserves. Locally, the Project area is situated at the north-western end of the Jellinbah Zone, which trends in a north-westerly direction and is fault bound to the east by the Yarrabee Fault and to the west by the Jellinbah Fault.

The stratigraphic units of Jellinbah include the Aries, Castor and Pollux (Upper and Lower) coal seams within the Rangal Coal Measures. Underlying the Rangal Coal Measures is the Burngrove Formation.

Overburden consists of weathered and unweathered Permo-Triassic sediments such as the Rewan Group.

Surface geology of the Jellinbah Project region incorporates areas of Tertiary, Quaternary and Holocene formations overlaying the Permo-Triassic Bowen Basin sediments. Recent (Holocene) alluvium is associated with the Mackenzie River.

3.3 GEOCHEMISTRY

The majority of the waste rock (spoil) at Jellinbah Mine is placed in mined-out pits following the extraction of coal; however, external spoil areas will be required to contain the spoil unable to be dumped in-pit.

Geochemical testing indicates that overburden/interburden materials across the site are generally non-acid forming (NAF) and have very low acid producing potential. Acid mine drainage or low pH has not been an issue at Jellinbah or at projects in similar geological sequences. The overburden/interburden materials at Jellinbah have a very high acid neutralising capacity, as such all water samples collected from Jelinbah have generally been alkaline (pH > 7.0) with no evidence of low pH of acid mine drainage.

The bulk of the spoil is typically comprised of clays and sands above siltstones and mudstones. Weathered overburden / interburden materials may be partly sodic and subject to surface crusting and high erosion rates if exposed directly to rainfall. Fresh overburden and interburden is typically sodic but non-dispersive. However, this fresh material has potential to become dispersive when under certain weathering conditions after mining.

3.4 WATER

The Jellinbah Coal Mine is located within the Mackenzie River catchment, which encompasses an area of 12,985 square kilometres (km^2) within the Fitzroy Basin. Water resource development has occurred along the Mackenzie River; with the significant water retaining structures being Bedford, Bingegang and Tartrus Weirs.

Under the *Environmental Protection (Water) Policy 2009* (EPP (Water)), environmental values are described for the Mackenzie River Sub-basin area in the *Mackenzie River Sub-basin Environmental Values and Water Quality Objectives* document (DES 2011). Environmental values ascribed to developed areas of the Mackenzie River main channel and tributaries to the north-west and south of the Mackenzie River Sub-basin are:

- Protection of aquatic ecosystems;
- Suitability for irrigation;
- Suitability for farm supply and use;
- Suitability for stock water;
- Suitability for aquaculture;
- Suitability for human consumption of aquatic foods;
- Suitability for primary contact recreation;
- Suitability for secondary contact recreation;
- Suitability for visual recreation;

- Suitability for drinking water supply;
- Suitability for industrial use; and
- Protection of cultural and/or spiritual values.

The immediate receiving environment of the Jellinbah Mine is the Mackenzie River to the north and Blackwater Creek to the west. The waters are classed as slightly to moderately disturbed with existing impacts from upstream land uses such as broad-scale agriculture, cattle grazing and other mining and resource developments. For example, the Curragh North Mine is located upstream of the Jellinbah Mine and shares the same receiving environment (i.e. The Mackenzie River and Blackwater Creek).

Suitability for stock water, irrigation and aquatic ecosystems are considered to be the directly applicable environmental values for surface water in the immediate receiving environment of the mine. Bingegang Weir is located 30 km downstream of Jellinbah Mine, however it was deemed to be outside the immediate receiving environment, and thus impacts to environmental values such as suitability for drinking water supply are not a significant risk.

Local Drainage Networks

The southern portion of the Project (Jellinbah South) drains directly eastward into the ephemeral Twelve Mile Creek, before discharging into the Mackenzie River 60 km downstream of the Jellinbah site (downstream of Bingegang Weir). Twelve Mile Creek also flows through the centre of the neighbouring Yarrabee Coal Mine approximately 20km downstream of Jellinbah South.

The central portion of the Project (Jellinbah Central) drains westward into the ephemeral Blackwater Creek, before discharging into the Mackenzie River 10 km north-west of Jellinbah Central (Upstream of MP4). Blackwater Creek passes to the south of the neighbouring Curragh North Coal Mine; however, the waterway does cross beneath a coal transfer conveyor connecting Curragh North to the Curragh Coal Mine 15 km south.

The area between the central and northern portions of the project drains to 3 Mile Lagoon to the north-west and 5 Mile Lagoon to the north-east of the site. 5 Mile Lagoon empties into an unnamed drainage feature which flows into the Mackenzie River approximately 2km downstream of MP5.

The northernmost portions of the Project (Jellinbah Plains and Mackenzie North) drain into the Mackenzie River, which joins the Fitzroy River approximately 220 km downstream of the mine. The total catchment area of the Mackenzie River to the Bingegang Weir is approximately 50,960 km^2.

Three and five mile lagoons are located to the east and west of the Plains operating area and were linked by a local drainage feature in the pre-mining landscape. These lagoons provided shade and watering points for livestock and native fauna habitat.

3.5 GROUNDWATER

Geological and hydrogeological units within the Project area include:

- Quaternary alluvial aquifers;
- Tertiary sedimentary units;
- Triassic sedimentary units; and
- Permian sedimentary units.

Quaternary Alluvium

The Quaternary alluvium associated with the Mackenzie River is of limited lateral extent, is localised within the reaches of the River and its associated floodplains and has an average depth of 20m. It forms an unconfined aquifer system consisting of a basal, fine to coarse grained sand and gravel layer, overlain by siltier and more clayey material. The basal sands and gravels are predominantly dry across the project site, however they thicken and become saturated along the alignment of the Mackenzie River. The alluvial groundwater system produces water of relatively low salinity and ion concentration. It would be suitable for use as stock water and in some cases potentially domestic use. However, the alluvium is considered a poor aquifer, as the long-term yield is too low to constitute a viable long-term water supply. This is supported by the lack of farm bores in the alluvium.

Tertiary Sediments

The Tertiary sediments have been completely eroded by the anastomosing channel of the Mackenzie River within the floodplain, and only occur to the south of the Mackenzie River where they are associated with a north-east trending ridge on which the Jellinbah Plains Mine is located. The Tertiary deposits are either remnant channel (fluvial) or valley fill (colluvial) material which is partially cemented. The sediments consist predominantly of multi-coloured iron oxide stained clays with some nodular ironstones. The tertiary sediments are generally dry within the Project site and lie unconformably over the Permian strata.

Triassic Sediments

The Rewan Formation occurs along the eastern margin of the Project site and to the east of the Project site as a discrete lens that is fault-bound to the east by the Yarrabee Fault. The Rewan Group forms the recognised basal confining unit of the hydrogeological Great Artesian Basin (GAB) and is normally conceptualised as being a regional aquitard. The Rewan Formation consists predominantly of green-grey claystone, siltstone and sandstone with a minor pebbly conglomerate unit at its base. The unit is known to contain structures or sandstone lenses that are capable of providing locally useable volumes of water for stock supply. However, in the surrounding region, the small number of bores constructed within Rewan Formation sediments are generally high in salinity (median 20,000 µS/cm) and are unsuitable for stock use. Likewise, observations from drilling at the Project site, support a conceptualisation of the Rewan Formation being dry and of low permeability. It is concluded that Triassic sediments do not form significant regional groundwater units and are unimportant as a potential source of groundwater.

Permian Sediments

The target coal seams for mining at Jellinbah are contained within the Permian-age Rangal Coal Measures. The coal measure consists of interbedded siltstone, sandstone, conglomerate, shale, tuff and coal. The two persistent coal horizons within the coal measures include the Pollux Upper and Pollux Lower Seams, which are 8.5 – 9.5 m thick. Within the Bowen Basin it is generally accepted that the coal seams are more permeable relative to the Permian overburden and interburden material. Bores are often drilled dry until a water-bearing coal seam is encountered, with water rising up the borehole indicating confined conditions within the coal seam. Due to the low permeability of the coal measures, groundwater residence time is often long, resulting in occurrences of highly saline (EC >30,000 µS/cm), poor quality groundwater in some areas. Recharge rates for the aquifers within the Permian sediments and coal seams is very low at only 0.7 mm/year (0.12% of rainfall). Likewise, groundwater yield within the Permian sediments and coal measures is low based off site observations and regional groundwater bore data.

3.6 ECOLOGICAL VALUES

The Jellinbah Mine is located in the Isaac – Comet Downs Sub-Bioregion within the broader Brigalow Belt Bioregion.

The vast majority of the ML areas were cleared for grazing land use before commencement of mining. Remnant vegetation typically remains in linear formations fringing watercourses and roads, or in isolated patches of limited connectivity and habitat value. There remains 10 distinct remnant vegetation communities occurring within the Jellinbah area.

- Brigalow Woodland 1 – 11.3.1, *Acacia harpophylla* and/or *Casurina cristata* open forest on alluvial plains.
- Poplar Box Woodland – 11.3.2, *Eucalytpus populnea* open woodland on alluvial plains.
- Red Gum Riparian Woodland – 11.3.25, *Eucalyptus camaldulensis* woodland fringing drainage lines.
- Coolabah Grassy Woodland – 11.3.3, *Eucalyptus coolabah* open woodland on alluvial plains.
- Coolabah Palustrine Wetlands – 11.3.3c, *Eucalyptus coolabah* open woodland to woodland with a sedge or grass understory in back swamps and old channels.
- Dawson Gum Woodland – 11.4.8, *Eucalyptus cambageana* woodland to open forest with *Acacia harpophylla* on Cainozoic clay plains.
- Brigalow Palustrine Wetlands – 11.4.8a, Gilgai and small depressions on clay plains usually associated with *Acacia harpophylla*.
- Brigalow Woodland 2 – 11.4.9, *Acacia harpohylla* shrubby woodland with *Terminalia oblongata* on Cainozoic clay plains.
- Brigalow and Dawson Gum Open Forest – 11.4.9b, *Acacia harpophylla* and *Eucalyptus cambageana* open forest to woodland on Cainozoic clay plains.
- Narrow-leaved Ironbark Woodland – 11.5.2, *Eucalyptus crebra* on lower slopes of Cainozoic sand plains.

3.7 COMMUNITY

Human settlement is relatively sparse in the area surrounding the Jellinbah Mine. A number of homesteads are located on surrounding properties. The nearest township to the Jellinbah mining leases is Bluff, which is located 13 km to the south east. The town of Blackwater is the nearest commercial centre, which is located 15 km south west of the Jellinbah mining leases. Both towns have a long term association with both agriculture and the mining industry.

4.0 JELLINBAH MINE CLOSURE DOMAINS

Discrete aspects of mine disturbance with similar geophysical characteristic and management requirements, known as ‘domains’, have been identified within the Jellinbah mining leases:

- Infrastructure;
- Levee Banks;
- Haul Roads;
- Topsoil Stripped Areas;
- Spoil Areas (<10% Slope);
- Spoil Areas (>10% Slope);
- Dams;
- Final Voids;
- Topsoil Stockpiles;
- Anabranch Diversion; and
- Three to Five Mile Lagoon Drainage Line.

These domains are described in Table G2 of the Jellinbah Mine EA.

6.0 POST MINING LAND OUTCOMES

The post mining land uses for the Jellinbah Mine were developed primarily in consideration of:

- The pre-mining land use of low intensity cattle grazing;
- Stakeholder consultation during the relevant approval;
- Planning considerations, as defined in the relevant council Planning Schemes;
- Environmental considerations, specifically the need to prevent release of contaminants to the receiving surface waters or groundwater;
- Environmental values and physical considerations as they relate to the safe and stable nature of the final landform and the development of self-sustaining ecosystems required for successful rehabilitation;
- Economic considerations relating to the cost of recreating the final land uses and the likelihood of achieving rehabilitation success.

Post mining land uses for the Jellinbah Mine are defined in Schedule G – Table 2 of the mine's Environmental Authority (Table 1). The relevant approval processes included stakeholder consultation, as well as, opportunity for comment and objection.

Table 1 Approved Final Land Use (EA Schedule G – Table 2)

Disturbance Type	Projective Surface Area (ha)	Post Mining Land Description	Post Mining Land Use	Post Land Suitability Classification
Infrastructure	837	Endemic Pasture Species	Low Intensity Cattle Grazing	5
Levee Bank	86			5
Haul Roads	218			4
Topsoil Stripped	300			3
Spoil Areas (<10% Slope)	2300			4
Spoil Areas (>10% Slope)	2347	Endemic Pasture Species	Endemic Vegetation Community	5
Dams	50	Water Containment	Water Containment	5
	55	Pasture Species	Low Intensity Cattle Grazing	
Final Voids	744	Water Containment	Water Containment	5
Topsoil Stockpiles	78	Endemic Pasture Species with a native species over-storey	Corridor Conservation	5
Anabranch Diversion	140			
Three to Five Mile Lagoon Drainage Line	N/A			

Final voids are described as areas of the post mining landform that are below the natural ground level and will not be rehabilitated to achieve a post mining land use. These voids do not support a beneficial post mining land use, and as such the final voids have been designated as Non-Use Management Areas (NUMAs). Final voids at the Jellinbah Mine are described in detail in Section 8.0.

Approved final land uses for the Jellinbah Mine are depicted in Figure 3 and Figure 4.

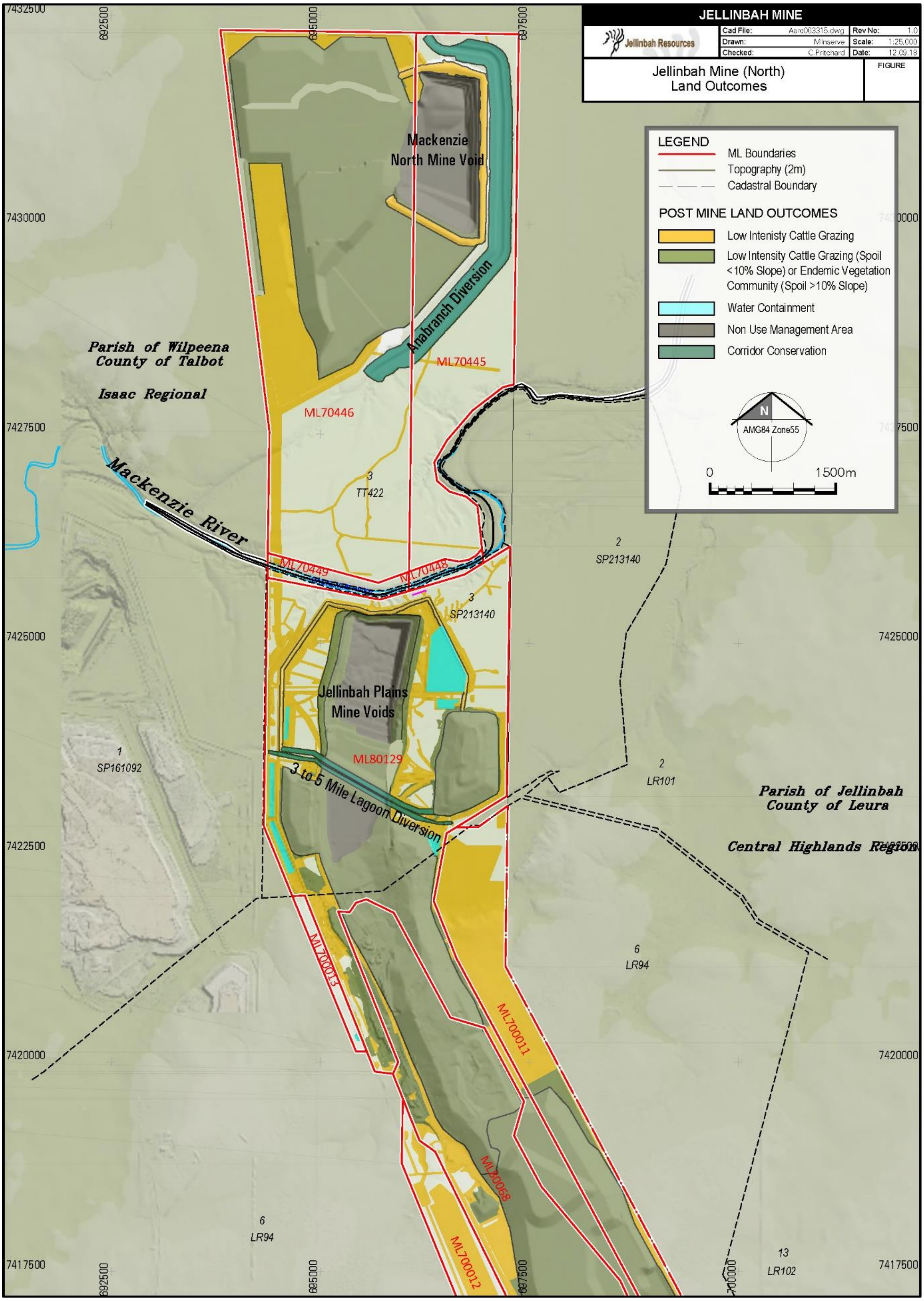

Figure 3 Jellinbah Post Mining Land Outcomes - North

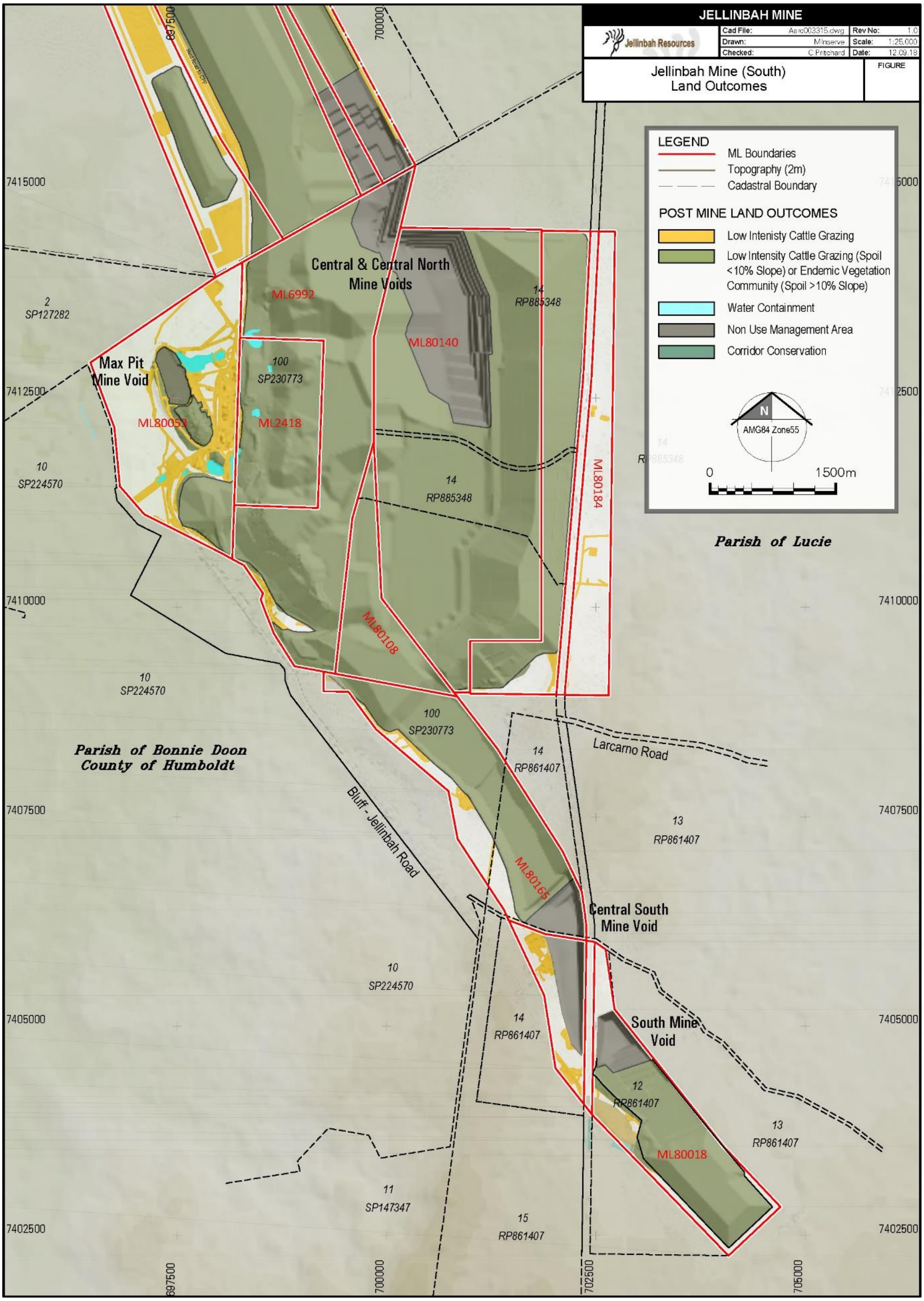

Figure 4 Jellinbah Post Mining Land Outcomes - South

7.0 CLOSURE GOALS, OBJECTIVES, INDICATORS AND ACCEPTANCE CRITERIA

7.1 REHABILTIATION GOALS

The closure goals associated with final land uses for the Jellinbah Mine include:

- Maintain a safe landform for humans and fauna;
- Stable;
- Non-polluting; and
- Sustainably support the identified post mining land use.

7.2 OBJECTIVES

Rehabilitation objectives have been developed for the Jellinbah Mine (see Table 2) to assist in achieving the Rehabilitation Goals. The Project's rehabilitation objectives incorporate the principles of Ecologically Sustainable Development (ESD).

The ESD principles for the mining sector include:

1) Ensure mine sites are rehabilitated to sound environmental and safety standards, and to a level at least consistent with the condition of surrounding land;
2) Provide appropriate community returns for using mineral resources and achieve better environmental protection and management in the mining sector; and
3) Improve community consultation and information, improve performance in occupational health and safety and achieve social equity objectives.

7.3 INIDICATORS & ACCEPTANCE CRITERIA

Rehabilitation indicators (see Table 2) are parameters that provide measures of progress towards domain rehabilitation objectives. In the case of the Jellinbah Mine, some indicators have been deemed relevant to a number of domains whilst other indicators have only a local significance to one domain.

Acceptance criteria (see Table 2) are the standards which provide a clear definition of successful rehabilitation for each domain. Acceptance criteria take the form of a set of measurable benchmarks against which the rehabilitation indicators can be compared, to determine if objectives are being met.

Evidence of the acceptance criteria having been addressed will be collected by Jellinbah to assist the administering authority to assess whether the criteria have been successful. If it has been deemed successful, then rehabilitation certification will be achieved. Final certification will be issued upon final rehabilitation having achieved the success criteria. The domains within the Project site are deemed to be successfully rehabilitated when completion criteria for each rehabilitation goal and objective have been met.

Table 2 Rehabilitation Goals, Objectives, Indicators and Completion Criteria Associated with Post Mine Land Uses

Domain	Mine Feature	Post-Mine Land Use	Rehabilitation Objective	Rehabilitation Indicator	Acceptance Criteria
Rehabilitation Goal: Safe Site					
Pit	Open-Cut Pit (Final Void)	Non-Use Management Area	Final pits and voids are safe for humans and animals now and in the foreseeable future	• Final landform survey • Safety assessment of final landform by an appropriately qualified person • Safety barriers and signage assessed against requirements of the *Mining and Quarrying Safety and Health Act 1999*	• Certification in rehabilitation report that ground is structurally sound and safe to people and animals. • Evidence in rehabilitation report that all safety precautions have been implemented in accordance with the relevant legislation. • Exclusion Fencing in place • Landform design is consistent with EA Table G5
Infrastructure	Buildings, Levee banks, haul road, topsoil stripped, roads & tracks	Low intensity Cattle Grazing	Infrastructure sites are safe for humans and animals now and in the foreseeable future	• Safety assessment of final landform by an appropriately qualified person • Contaminated Land assessment where notifiable activities have been carried out.	• Evidence in rehabilitation report that ground is structurally safe and sound. • Sign off by a suitably qualified person that the land is safe and non-toxic for humans and animals • Landform design is consistent with EA Table G3
Dams	Dams Retained & Rehabilitated	Retained or low intensity cattle grazing	Retained sediment dam sites are safe for humans now and in the	• Safety assessment of final landform by an appropriately qualified person	• Certification in rehabilitation report that ground is structurally sound and safe to people and animals. • Water quality complies with stock watering limits (ANZECC 2000 Guidelines)

Domain	Mine Feature	Post-Mine Land Use	Rehabilitation Objective	Rehabilitation Indicator	Acceptance Criteria
			foreseeable future	• Water quality testing; • Sediment / substrate testing; • Stable substrate for access.	• Sediments quality is consistent with surrounding land and does not contain toxic levels of contaminants.
Topsoil Stockpiles	Topsoil Stockpiles	Conservation corridor	Remaining topsoil stockpiles safe for humans and animals now and in the foreseeable future	• Safety assessment of final landform by an appropriately qualified person	• Evidence in rehabilitation report that ground is structurally safe and sound.
Spoil Areas	In-pit and out-of-pit dumps	Low intensity grazing (<10% slope) or Endemic vegetation community (>10% slope)	Overburden and waste sites are safe for humans and animals now and in the foreseeable future	• Final landform survey • Safety assessment of final landform by an appropriately qualified person • Erosion monitoring	• Evidence in rehabilitation report that ground is structurally safe and stable. • Erosion rates equivalent to surrounding land with no risk of major structural failures evident • Landform design is consistent with EA Table G3 & G4
Recreated Drainage Features	Three to five mile lagoon drainage line Anabranch diversion	Conservation corridor	Sites are safe for humans and animals now and in the foreseeable future	• Final landform survey • Safety assessment of final landform by an appropriately qualified person • Erosion monitoring	• Evidence in rehabilitation report that ground is structurally safe and stable. • Erosion rates equivalent to surrounding land with no risk of major structural failures evident

Domain	Mine Feature	Post-Mine Land Use	Rehabilitation Objective	Rehabilitation Indicator	Acceptance Criteria
Rehabilitation Goal: Non-Polluting					
Pit	Open-Cut Pit (Final Void)	Non-Use Management Area	Hazardous and contaminated material are adequately managed	• Monitoring targeting downstream surface water, groundwater and stream sediments • REMP	• Evidence in the rehabilitation report that receiving environment monitoring program indicates no evidence of contamination • Contaminated water must be contained within the final void areas.
			Polluted runoff and seepage are contained within void	• Monitoring targeting downstream surface water, groundwater and stream sediments • REMP	• Evidence in the rehabilitation report that receiving environment monitoring program indicates no evidence of contamination • Contaminated water must be contained within the final void areas.
Infrastructure	Buildings, Levee banks, haul road, topsoil stripped, roads & tracks	Low intensity Cattle Grazing	Hazardous and contaminated material are adequately managed	• Contaminated land assessment and site inspection • Rehabilitation monitoring plan in place to monitor downstream surface, groundwater and stream sediments	• Evidence of remediated landform in a contaminated land assessment report. • Evidence in the rehabilitation report that receiving environment monitoring program indicates no evidence of contamination.
			Polluted runoff and seepage are contained on site	• Monitoring targeting downstream surface water, groundwater and stream sediments • REMP	• Evidence in the rehabilitation report that receiving environment monitoring program indicates no evidence of contamination • Contaminated water must be contained within the final void areas.

Domain	Mine Feature	Post-Mine Land Use	Rehabilitation Objective	Rehabilitation Indicator	Acceptance Criteria
Dams	Dams Retained & Rehabilitated	Retained or low intensity cattle grazing	Sediment dams to remain on closure will not contribute contaminants to the environment	• Rehabilitation monitoring plan in place to monitor water in the dam and downstream surface/groundwater	• Evidence in the rehabilitation report that receiving environment monitoring program indicates no evidence of contamination
			Hazardous and contaminated material are adequately managed	• Contaminated land assessment and site inspection	• Evidence of remediated landform in a contaminated land assessment report.
Topsoil Stockpiles	Topsoil Stockpiles	Conservation corridor	Polluted runoff and seepage are contained on site	• Monitoring of surface and groundwater • Erosion monitoring	• Evidence in the rehabilitation report that receiving environment monitoring program indicates no evidence of contamination • Rates of erosion are consistent with the natural landscape
Spoil Areas	In-pit and out-of-pit dumps	Low intensity grazing (<10% slope) or	Polluted runoff and seepage are contained on site	• Monitoring of surface and groundwater • Erosion monitoring	• Evidence in the rehabilitation report that receiving environment monitoring program indicates no evidence of contamination

Domain	Mine Feature	Post-Mine Land Use	Rehabilitation Objective	Rehabilitation Indicator	Acceptance Criteria
		Endemic vegetation community (>10% slope)			• Rates of erosion are consistent with the natural landscape
			Hazardous and contaminated material are adequately managed	• Contaminated land assessment and site inspection	• Evidence of remediated landform in a contaminated land assessment report.
Recreated Drainage Features	Three to five mile lagoon drainage line Anabranch diversion	Conservation corridor	Polluted runoff and seepage are contained on site	• Monitoring of surface water and the receiving environment • Erosion monitoring	• Evidence in the rehabilitation report that receiving environment monitoring program indicates no evidence of contamination • Rates of erosion reflect natural drainage features
Rehabilitation Goal: Stable Landform					
Pit	Open-Cut Pit (Final Void)	Non-Use Management Area	Establish safe and stable waterbody with a low risk of environmental harm	• Monitoring of water level and quality in the residual void and surrounding aquifer	• Evidence in rehabilitation report that adequate water levels and quality are maintained in the residual void and surrounding aquifer.
			Landform design is stable	• Final survey • Engineer's assessment of factor of safety	• Engineer certification in rehabilitation report that the final void achieves suitable factor of safety for stability • Landform design is consistent with EA Table G5
Infrastructure	Buildings, Levee banks, haul road, topsoil stripped,	Low intensity Cattle Grazing	Landform design achieves appropriate erosion rates	• Erosion monitoring • Survey	• Rates of erosion are consistent with the natural landscape • Landform design is consistent with EA Table G3

Domain	Mine Feature	Post-Mine Land Use	Rehabilitation Objective	Rehabilitation Indicator	Acceptance Criteria
	roads & tracks		Adequate vegetation cover to minimise erosion	• Revegetation assessment	• Evidence in the rehabilitation report that the vegetation foliage cover meets the limits set by the analogue sites.
Dams	Dams Retained & Rehabilitated	Retained or low intensity cattle grazing	Establish safe and stable waterbody with a low risk of environmental harm	• Monitoring of water level and quality in the dam • Assessment by a suitably qualified expert	• Evidence in rehabilitation report that retained dams are stable and not a risk of failure
			Landform design achieves appropriate erosion rates	• Erosion monitoring	• Rates of erosion are consistent with the natural landscape
Topsoil Stockpiles	Topsoil Stockpiles	Conservation corridor	Landform design achieves appropriate erosion rates	• Erosion monitoring	• Rates of erosion are consistent with the natural landscape
			Adequate vegetation cover to minimise erosion	• Revegetation assessment	• Evidence in the rehabilitation report that the vegetation foliage cover meets the limits set by the analogue sites.
Spoil Areas	In-pit and out-of-pit dumps	Low intensity grazing (<10%	Very low probability of slope slippage	• Final survey of landform	• Evidence in rehabilitation report that an appropriate risk assessment has been undertaken and control

Domain	Mine Feature	Post-Mine Land Use	Rehabilitation Objective	Rehabilitation Indicator	Acceptance Criteria
		slope) or Endemic vegetation community (>10% slope)	with serious consequences	• Geotechnical, and hydrological studies of existing structures (outer batter slopes of dumps)	measures are in place that will continue to meet agreed requirements. • Landform design is consistent with EA Table G3 and G4.
			Landform design achieves appropriate erosion rates	• Erosion monitoring	• Rates of erosion are consistent with the natural landscape
			Adequate vegetation cover to minimise erosion	• Revegetation assessment	• Evidence in the rehabilitation report that the vegetation foliage cover meets the limits set by the analogue sites.
Recreated Drainage Features	Three to five mile lagoon drainage line Anabranch diversion	Conservation corridor	Landform design is stable	• Erosion monitoring • Stability monitoring • Survey	• Rates of erosion are consistent with the natural landscape • Engineers certification of design in the final rehabilitation report.
			Adequate vegetation cover to minimise erosion	• Revegetation assessment	• Evidence in the rehabilitation report that the vegetation foliage cover meets the limits set by the analogue sites.
Rehabilitation Goal: Sustains Agreed Land Use					
Pit	Open-Cut Pit (Final Void)	Non-Use Management Area	Establish final void as containment	N/A	N/A

Domain	Mine Feature	Post-Mine Land Use	Rehabilitation Objective	Rehabilitation Indicator	Acceptance Criteria
			for contaminated water		
Infrastructure	Buildings, Levee banks, haul road, topsoil stripped, roads & tracks	Low intensity Cattle Grazing	Soil properties that support and will continue to support desired land use	• Soil testing of chemical, physical and biological properties to ensure soil is able to support post-mining land use before placement	• Evidence in rehabilitation report that all soil chemical, physical and biological properties are within acceptable limits that ensure soil is able to support post-mining land use.
			Self-sustaining vegetation cover and species similar to adjoining undisturbed areas	Vegetation assessment to determine: • Presence of key species for land use • Species composition and structure; and • Abundance of weeds	• Certification within the rehabilitation report that key species are present, suitable diversity has been achieved and cover/density is adequate when compared to analogue sites. • Yield of pasture grasses consistent with land suitability class in EA Table G2; • Evidence that weed management has been successful.
Dams	Dams Retained & Rehabilitated	Retained or low intensity cattle grazing	Establish safe and stable water body with a low risk of environmental harm	• Water quality monitoring in retained dams	• Water quality is consistent with local farmer dams and below stock watering criteria (ANZECC 2000 Guidelines)

Domain	Mine Feature	Post-Mine Land Use	Rehabilitation Objective	Rehabilitation Indicator	Acceptance Criteria
			Self-sustaining vegetation cover and species similar to adjoining undisturbed areas	Vegetation assessment to determine: • Presence of key species for land use • Species composition and structure; and • Abundance of weeds	• Certification within the rehabilitation report that key species are present, suitable diversity has been achieved and cover/density is adequate when compared to analogue sites. • Yield of pasture grasses consistent with land suitability class in EA Table G2; • Evidence that weed management has been successful.
Topsoil Stockpiles	Topsoil Stockpiles	Conservation corridor	Soil properties that support and will continue to support desired land use	• Soil testing of chemical, physical and biological properties to ensure soil is able to support post-mining land use before placement	• Evidence in rehabilitation report that all soil chemical, physical, and biological properties are within acceptable limits that ensure soil is able to support post-mining land use.
			Self-sustaining vegetation cover and species similar to adjoining undisturbed areas	Vegetation assessment to determine: • Presence of key species for land use • Species composition and structure; and Abundance of weeds	• Certification within the rehabilitation report that key species are present, suitable diversity has been achieved and cover/density is adequate when compared to analogue sites. • Evidence that weed management has been successful.
Spoil Areas	In-pit and out-of-pit dumps	Low intensity grazing (<10% slope) or Endemic vegetation	Soil properties that support and will continue to support	• Soil testing of chemical, physical and biological properties to ensure soil is able to support post-mining	• Evidence in rehabilitation report that all soil chemical, physical, and biological properties are within acceptable limits that ensure soil is able to support post-mining land use.

Domain	Mine Feature	Post-Mine Land Use	Rehabilitation Objective	Rehabilitation Indicator	Acceptance Criteria
		community (>10% slope)	desired land use	land use before placement	
			Establish self-sustaining natural vegetation similar to adjoining undisturbed areas and consistent with post-mine land use.	Vegetation assessment to determine: • Presence of key species for land use • Species composition and structure; and • Abundance of weeds	• Certification within the rehabilitation report that key species are present, suitable diversity has been achieved and cover/density is adequate when compared to analogue sites. • Yield of pasture grasses consistent with land suitability class in EA Table G2 • Evidence that weed management has been successful.
Recreated Drainage Features	Three to five mile lagoon drainage line Anabranch diversion	Conservation corridor	Soil properties that support and will continue to support desired land use	• Soil testing of chemical, physical and biological properties to ensure soil is able to support post-mining land use before placement	Evidence in rehabilitation report that all soil chemical, physical, and biological properties are within acceptable limits that ensure soil is able to support post-mining land use.
			Establish self-sustaining natural vegetation similar to	Vegetation assessment to determine: • Presence of key species for land use	• Certification within the rehabilitation report that key species are present, suitable diversity has been achieved and cover/density is adequate when compared to analogue sites. • Evidence that weed management has been successful.

Domain	Mine Feature	Post-Mine Land Use	Rehabilitation Objective	Rehabilitation Indicator	Acceptance Criteria
			surrounding waterways	• Species composition and structure; and • Abundance of weeds	

8.0 RESIDUAL VOID STUDY

Residual voids are defined as areas of the post mining landform that are below the natural ground level and will not be rehabilitated to achieve a post mining land use.

Condition G10 of the Jellinbah Mine Environmental Authority, outlines the requirement for residual voids at Jellinbah Mine:

> *Residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater 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*

This residual void study assesses the potential for environmental harm to land or waters associated with the current Jellinbah closure plan and void design.

8.1 RESIDUAL VOID DESIGN

The location and boundary of final voids is depicted in the final landform plans presented in Figure 5 - Figure 9.

The final void design complies with Table G5 in the Jellinbah Mine EA. Table 3 below defines the residual void design parameters adopted in the final landform design. The Void ID column represents additional void areas incorporated into the authorised mine plan during past EA amendments. These void ID areas represent components of residual voids in the final mine plan, as described in Table 3.

Table 3 Residual Void Design Parameters

<table>
<tr><th>Void Name</th><th>Void ID (as per EA)</th><th>Void wall competent rock max slope (°)</th><th>Void wall incompetent rock max slope (°)</th><th colspan="2">Void maximum surface area (ha)</th></tr>
<tr><td>Mackenzie North Void</td><td>Mackenzie North</td><td>70°</td><td>45°</td><td>149</td><td>149</td></tr>
<tr><td rowspan="3">Plains Void (South & North)</td><td>Mackenzie South</td><td rowspan="3">70°</td><td rowspan="3">45°</td><td>30</td><td rowspan="3">147</td></tr>
<tr><td>Plains North</td><td>52</td></tr>
<tr><td>Plains South</td><td>65</td></tr>
<tr><td rowspan="4">Central Void</td><td>Central North Extension</td><td rowspan="4">70°</td><td rowspan="4">45°</td><td>95</td><td rowspan="4">330</td></tr>
<tr><td>Central North</td><td>140</td></tr>
<tr><td>Central</td><td>45</td></tr>
<tr><td>Central East</td><td>50</td></tr>
</table>

Central South Void	Central South	70°	45°	70	70
Jellinbah South	South	70°	45°	30	30
Max Pit	Max Void	70°	45°	18	18

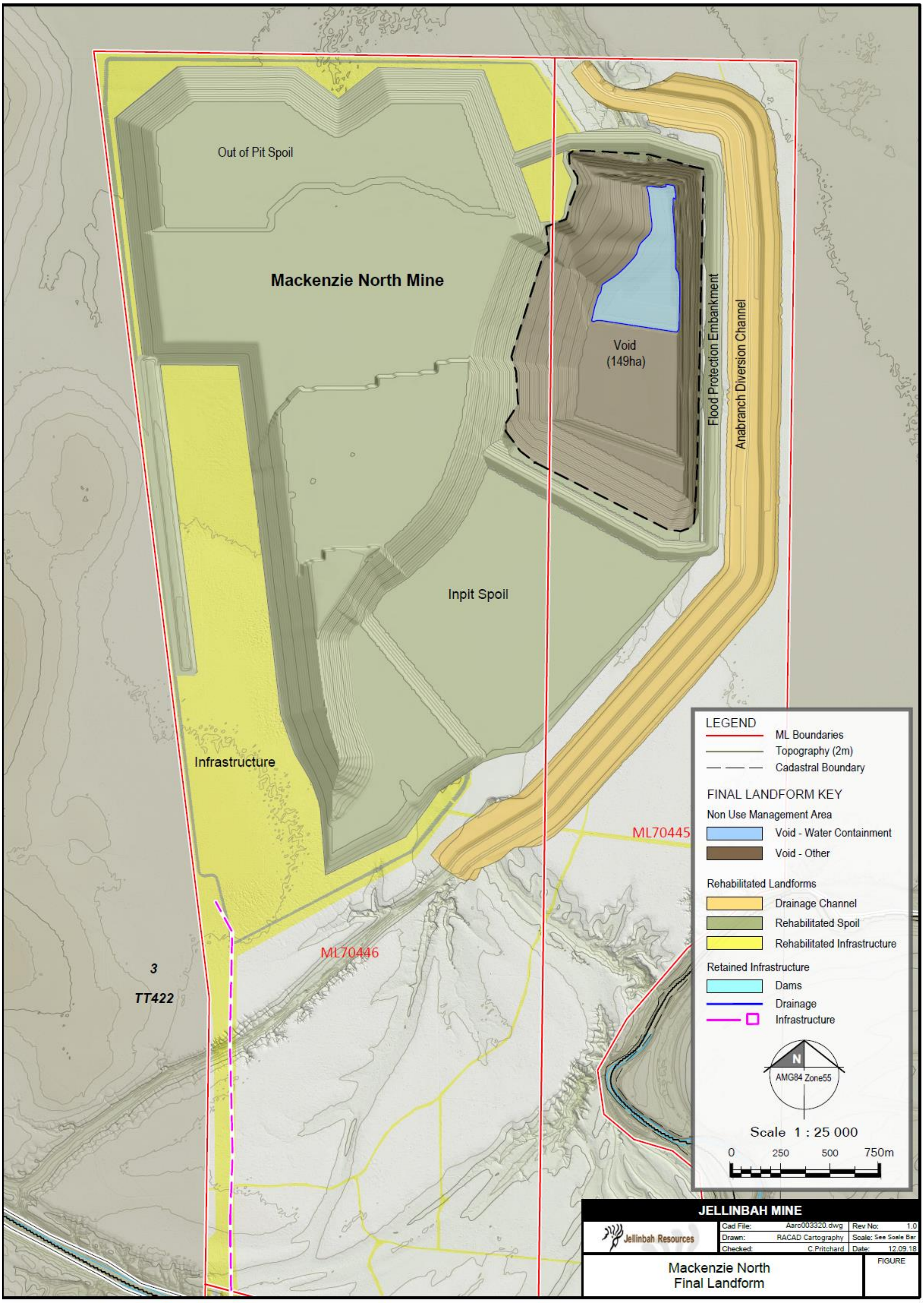

Figure 5 Final Landform Mackenzie North

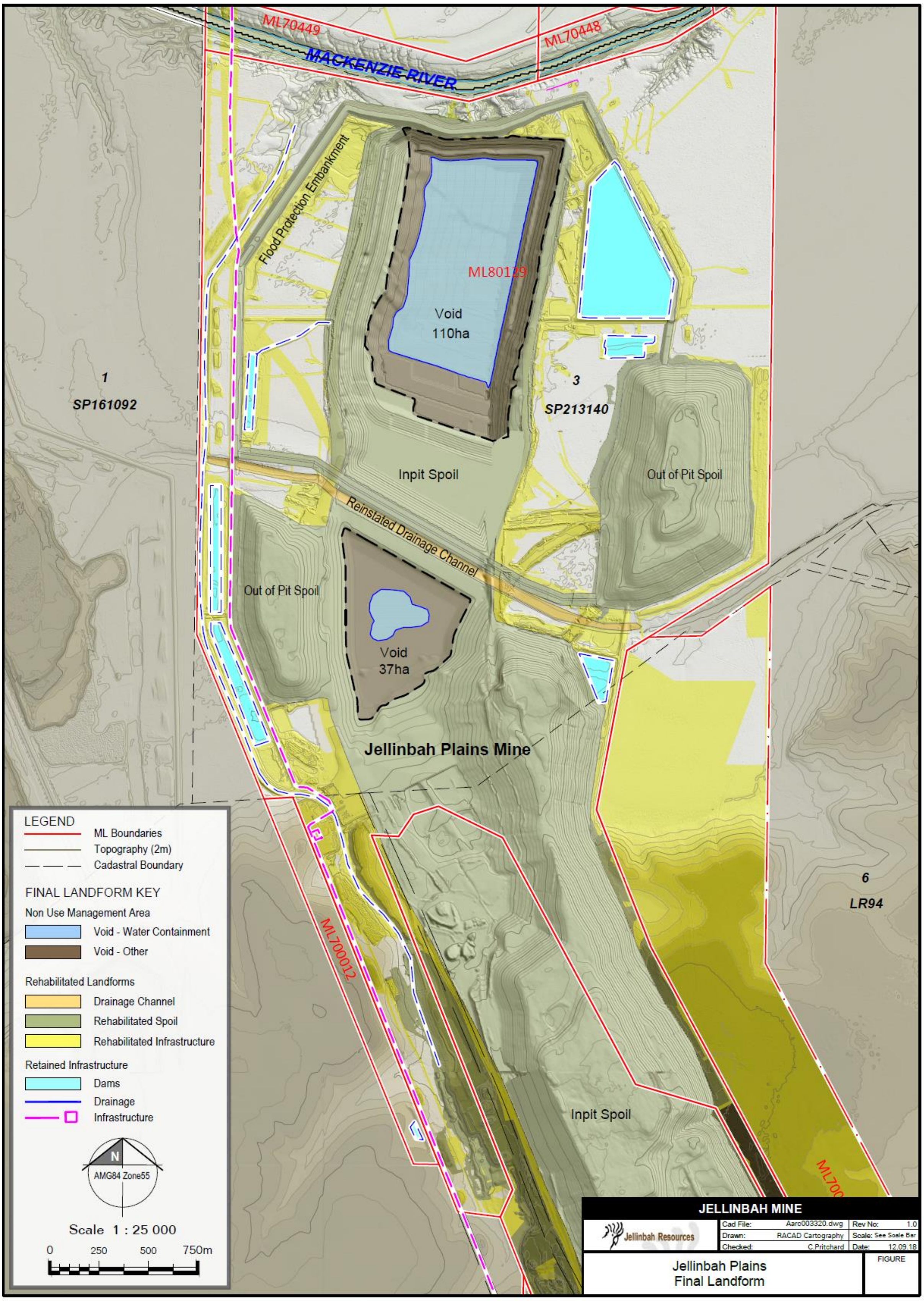

Figure 6 Final Landform Plains

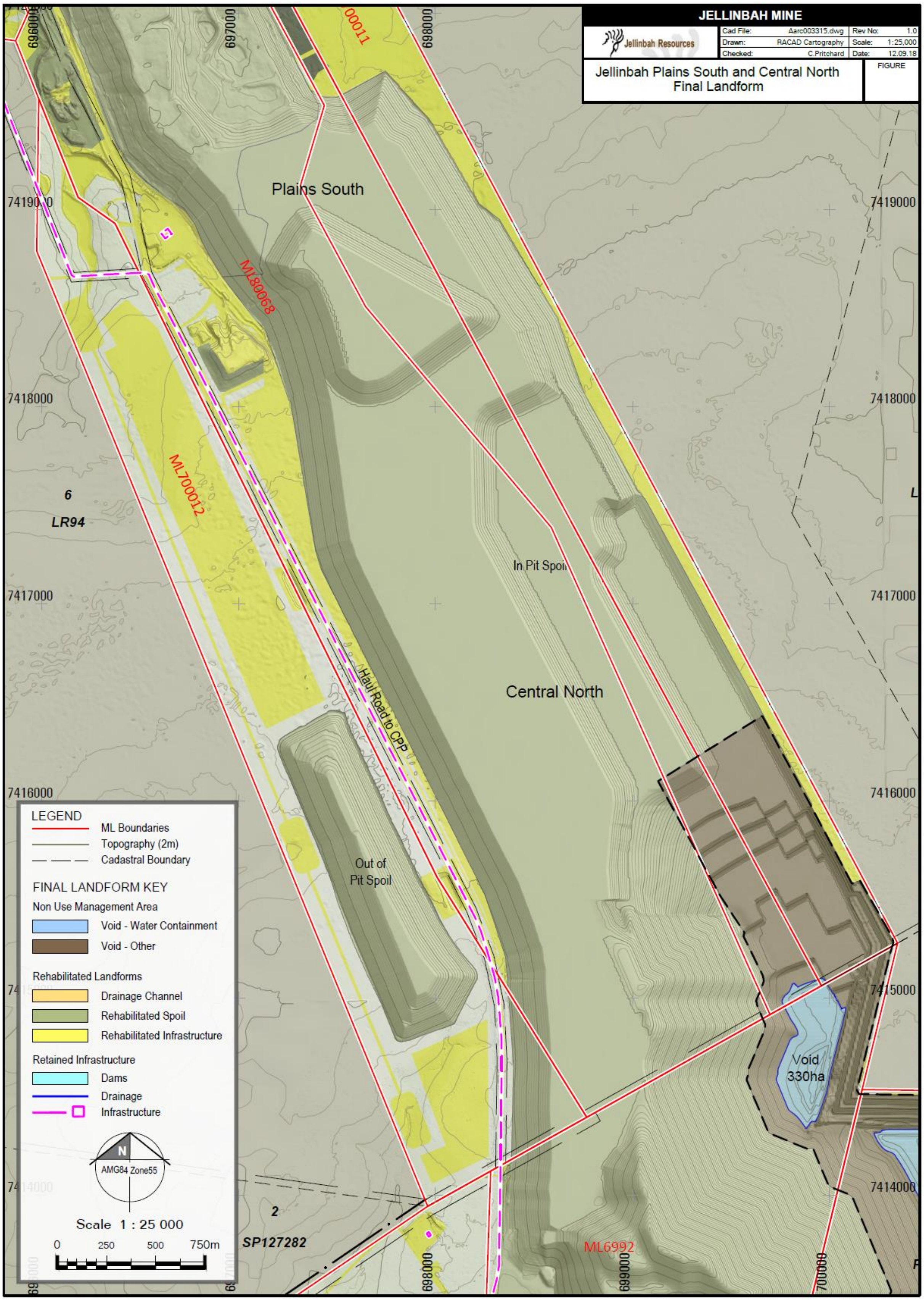

Figure 7 Final Landform Central North

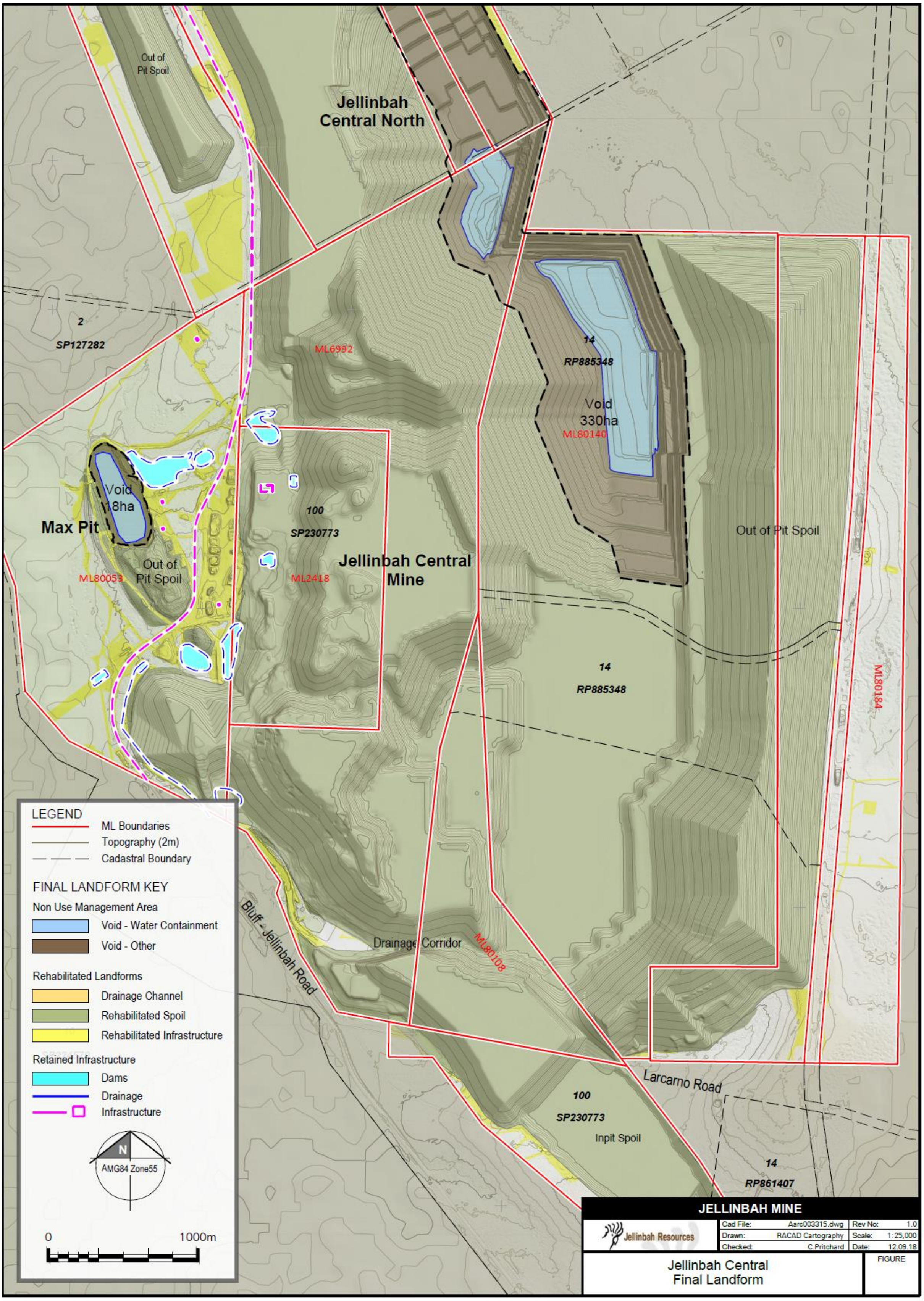

Figure 8 Final Landform Central

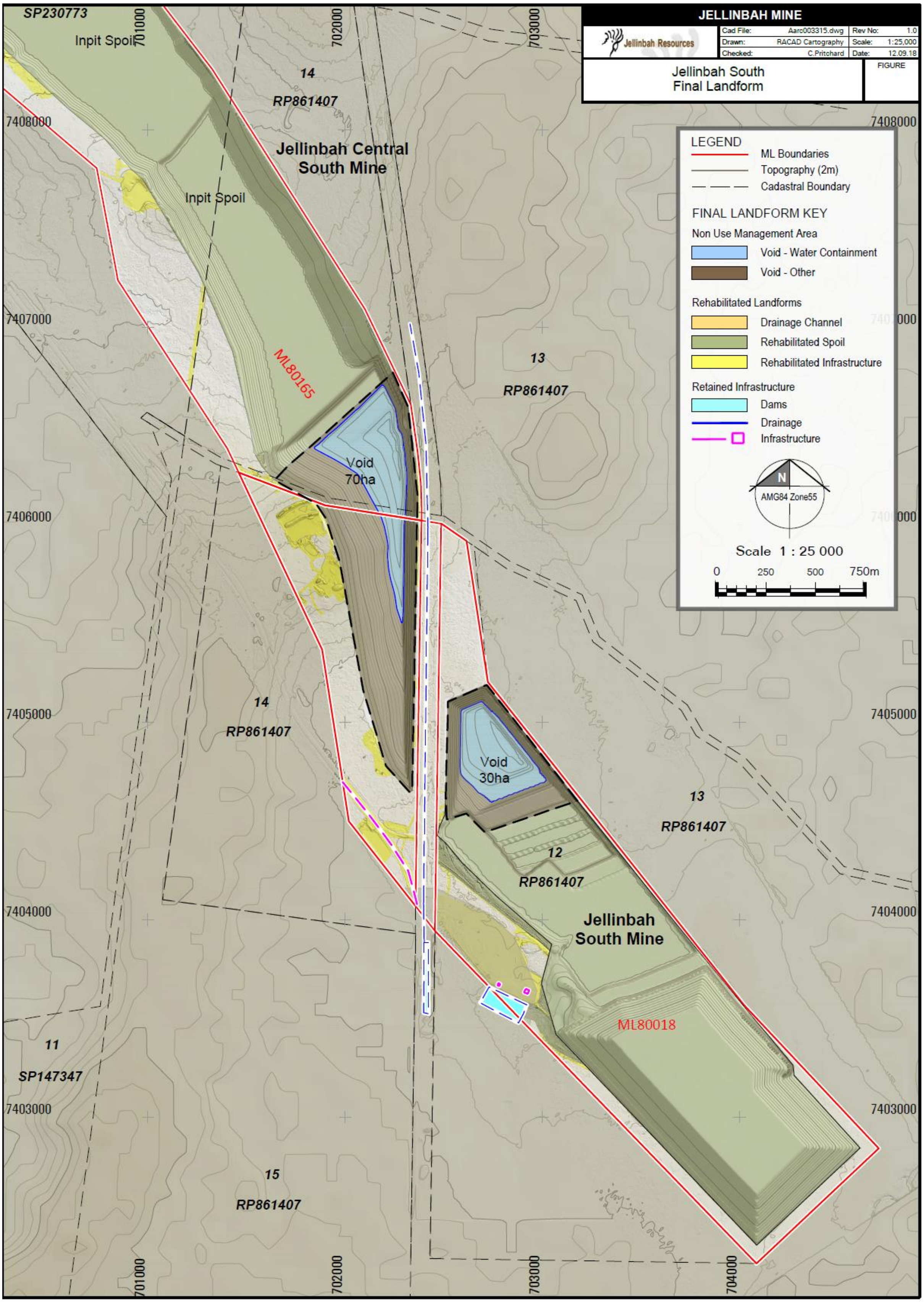

Figure 9 Final Landform South

8.2 RESIDUAL VOID HYDROGEOLOGY

A final void inflow assessment has been undertaken by JBT Consulting for each void, with the assumptions/ data sources for each void area discussed in Appendix A. The inflow rates presented in this report have been used for assessment of final void water balance modelling (undertaken by Engeny Water Management Pty Ltd).

8.2.1 Pit Inflows

Mackenzie North Void

The background and assumptions with respect to inflows to the final void at Mackenzie North are based on groundwater modelling undertaken by AGE and reported in AGE (2013). Observations and assumptions from AGE (2013) are as follows:

- The Mackenzie River alluvium in the area of the mine is currently dry and the only areas where alluvium is saturated are located to the south (towards the Mackenzie River) where base of alluvium occurs at a lower RL than the base of alluvium in the mining area (i.e. the RL of the water surface in the alluvium to the south is below the base of alluvium in the mining area);

- Groundwater that flows from the alluvium to the mining pit is derived from downward/lateral seepage as the underlying Permian sediments are depressurised, rather than direct inflow from the alluvium adjacent to the pit (which, as stated above, tends to be dry)

- The majority of groundwater inflow occurs during the active phase of mine life (peaking at year 15), reducing to less than 0.1 ML/day (<1 L/s) towards the end of mine life and post-mining.

- It was noted in AGE (2013) that the predicted inflow rates do not take into account evaporation, therefore the net rate of inflow was predicted to be close to zero (i.e. the rate of evaporation is higher than the rate of inflow, resulting in a generally dry pit).

Based on the above assumptions, a long-term inflow rate of 1 L/s (0.1 ML/day) is therefore assumed for the purpose of final void modelling.

Plains Void (North)

In order to provide an estimate of long-term groundwater inflow rates to the Plains final void, a simple 2-dimensional cross section model was developed using the program Seep/W. Inflow rates from the model, which are calculated per metre width of pit face, were multiplied by the pit perimeter to obtain an estimate of pit inflow rates over time.

The model shows that pit inflow rates reduce from 5.9 ML/day (for the current time, with results consistent with observed groundwater inflow rates) to approximately 1.2 ML/day after 100 years (this inflow rate is taken as the steady-state inflow rate from the alluvium to the Plains Void).

Central Void and Central Void (North)

There is no alluvium at the Central Void /Central Void (North) area and the Tertiary sediments have been assessed to be dry (JBT 2006), therefore only inflow from the Permian coal measures is considered. Assumptions for inflow calculations include:

- Groundwater flow within the Permian coal measures will occur mainly via the Pollux seam, and it is assumed that there will be no flow, or minimal flow, from the interburden (AGE 2006)

- The hydraulic conductivity of the Pollux seam is assumed to be 0.1 m/day (AGE 2006)
- The average thickness of the Pollux seam is 9 m (AGE 2016);
- The deepest area of the final void and Central void is ~RL-60)
- The average depth to water in the Central/Central North area is ~40 m, for an average RL of ~ RL 90
- The dimensions of the final void through which inflow will occur are approximately 2,300 m x 600 m

Based on a review of the extent of drawdown from the central pit (JBT 2006) the extent of drawdown is assumed to be 1,500 m.

Based on the above assumptions, the steady-state inflow rate is calculated analytically (via Darcy's law) to be 300 m^3/day (3.4 L/s, 0.3 ML/day)

Observations from site (JBT 2006) are that the Central pit is generally dry. The steady-state inflow rates that are calculated above do not take into account evaporation. With evaporation applied, the net inflow would be closer to zero and account for the observation of dry pits (i.e. some groundwater inflow to the pits does occur, but at a rate that is below the rate of evaporation leading to the observation of dry pits).

Central South Void and Jellinbah South Void

Central South and South voids will be shallow relative to other voids (base of void of RL 74.4 and 54.8 mAHD respectively – refer Appendix A). Observations from site are that both pits are dry, which is to say that the rate of groundwater inflow is less than the rate of evaporation leading to the observation of dry pits. For the purpose of final void modelling, an assumption of 1.5 L/s (0.13 ML/day) has been made for the rate of groundwater inflow to each pit.

Max Pit Void and Plains Void (South)

Max Pit and Plains Void (south) will be shallow relative to other voids (base of void of RL 122.7 and 113.9 mAHD respectively – Appendix A. For the purpose of final void modelling it is assumed that the rate of groundwater inflow to each void is zero.

8.3 RESIDUAL VOID HYDROLOGY

Engeny have been engaged to review the current proposed final landform designs through the development of long-term water balance model simulations for void quantity and quality (Appendix B).

The key objectives of the Jellinbah Mine final void hydrology assessment are:

- Review final void landform designs and develop final drainage catchments;
- Identify changes to storage volumes and water quality over time, and predicted equilibrium status. Quantify overflow probability and filling times;
- Recommend final landform drainage diversions to manage void catchments and

- Assess long-term groundwater interactions and potential for seepage to alluvial aquifers, based on inputs from JBT Consulting.

8.3.1 Drainage Catchments

Figure 10 presents the adopted final landform catchments and surfaces for each void based on existing topography and provided final void surfaces from Minserve (2018). Final landform drains were incorporated to divert external catchments where possible to reduce the volume of runoff reporting to the voids. Two options are shown for Central and Central North, depending on the final material balance and the extent of work conducted at mine closure.

Potential seepage paths through backfilled spoil, from Plains South to North and Central north to Central, were identified. These connections were simulated to quantify effect and magnitude.

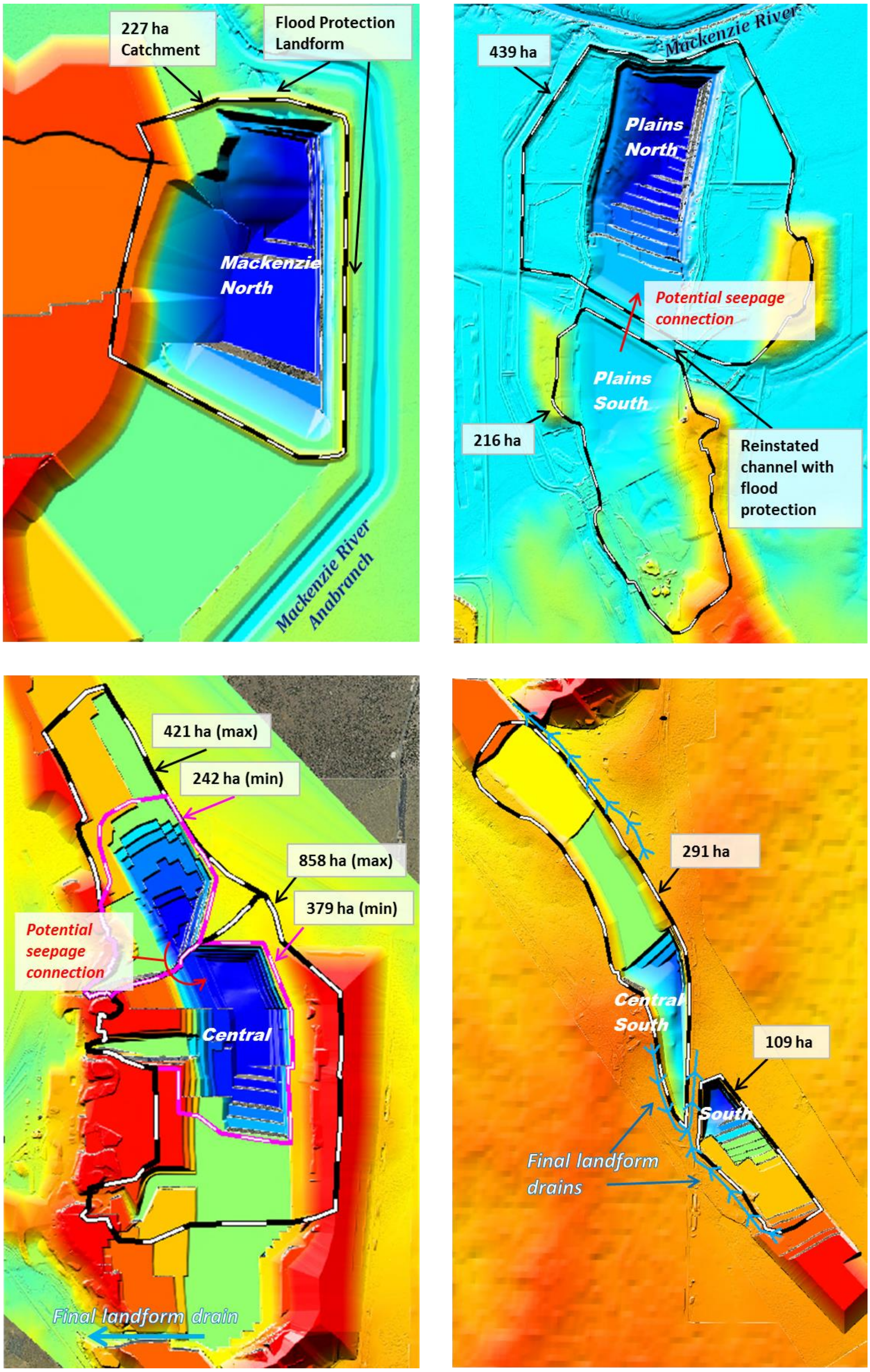

Figure 10 Final Landform Catchment Maps

Max Pit Tailings Dam is an inactive void currently used for tailing storage and water recycling. Various options for Max Pit Tailing Dam are being considered, including reprocessing of the tailings and backfill of the void for closure. For the purpose of this assessment, the current storage curve (based on 2018 bathymetric survey) and existing catchment (see Figure 11) were adopted to represent the worst case scenario with respect to final void level and containment risk. Final landform drains for the rehabilitated areas or tailings processing would increase available storage risk and backfilling would remove the void altogether.

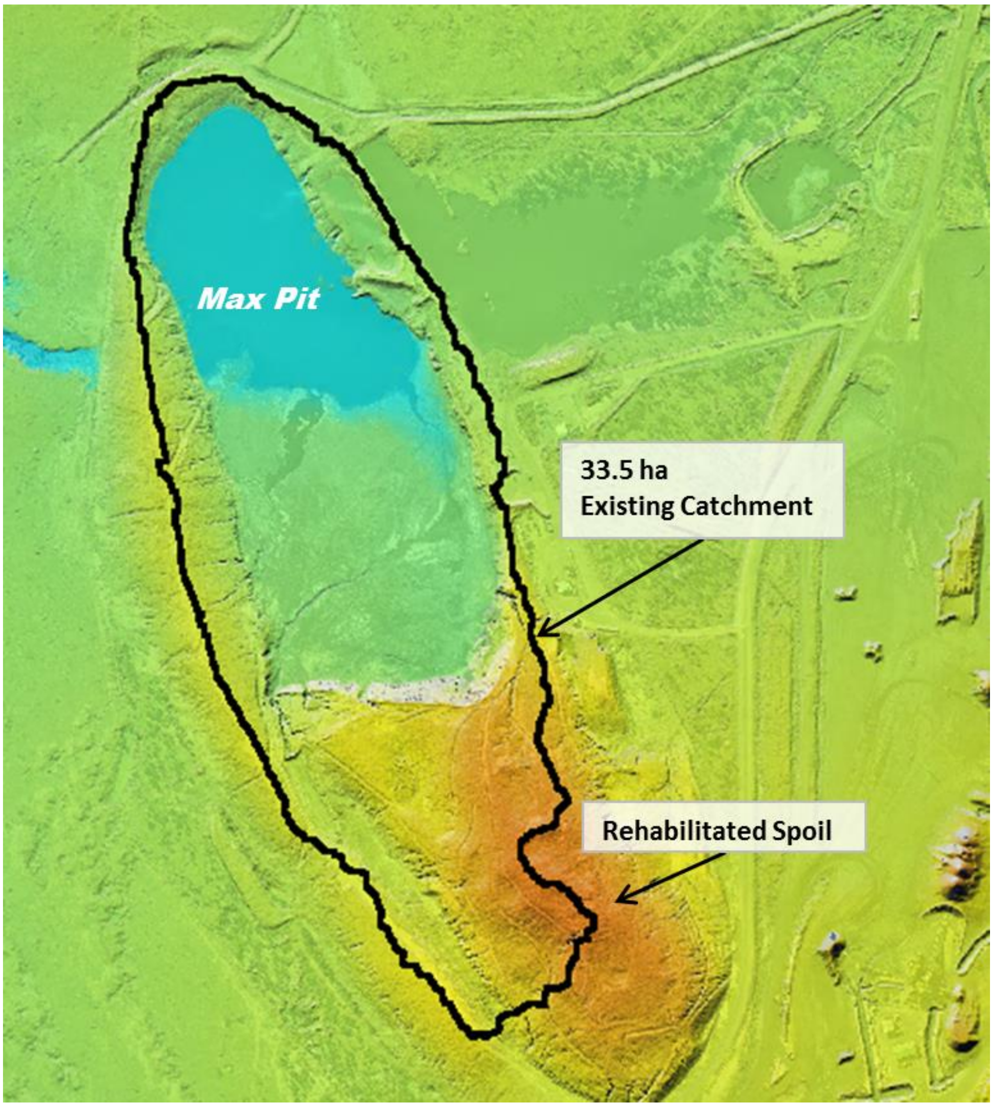

Figure 11 Final Landform Catchment Map Max Pit Void

8.3.2 Residual Void Water and Salt Balance

The post-closure water and salt balance of the final voids at Jellinbah Mine was simulated using the GoldSim software. The water balance model of the final voids utilises a daily time step, and simulates rainfall, runoff, evaporation, groundwater ingress, overflows (where applicable) and the long-term void lake water quality changes as a result of these flows.

The GoldSim model was simulated by looping the 129 years of available SILO climate data, until the volume of each void was observed to reach an equilibrium state. All model assumptions and parameters are described in Appendix B.

Table 4 summarises the final void water balance results. The forecast void lake levels and salinities for each final void are presented in Appendix B. No final voids pose an overtopping risk or seepage risk to groundwater systems (i.e. the final voids act as ‘sinks’ and will not contribute to sustained baseflow recharge). All final void equilibrium volumes are under 25% total void capacity.

The salinity of the final voids will continue to slowly increase over time due to the ongoing concentration from evaporation with no significant clean water flushing from rainfall runoff but long-term simulated concentrations are tabulated for each void for reference. Stratification is expected to result in lower solute concentrations in the surface layer of the lakes and higher solute concentrations in the deeper layer of the lakes compared to the average concentrations presented fully mixed lake conditions.

Void lake quality is expected to worsen over time for all voids as a result of evapo-concentration – there are no solute outflows from the voids. All final voids become hypersaline salt lakes within the first 100 years except for Plains (North) Void.

Table 4 Summary of Water and Salt Balance Results

Final Void	Catchment Scenario	Bottom of Pit (m AHD)	Void Spill Elevation (m AHD)	Time to Equilibrium (years)	Void Equilibrium Water Level (m AHD)	Max Level after Equilibrium Reached	Void Equilibrium Lake Area (ha)	Equilibrium Volume (GL, % of total)	Void EC after 100 years (µS/cm)	Void EC after 400 years (µS/cm)
Mackenzie North Void	-	5.7	119.5	100	33.4	38.8	17.6	2,370 (2.9%)	42,662	187,852
Plains (North) Void	-	-34.6	118	125	57.9	61.4	56.3	21,414 (25%)	5,185	18,537
Plains (South) Void	-	113.9	120	0	114.3	117.5	23.0	83 (4.0%)	>10^6	>10^6
Central Void (North)	Min	-6.2	140	85	39.4	41.2	20.3	4,125 (4.3%)	60,942	134,748
	Max			30	40.0	41.2	22.2	4,254 (4.5%)	25,567	37,047
Central Void	Min	-60.0	140	70	-25.6	-21.3	49.2	7,332 (3.0%)	86,565	315,072
	Max			90	-9.3	-2.7	71.3	17,283 (7.1%)	36,026	140,221
Max Pit Void	-	122.7	136.4	20	127.6	131.6	2.7	77 (8.8%)	33,445	284,628
Central South Void	-	74.4	153.9	30	113.8	118.2	19.7	2,876 (13%)	46,645	207,017
Jellinbah South Void	-	54.8	159.9	100	97.3	101.3	10.9	2,437 (13%)	55,466	206,442

8.4 CONCLUSIONS

This investigation of residual voids established the location of final voids on the Jellinbah Mine site and verified conformance with the design parameters / acceptance criteria defined in the Project's EA.

The assessment of residual void hydrology and hydrogeology addressed the potential for long-term environmental harm associated with final voids planned for the mine, concluding:

- No voids described in the final landform are expected to overtop or seep to groundwater.
- The voids will remain as a contaminated water sink. Saline water will be contained within the void footprint; and
- The residual voids are not predicted to be a risk of environmental harm to surface or groundwaters.

9.0 REFERENCES

AGE 2006, *Mackenzie South Project – Groundwater Impact Assessment.* Report prepared by Australasian Groundwater and Environmental Consultants (AGE) for AARC Environmental Solutions Pty Ltd (AARC), February 2006.

AGE 2013, *Mackenzie North Groundwater Assessment.* Report prepared by Australasian Groundwater and Environmental Consultants (AGE) for AARC Environmental Solutions Pty Ltd (AARC), June 2013.

AGE 2016, *Jellinbah Plains North – Pit Inflows Groundwater Assessment.* Report prepared by Australasian Groundwater and Environmental Consultants (AGE) for Engeny Water Management, September 2016

Department of Environment and Science (DES) 2011, *Environmental Protection (Water) Policy 2009 Mackenzie River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Mackenzie River Sub-basin*, Queensland Government, September 2011.

Ison Environmental Planners 1998, *Soil and Land Capability Assessment*, Jellinbah West Extension Project, January 1998.

JBT (2006) *Groundwater Assessment and Response to EHP Information request – Jellinbah Central North Extension (CNE) Area*. Report prepared by JBT Consulting for Jellinbah Group Pty Ltd, March 2006

Appendix A Jellinbah Final Void Groundwater Inflow Assessment

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Our reference: JBT01-061-003-Final Void Inflows.docx

16 November 2018

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Groundwater Inflow Rate to Jellinbah Final Voids

1. Introduction

Jellinbah Mine is an open-cut coal operation located approximately 190 kilometres (km) west of Rockhampton and 25 km north of the township of Blackwater in central Queensland. Mining activities at Jellinbah Coal Mine are approved under Environmental Authority (EA) EPML00516813 (DEHP, 2017). The EA outlines requirements for final voids, which are defined as areas of the final landform below natural surface that cannot be rehabilitated achieve a post mining land use.

JBT Consulting (JBT) has been commissioned by AARC Environmental Solutions Pty Ltd (AARC) to undertake an assessment of groundwater inflows to the final voids at Jellinbah Mine, as input to Final Land Use and Rehabilitation Plan (FLURP). The locations of the final voids are shown on Figure 1-1 and include:

- Mackenzie North (MN) Void;
- Plains Voids;
- Central North Void;
- Central Void;
- Max Pit Void;
- Central South Void; and,
- South Void.

A final void inflow assessment has been undertaken for each void, with the assumptions/ data sources for each void area discussed in Section 2. The inflow rates presented in this report have been used for assessment of final void water balance modelling (undertaken by Engeny Water Management Pty Ltd).

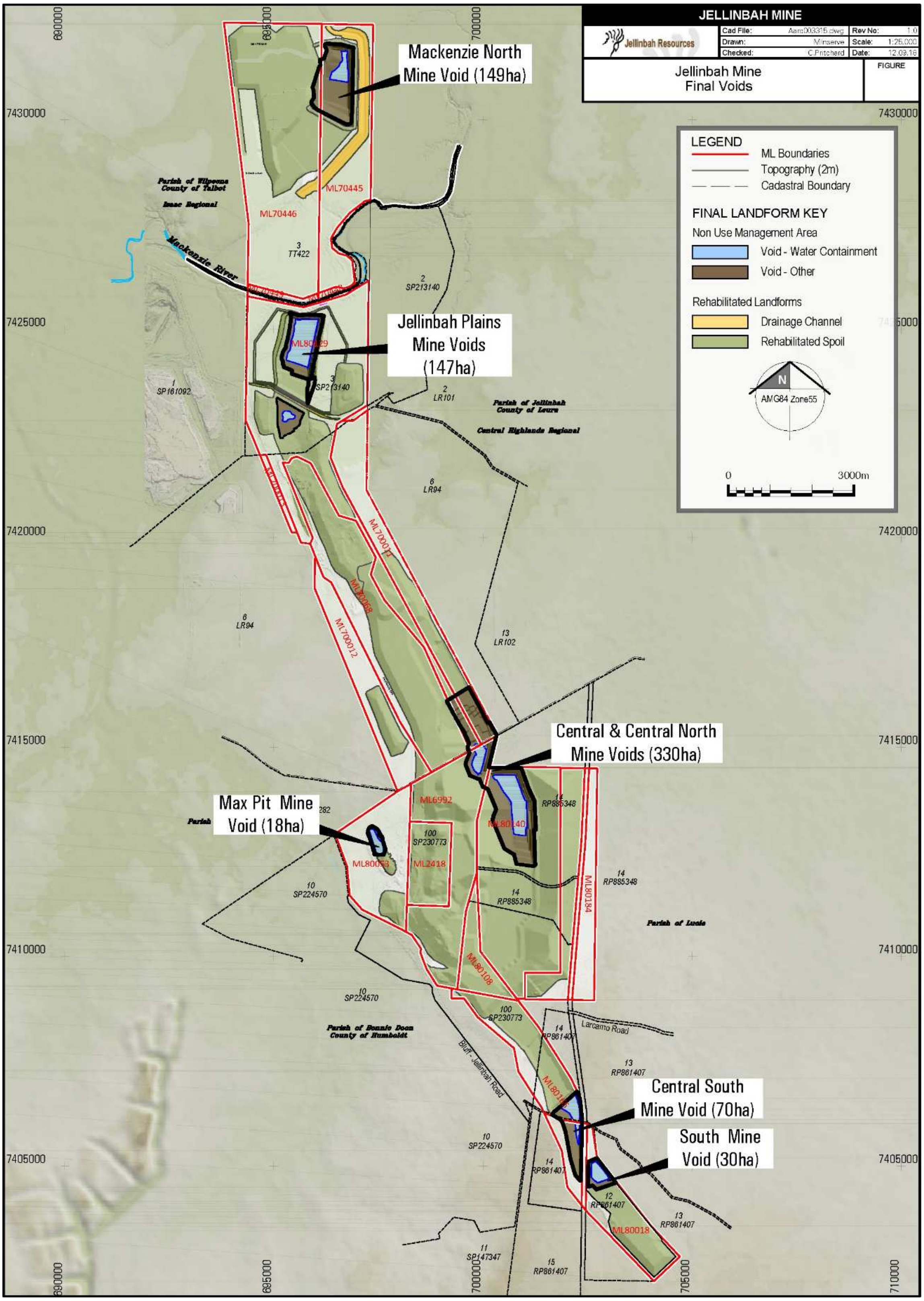


Figure 1-1: Locations of Final Voids

2. Groundwater Inflow Assessment

2.1. Mackenzie North Void

2.1.1. Pit Inflows

The background and assumptions with respect to inflows to the final void at Mackenzie North are based on groundwater modelling undertaken by AGE and reported in AGE (2013). Observations and assumptions from AGE (2013) are as follows:

- The Mackenzie River alluvium in the area of the mine is currently dry and the only areas where alluvium is saturated are located to the south (towards the Mackenzie River) where base of alluvium occurs at a lower RL than the base of alluvium in the mining area (i.e. the RL of the water surface in the alluvium to the south is below the base of alluvium in the mining area);
- Groundwater that flows from the alluvium to the mining pit is derived from downward/lateral seepage as the underlying Permian sediments are depressurised, rather than direct inflow from the alluvium adjacent to the pit (which, as stated above, tends to be dry)
- The majority of groundwater inflow occurs during the active phase of mine life (peaking at year 15), reducing to less than 0.1 ML/day (<1 L/s) towards the end of mine life and post-mining.
- It was noted in AGE (2013) that the predicted inflow rates do not take into account evaporation, therefore the net rate of inflow was predicted to be close to zero (i.e. the rate of evaporation is higher than the rate of inflow, resulting in a generally dry pit).

Based on the above assumptions, a long-term inflow rate of 1 L/s (0.1 ML/day) is therefore assumed for the purpose of final void modelling

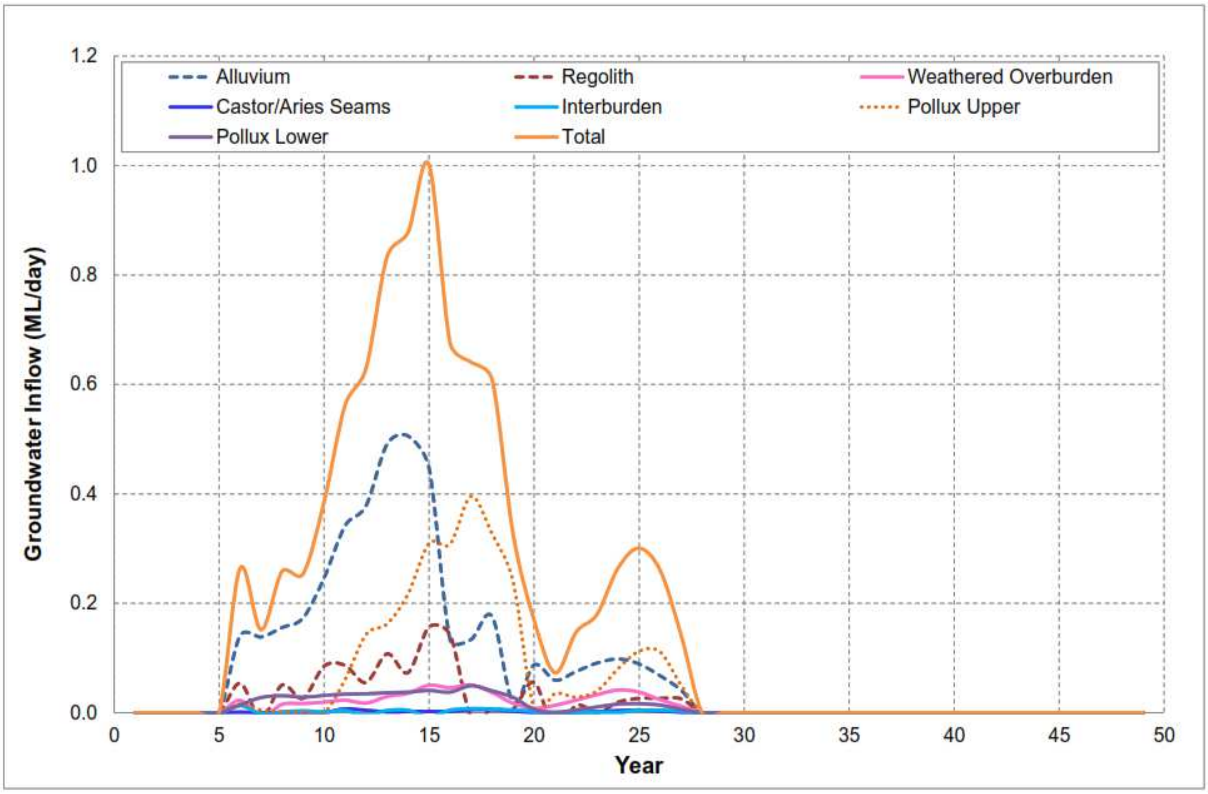


Figure 2-1: Modelled Groundwater Inflow Rates to Mackenzie North Pit (Source: AGE 2013)

2.1.2. Potential for Seepage from Final Void to Groundwater

This section presents an assessment of the potential for water within the final void to interact with the shallow groundwater system. For the Mackenzie North pit, it is assessed that potential exists for groundwater impacts to occur if the water levels in the final void rises above the base of alluvium and can therefore potentially seep to environment via the base of alluvium. According to AGE (2013), the thickness of the alluvium in the area of Mackenzie South varies from approximately 14 m in the area of the mine and thickens to ~42 m towards the Mackenzie River. Even assuming a 42 m thickness of alluvium in the area of the mine, the maximum void water level of 38.8 mAHD (Table 2-1) is significantly lower than the base of alluvium (i.e. the lowest surface elevation in the area of the mine is the spill point level of 119.5 mAHD, therefore a 42 m thickness of alluvium would have an elevation of 77.5 mAHD, which is higher than the modelled maximum void water level of 38.8 mAHD – refer Table 2-1); therefore it is assessed that the final void water level will remain below the base of alluvium and therefore that seepage from the final void to the shallow groundwater system is unlikely.

Table 2-1: Modelled Final Void Water Levels (source: Engeny 2018)

Final Void	Bottom of Pit (m AHD)	Void Spill Elevation (m AHD)	Void Equilibrium Water Level (m AHD)	Max Level after Equilibrium Reached (m AHD)
Mackenzie North	5.7	119.5	33.4	38.8
Plains	-34.6	118	57.9	61.4
Plains South	113.9	120	114.3	117.5
Central-North	-6.2	140	39.4	41.2
			40.0	41.2
Central	-60.0	140	-25.6	-21.3
			-9.3	-2.7
Max Pit	122.7	136.4	127.6	131.6
Central-South	74.4	153.9	113.8	118.2
Jellinbah South	54.8	159.9	97.3	101.3

2.2. Plains Void

2.2.1. Pit Inflows

At the northern-most extent, the Plains final void will be located approximately 250 m south of the Mackenzie River and the final void will be located within the Mackenzie River floodplain (i.e. the within the Mackenzie River alluvium). Groundwater inflow rates to the Plains Pit have previously been predicted by numerical modelling (AGE 2016) and pit inflow rates are currently calculated for the purpose of associated water licence reporting. Additional analysis of long-term groundwater inflow rates have also been undertaken for this report. Observations are summarised as follows:

- AGE developed a numerical groundwater model that covered all of the Jellinbah operations (AGE 2013), but was focussed on the Mackenzie North mine. The model was subsequently utilised to provide a prediction of the rate of groundwater inflow to the Plains Pit from the alluvium and underlying coal measures (AGE 2016). The model predicted inflow rates that were generally less than 4 ML/day, but which peaked at 7.6 ML/day (88 L/s) as mining approached the Mackenzie River. It was noted in AGE (2013) that the model was calibrated to steady-state based on alluvial water levels in 2013 (with a saturated alluvium thickness of 15 m), which was at the peak of water levels in the alluvium (following the significantly above-average wet season rainfall of 2010-2011 and 2012-2013). The AGE (2016) report noted peak inflow rates, but did not extend to the prediction of long-term groundwater inflow rates to the final void;
- Available data from site (a spreadsheet maintained for the associated water licence, which was provided to JBT for review) indicates that daily inflow rates from all sources (i.e. alluvium and Permian coal measures) is in the order of 4 to 6 ML/day during recent operations. A component of this water is understood to be recirculation of water from the environmental dam, though the component of pit pumping that is recycled water has not been quantified. Calculations for recent months indicate that the rate of groundwater inflow is increasing, with the most recent calculations indicating groundwater pumping rates from the pit of approximately 8 ML/day (April 2018) before reducing to less than 5 ML/day in June 2018. Variations in the calculated monthly inflow rates are assumed to be related to the development of mining into new areas of saturated alluvium and that the higher rates of groundwater inflow would not be sustained in the long term;
- It is judged that the currently assessed groundwater inflow rates, as well as the peak inflow rate calculated from AGE modelling (AGE 2016) will not be sustainable in the long-term and that inflow rates, especially from the alluvium, could be expected to reduce as the overall groundwater level in the alluvium reduces (partly due to inflow to the Plains pit void, partly due to an overall groundwater level reduction that could be expected following the 2010/2011 recharge event). The water level response of the alluvium to rainfall, and the reduction in water level as the Plains Pit approaches, is shown below in Figure 2-4.
- In order to provide an estimate of long-term groundwater inflow rates to the Plains Pit final void, a simple 2-dimensional cross section model was developed using the program Seep/W. Inflow rates from the model, which are calculated per metre width of pit face, were multiplied by the pit perimeter to obtain an estimate of pit inflow rates over time. The model layout for the area close to the pit is shown below as Figure 2-2. Assumptions relating to the thickness of alluvium, saturated thickness of alluvium, as well as hydraulic properties of the alluvium and underlying coal measures, were obtained from AGE (2013, 2016) as well as water level data from alluvial bores adjacent to the Mackenzie River (Refer Figure 2-3 for bore locations and Figure 2-4 for bore hydrographs). In summary:
  - The thickness of alluvium was modelled as 35 m with an initial water level at RL 101 mAHD (approximate current water level – refer Figure 2-4), giving a saturated thickness of alluvium of approximately 16 m;

- Recharge was applied to the model at a rate equivalent to 7% of average annual rainfall (consistent with assumptions from AGE 2013)
- Inflow rates from the alluvium to the pit were obtained for model times shown below in Table 2-2. The modelled inflow rates, which are calculated on a metre-width basis, were multiplied by the length of the perimeter where alluvium will occur in the final void (i.e. along 3 sides of the void and assuming 3200 m perimeter). From Table 2-2 it is observed that pit inflow rates reduce from 5.9 ML/day (for the current time, with results consistent with observed groundwater inflow rates) to approximately 1.2 ML/day after 100 years (this inflow rate is taken as the steady-state inflow rate from the alluvium to the Plains Void).

Table 2-2: Predicted Inflow Rates to Plains Void from Alluvium

Year	Inflow Rate (ML/day)
Current	5.9
10	3.7
15	2.8
20	2.3
25	2.3
30	1.8
35	1.6
40	1.5
45	1.4
50	1.4
100	1.2

Steady-state Inflow from coal seams is calculated to be approximately 2.1 L/s (0.18 ML/day), with full inflow rate when pit empty, reducing in a linear fashion to zero inflow at RL 60 (as the void lake will have risen able the RL of the coal seams and effectively reduce the inflow rate to zero).

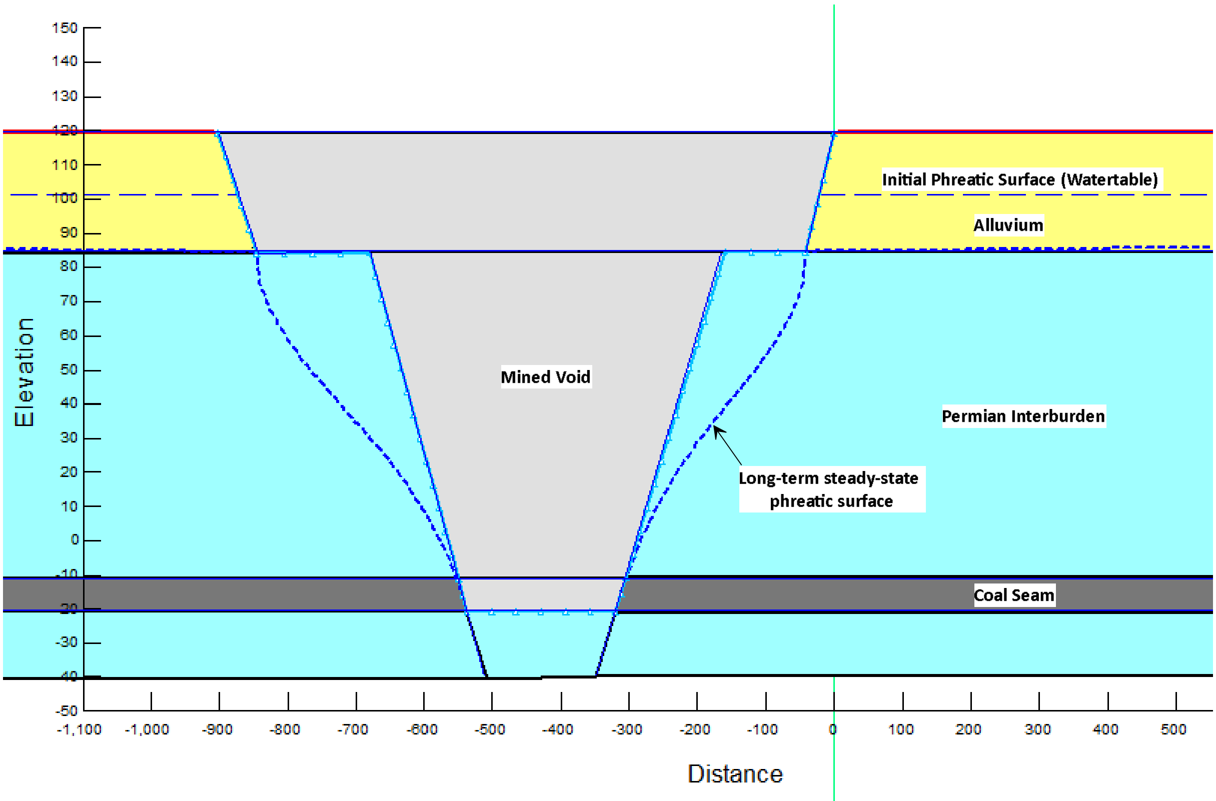


Figure 2-2: Detail of Seep/W Model in area of Pit

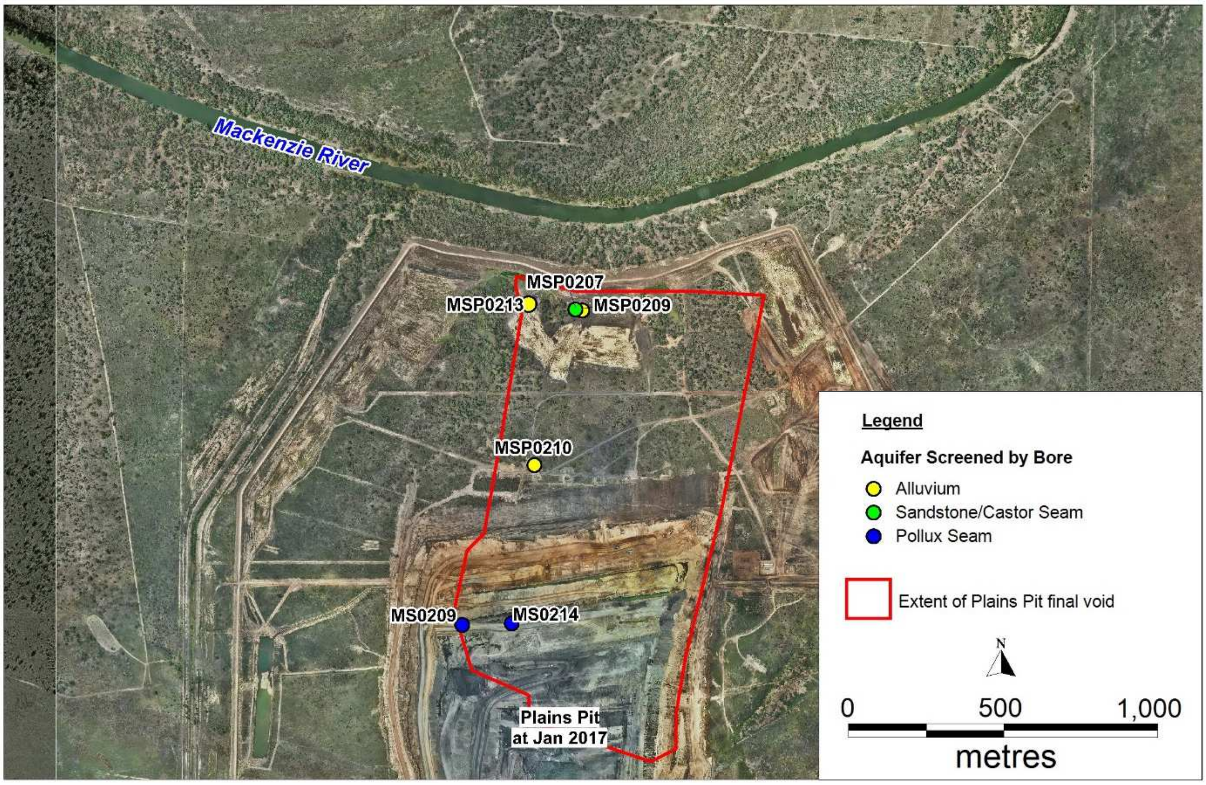


Figure 2-3: Location of Monitoring Bores – Plains Pit

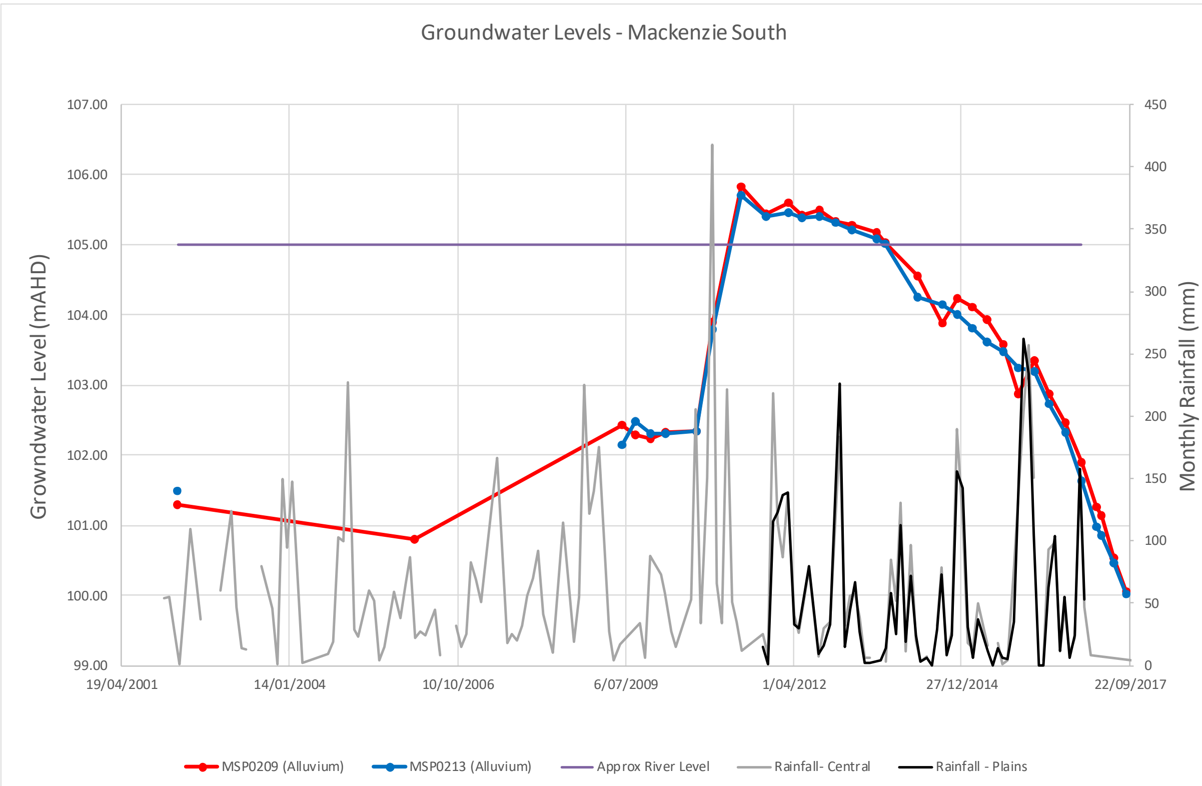


Figure 2-4: Hydrographs for Alluvial Bores between Plains Pit and Mackenzie River

2.2.2. Potential for Seepage from Final Void to Groundwater

This section presents an assessment of the potential for water within the final void to interact with the shallow groundwater system. For the Plains pit void, it is assessed that potential exists for groundwater impacts to occur if the water levels in the final void rises above the base of alluvium and can therefore potentially seep to environment via the base of alluvium. Jellinbah were not able to provide a surface for base of alluvium in the area of the Plains void, however a surface of base of weathering was provided. According to site personnel, the base of weathering is generally several metres below the base of alluvium. Figure 2-5 shows RL contours of the base of weathering for the area near the Plains void. The deepest area in the base of weathering is at ~RL 75 mAHD, with this area corresponding with the location of a prior channel of the Mackenzie River. The modelled maximum level of the Plains void is 61.4 mAHD (Table 2-1), therefore it is assessed that the final void water level will be below the base of alluvium and therefore that seepage from the final void to the shallow groundwater system is unlikely.

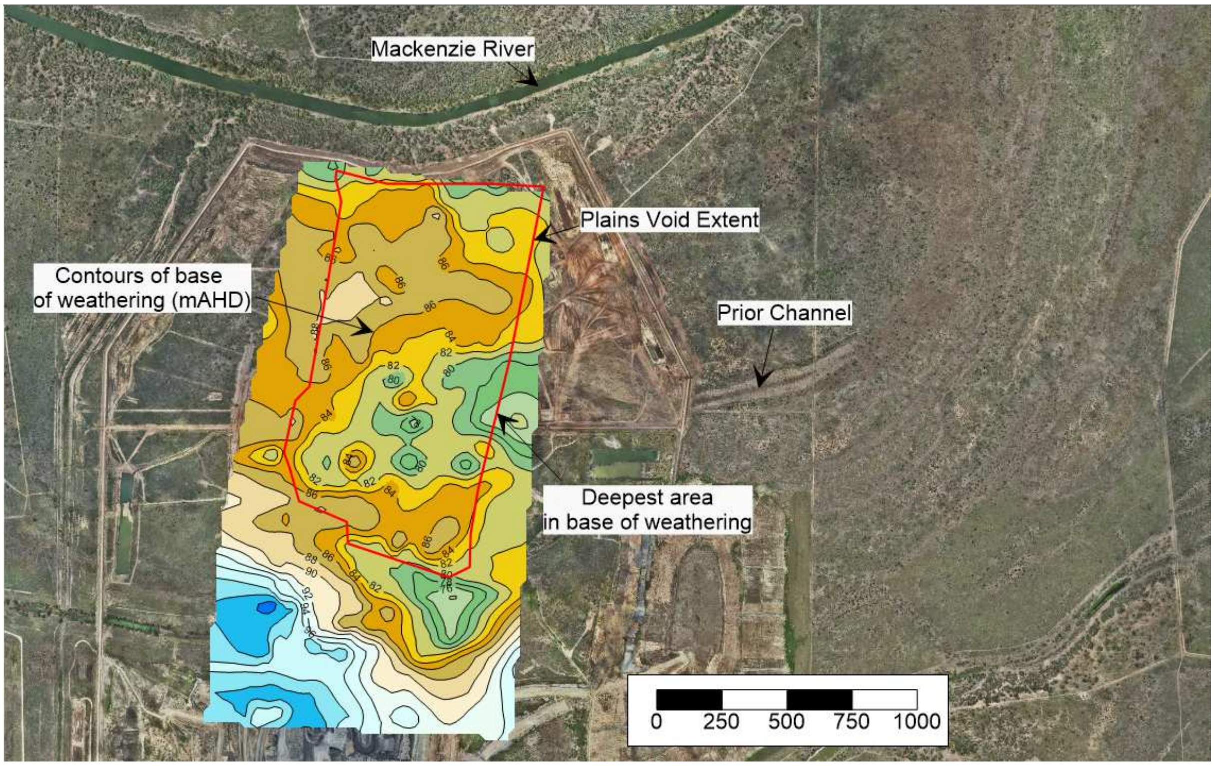


Figure 2-5: RL Base of Weathering in Area of Plains Void

2.3. Central/ Central North Extension Pits

The assumptions that are made for inflow from the Permian coal measures to the central/ CN pits are generally the same as for the Plains pit. There is no alluvium at the Central/ CN pit area and the Tertiary sediments have been assessed to be dry (JBT 2006), therefore only inflow from the Permian coal measures is considered. Assumptions for inflow calculations include:

- Groundwater flow within the Permian coal measures will occur mainly via the Pollux seam, and it is assumed that there will be no flow, or minimal flow, from the interburden (AGE 2006)
- The hydraulic conductivity of the Pollux seam is assumed to be 0.1 m/day (AGE 2006)
- The average thickness of the Pollux seam is 9 m (AGE 2016);

- The deepest area of the final void and Central void is ~RL-60)
- The average depth to water in the Central/CN area is ~40 m, for an average RL of ~ RL 90
- The dimensions of the final void through which inflow will occur are approximately 2,300 m x 600 m
- Based on a review of the extent of drawdown from the central pit (JBT 2006) the extent of drawdown is assumed to be 1,500 m.
- Based on the above assumptions, the steady-state inflow rate is calculated analytically (via Darcy's law) to be 300 m^3/day (3.4 L/s, 0.3 ML/day)

Observations from site (JBT 2016) are that the Central pit is generally dry. The steady-state inflow rates that are calculated above do not take into account evaporation. With evaporation applied, the net inflow would be closer to zero and account for the observation of dry pits (i.e. some groundwater inflow to the pits does occur, but at a rate that is below the rate of evaporation leading to the observation of dry pits).

The calculations above make no allowance for groundwater exchange with mined spoil.

2.4. Central South and South and Max Voids

Central South and South voids will be shallow relative to other voids (base of void of RL 74.4 and 54.8 mAHD respectively – refer Table 2-1). Observations from site are that both pits are dry, which is to say that the rate of groundwater inflow is less than the rate of evaporation leading to the observation of dry pits. For the purpose of final void modelling, an assumption of 1.5 L/s (0.13 ML/day) has been made for the rate of groundwater inflow to each pit.

2.5. Max Pit and Plains South Voids

Max Pit and Plains South voids will be shallow relative to other voids (base of void of RL 122.7 and 113.9 mAHD respectively – refer Table 2-1). For the purpose of final void modelling it is assumed that the rate of groundwater inflow to each void is zero.

3. References

AGE (2006) Mackenzie South Project – Groundwater Impact Assessment. Report prepared by Australasian Groundwater and Environmental Consultants (AGE) for Australasian Resource Consultants Pty Ltd (AARC), February 2006

AGE (2013) Mackenzie North Groundwater Assessment. Report prepared by Australasian Groundwater and Environmental Consultants (AGE) for Australasian Resource Consultants Pty Ltd (AARC), June 2013

AGE (2016) Jellinbah Plains North – Pit Inflows Groundwater Assessment. Report prepared by Australasian Groundwater and Environmental Consultants (AGE) for Engeny Water Management, September 2016

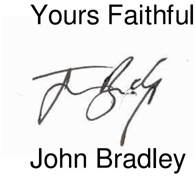
Engeny (2018) Jellinbah Final Void Hydrology Study. Report prepared for Jellinbah Resources by Engeny Water Management, November 2018.

JBT (2006) Groundwater Assessment and Response to EHP Information Request – Jellinbah Central North Extension (CNE) Area. Report prepared by JBT Consulting for Jellinbah Group Pty Ltd, March 2016

PB (2003) Curragh North Coal Mine – Hydrology, Flooding and Groundwater Report. Parsons Brinkerhoff, August 2003, Appendix G of Curragh North Project, Environmental Impact Statement

Please contact the undersigned should you have any queries in relation to this letter report.

Yours Faithfully,



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Appendix B Jellinbah Final Void Hydrology Study

JELLINBAH RESOURCES

Jellinbah Final Void Hydrology Study

November 2018

M61000_014

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REV	DESCRIPTION	AUTHOR	REVIEWER	APPROVED BY	DATE
Rev 0	Client Issue	Joel Khouri	Aaron Hallgath	Aaron Hallgath	16 November 2018
Signatures					

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1. INTRODUCTION

1.1 Background

Jellinbah Mine is an open-cut coal operation located approximately 25 km north of the township of Blackwater in central Queensland. Mining activities at Jellinbah Coal Mine are approved under Environmental Authority (EA) EPML00516813 (DEHP, 2017), which includes requirements for final voids. Final voids are areas of the final landform below natural surface that cannot achieve a post mining land use.

Engeny have been engaged to assess the hydrologic behaviour of the proposed final landform designs through the development of long-term water balance model simulations for void quantity and quality.

Table 1-1 outlines the existing or proposed final voids for Jellinbah Mine.

Table 1-1 Summary of Jellinbah Mine Final Voids

<table>
<tr><th>Jellinbah Mine Void</th><th>Current Use</th></tr>
<tr><td>Mackenzie North</td><td>n/a (proposed void)</td></tr>
<tr><td>Plains North</td><td rowspan="2">Active mining (currently combined)</td></tr>
<tr><td>Plains South</td></tr>
<tr><td>Central South</td><td rowspan="2">Active mining</td></tr>
<tr><td>Central</td></tr>
<tr><td>Central North</td><td rowspan="2">Active water storage, mining to recommence in later years</td></tr>
<tr><td>Jellinbah South</td></tr>
<tr><td>Max Pit</td><td>Tailings storage</td></tr>
</table>

1.2 Project Objectives

The key objectives of the Jellinbah Mine final void hydrology assessment are:

- Review final void configuration and develop final drainage catchments.
- Identify changes to storage volumes and water quality over time as well as predicted equilibrium status. Quantify overflow probability and filling times.
- Recommend final landform drainage diversions to manage void catchments.
- Assess long-term groundwater interactions and potential for seepage to alluvial aquifers, based on inputs from JBT Consulting.

1.3 Regulatory Requirements

Condition G10 of the site Environmental Authority, EPML00516813, outlines the requirement for residual voids at Jellinbah:

- Residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater 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.
- Residual voids must comply with Table G4 (outlined maximum surface areas and wall slopes for each final void).

The Department of Environment and Heritage Protection (DEHP) last updated the Rehabilitation Requirements for Mining Resource Activities Guideline in May 2014 (previously referred to as Guideline 18).

There are four general rehabilitation goals that require rehabilitation of areas disturbed by mining to result in sites that are:

- Safe to humans and wildlife
- Non-polluting
- Stable, and
- Able to sustain an agreed post-mining land use.

2. FINAL VOID DESIGNS

2.1 Flood Ingress Risk

Final voids at mine closure (relinquishment) are required to have flood immunity to extreme weather events in order to reduce clean water capture and long term storage of floodwater. Final voids without adequate flood immunity could lead to unlicensed harvest of runoff within regulated water resource catchments, long term storage of flood water leading to deterioration in water quality and associated potential impacts to connected groundwater aquifers and surrounding environmental values.

While limited guidance is currently available on the specific level of flood immunity required for open voids within a final landform, 1:1000 AEP design flood immunity has been adopted as a minimum. Flood protection measures for final voids will need to conform to final landform design principals (safe, stable and non-polluting) and be able to provide on-going flood protection without the need for on-going maintenance.

The three flood protection landforms required to prevent flood ingress to final voids at Jellinbah are:

- Plain North levee: the existing levee crest levels will be maintained to continue to provide 1:1000 AEP flood immunity from Mackenzie, and investigations into the long-term geotechnical stability and potential reshaping requirements are required.
- Mackenzie North levee: proposed landform to provide pit protection from the Mackenzie River anabranch.
- Levees between Plains North and Plains South to prevent ingress from the re-established Three Mile Lagoon flow path.

2.2 Final Landform Arrangements

Figure 2-1 present the adopted final landform catchments and surfaces for each void based on existing topography and provided final void surfaces from Minserve (2018). Final landform drains were incorporated to divert external catchments where possible to reduce the volume of runoff reporting to the voids. Two options are shown for Central and Central North, depending on the final material balance and the extent of work conducted at mine closure.

Potential seepage paths through backfilled spoil, from Plains South to North and Central North to Central, were identified. These connections were simulated to quantify effect and magnitude.

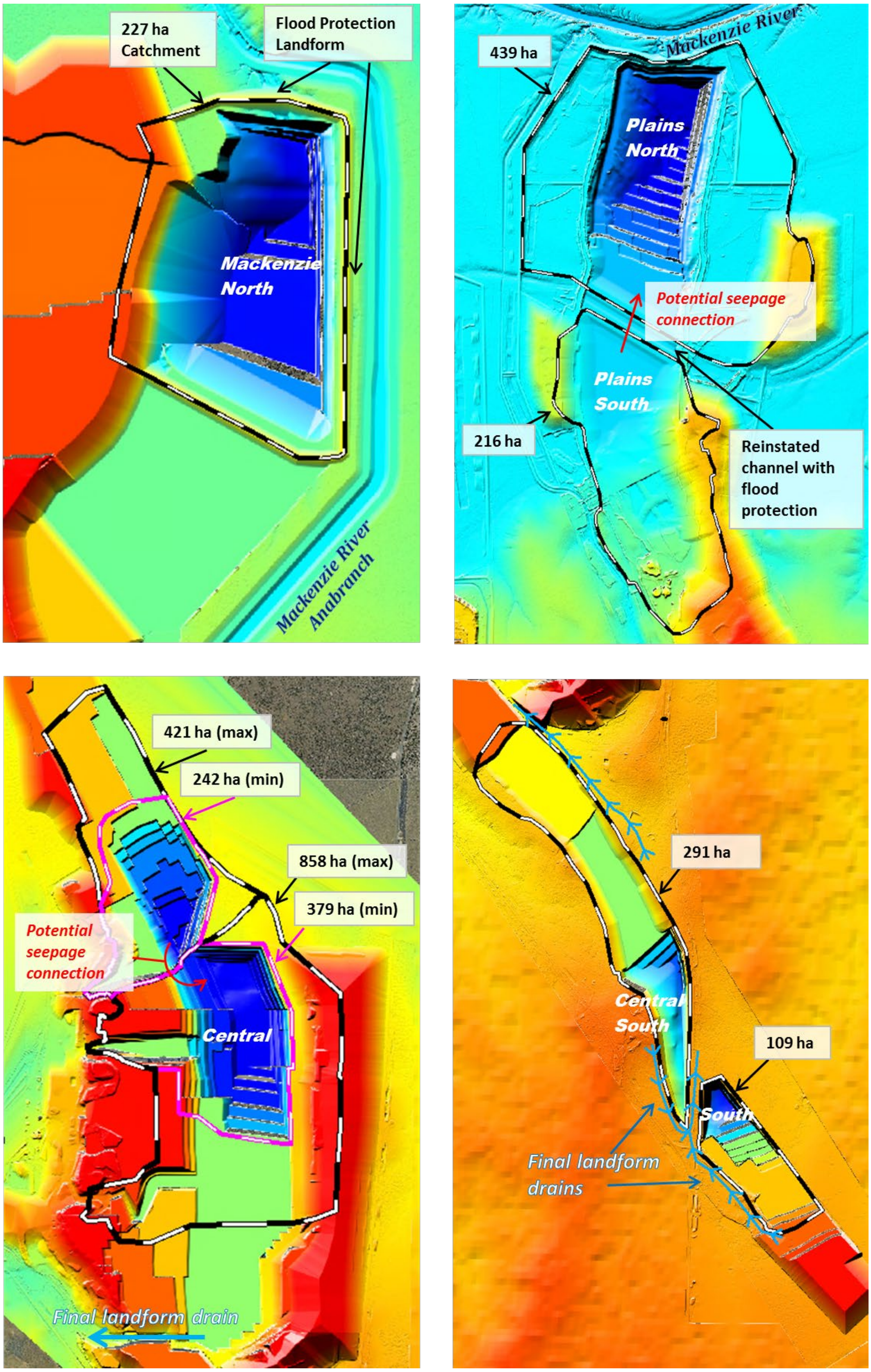

Figure 2-1 Final Void Arrangements

Max Pit Tailings Dam is an inactive void currently used for tailing storage and water recycling. Various options for Max Pit Tailing Dam are being considered, including reprocessing of the tailings and backfill of the void for closure. For the purpose of this assessment, the current storage curve (based on 2018 bathymetric survey) and existing catchment (see Figure 2-2) were adopted to represent the worst case scenario with respect to final void level and containment risk. Final landform drains for the rehabilitated areas or tailings processing would increase available storage risk and backfilling would remove the void altogether.

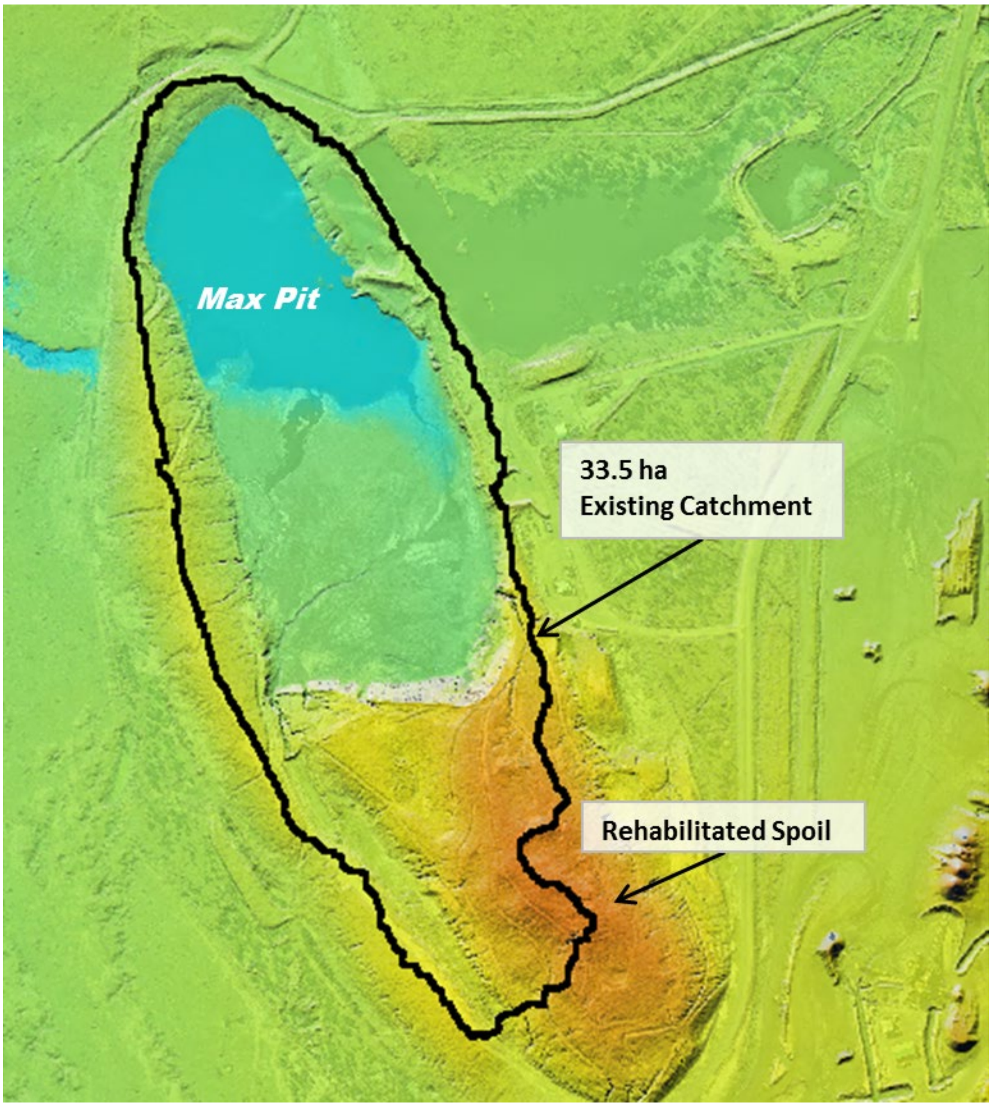

Figure 2-2 Max Pit Existing Catchment

3. WATER BALANCE MODELLING APPROACH

3.1 Overview

The post-closure water and salt balance of the final voids at Jellinbah Mine was simulated using the GoldSim software. GoldSim is a general purpose software package for simulating complex systems in engineering, science and business. All inputs and assumptions are outlined in the subsequent sections.

The water balance model of the final voids utilises a daily time step, and simulates rainfall, runoff, evaporation, groundwater ingress, overflows (where applicable) and the long-term void lake water quality changes as a result of these flows.

3.2 Final Surfaces

The final void concept design landforms were provided by Jellinbah Mine for all voids except Max Pit. These designs were used to develop storage curves and catchments for the final voids.

A storage curve for Max Pit was provided by Jellinbah Mine developed from survey taken in May 2018. As outlined in Section 2.2, Max Pit tailings may be re-processed, increasing the void storage capacity. Max Pit may also be backfilled with spoil. Use of the current storage curve presents the worst case scenario for final void area, level and quality.

3.3 Climate Data

Jellinbah Mine has a sub-tropical climate, dominated by a wet humid summer and dry winter. Long-term climate for Jellinbah Mine was obtained from the SILO climate database facility hosted by the Department of Science, Information Technology, and Innovation (DSITI). A SILO Patched Point Data climate series was obtained for the New Caledonia Station (35132), which is located about 5 km from Jellinbah Mine. This site is considered to be representative of Jellinbah Mine site rainfall and the data set ranges back to January 1889. Table 3-1 presents a summary of this data.

Table 3-1 Average Climate Data Statistics for New Caledonia Station (BoM, 2018)

Month	Mean Rainfall (mm)	Mean Maximum Temperature (°C)	Mean Minimum Temperature (°C)	Mean Morton's Lake Evap. (mm)
Jan	95.0	33.7	21.6	205
Feb	83.7	32.9	21.4	171
Mar	59.5	31.9	20.1	172

Month	Mean Rainfall (mm)	Mean Maximum Temperature (°C)	Mean Minimum Temperature (°C)	Mean Morton's Lake Evap. (mm)
Apr	30.3	29.4	16.5	133
May	30.5	26.1	12.3	101
June	30.5	23.3	9.4	79
July	25.2	23.0	7.8	88
Aug	18.0	25.0	9.4	116
Sept	22.7	28.2	12.8	150
Oct	40.1	30.8	16.5	187
Nov	55.2	32.4	18.9	199
Dec	86.5	33.7	20.7	212
Annual	**577.2**	**-**	**-**	**1812**

Morton's lake evaporation represents a theoretical calculation of lake evaporation based on other observed climate parameters. Morton's lake evaporation was used to calculate the evaporation rate from the void lakes.

Corrections to the lake evaporation rates were applied in the final void water balance model to reflect the reduction to the fresh water evaporation rate that occurs for a saline water body. The evaporation reduction relationship proposed by Grayson, et al. (1996) was utilised as follows:

- Evaporation reduction factor = $1/[1+TDS\ (mg/L)/10^6]$

This equation predicts a relatively small evaporation correction for salinity of approximately 1% reduction per 10,000 mg/L total dissolved solids (TDS) for TDS values up to 50,000 mg/L (i.e. 5% reduction for 50,000 mg/L TDS).

3.4 Catchment Runoff

Catchment runoff has been simulated using the Australian Water Balance Model (AWBM). A schematic representation of the AWBM model is provided in Figure 3-1. The model represents the catchment using three surface stores to simulate partial areas of runoff. The water balance of each surface store is calculated independently of the others. The model calculates the water balance of each partial area at daily time steps. At each time step, rainfall is added to each of the three surface stores and evapotranspiration is subtracted from each store. If the value of water in the store exceeds the capacity of the store, the excess water becomes runoff. Part of this runoff becomes recharge of the baseflow store if there is a baseflow component to the stream flow.

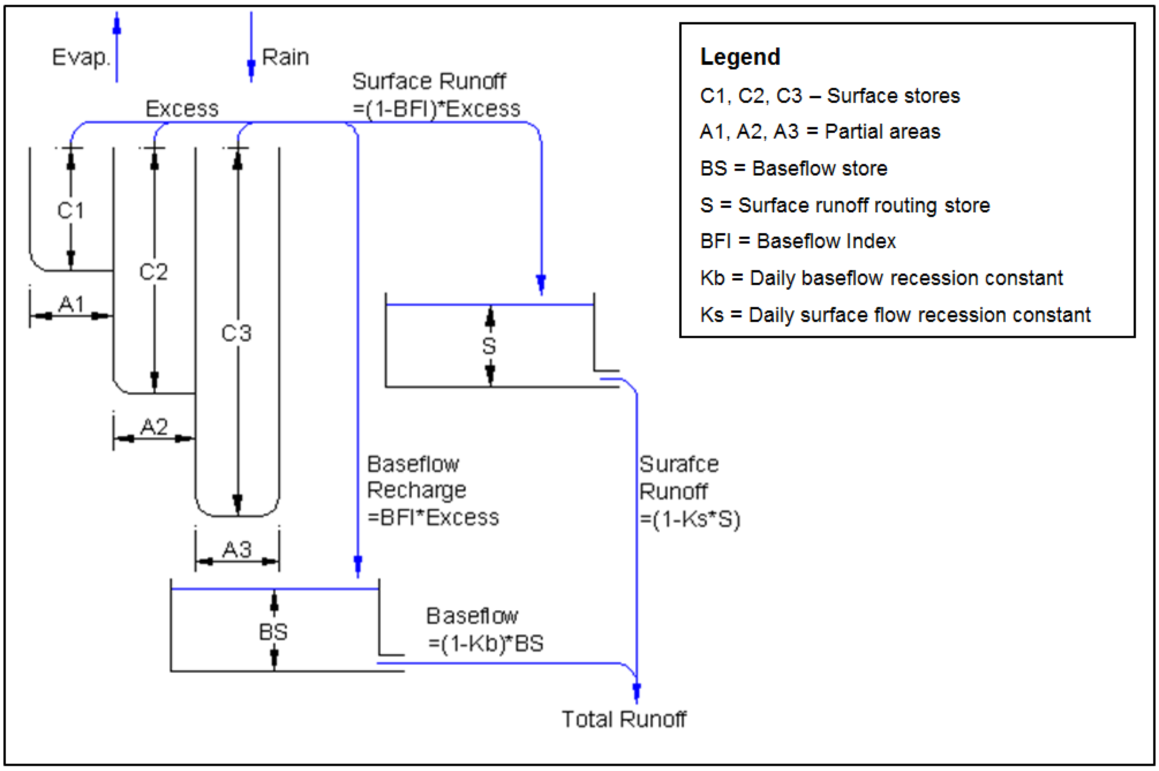

Figure 3-1 AWBM Schematic

The adopted AWBM parameters are shown in Table 3-2. These parameters are consistent with those adopted for the Jellinbah Mine water balance models. Pit and rehabilitated spoil AWBM land use catchment runoff parameters were adopted from parameters developed for similar sites in the Bowen Basin. AWBM natural land use catchment runoff parameters have been adopted from parameters calibrated to the streamflow gauging station at Blackwater Creek at Curragh (130108).

Table 3-2 Adopted AWBM Runoff Parameters

Land Use	C1 (mm)	C2 (mm)	C3 (mm)	A1	A2	A3	BFI	Kb	Ks
Natural	25.	95	230	0.134	0.433	0.433	0.03	0.98	0.50
Rehab Spoil	11	60	130	0.134	0.433	0.433	0.00	0.60	0.00
Pit	10	25	50	0.134	0.433	0.433	0.10	0.60	0.10

Blackwater Creek gauging station was considered the most suitable gauge as it has a similar catchment landuse, a long streamflow record and an accurate flow control structure. Blackwater Creek at Curragh (Station Number 130108) gauging station commenced in August 1972 and closed in May 2009. The results of the calibration are shown in Figure 3-2 and Figure 3-3.

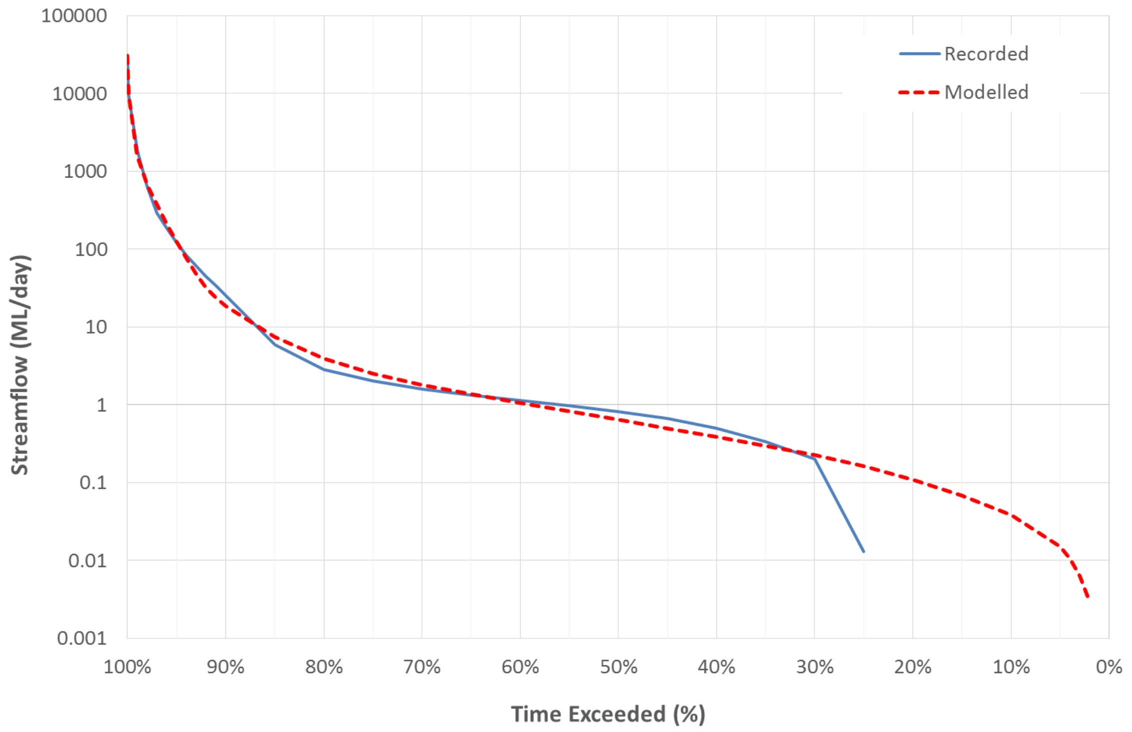

Figure 3-2 Modelled Flow Duration Curve for Blackwater Creek at Curragh

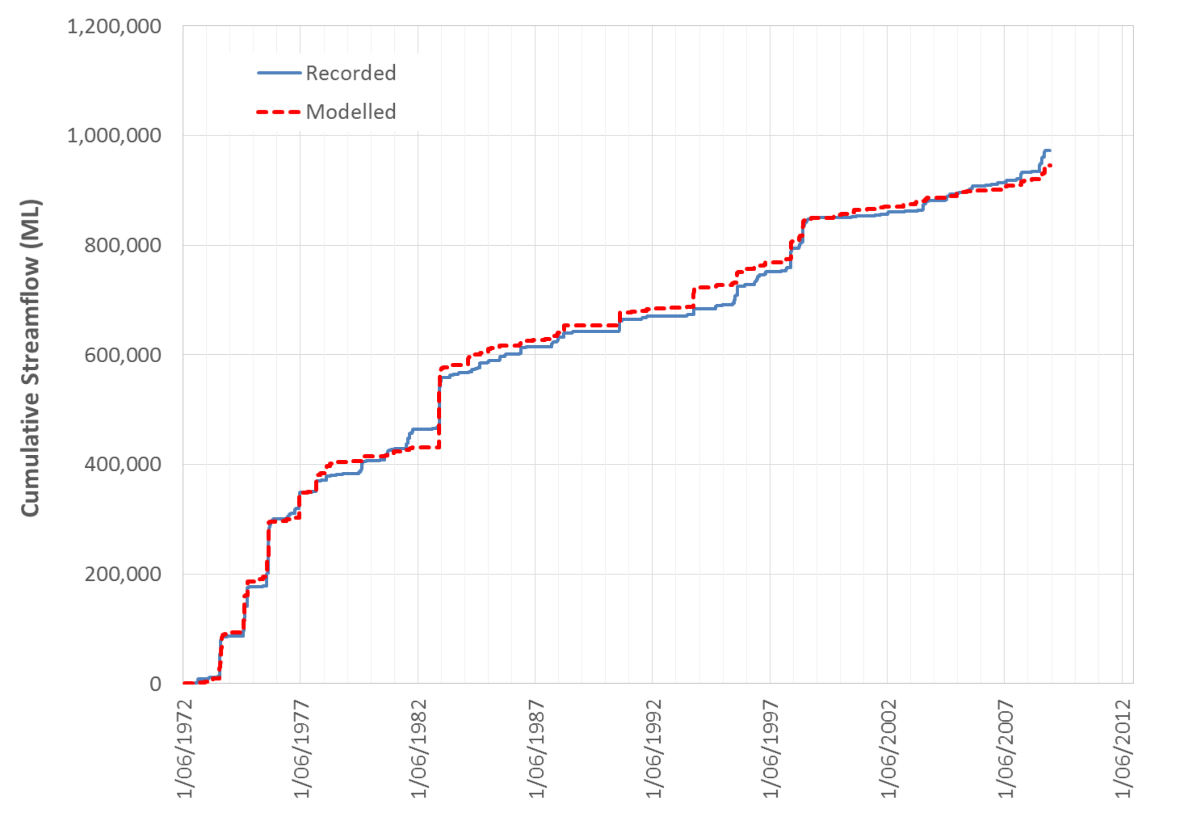

Figure 3-3 Modelled Cumulative Streamflows for Blackwater Creek at Curragh

3.5 Groundwater Interactions

Long-term estimated groundwater inflow rates were provided by JBT Consulting (2018) and are summarised in Table 3-3.

Table 3-3 Groundwater Inflow Estimates from JBT Consulting

Jellinbah Mine Void	Inflow from Alluvium	Inflow from Permian Coal Measures
Mackenzie North	-	0.1 ML/day
Plains North	5.9 ML/day at closure to a constant 1.2 ML/day after 100 years (trend provided)	0.18 ML/day (empty) to 0 Ml/day at 60 m AHD
Plains South	-	-
Central North	-	0.3 ML/day
Central	-	0.3 ML/day
Central South	-	0.13 ML/day

Jellinbah Mine Void	Inflow from Alluvium	Inflow from Permian Coal Measures
Jellinbah South	-	0.13 ML/day
Max Pit	-	-

3.6 Inter-void Seepage

Potential seepage connections were identified through backfilled spoil, which has a higher hydraulic conductivity than in-situ material, from Plains South to Plains North and from Central North to Central as indicated in Figure 2-1. Darcy's law was used to develop seepage flow rate (Q) estimates, using the cross-sectional area to flow A, the difference in hydraulic head Δh, the seepage path length L and hydraulic conductivity K.

$$Q = \frac{KA\Delta h}{L}$$

A horizontal hydraulic conductivity of 1 m/day was adopted by AGE for numerical groundwater modelling (AGE, 2013). This value is significantly higher than other observed spoil values at similar sites, but was adopted to provide an upper estimate of seepage potential.

Water balance modelling was conducted with and without allowing for seepage. The results presented show the highest final void levels between these simulations i.e. seepage was modelled for the receiving void results (Plains North and Central) and excluded for the source void results (Plains South and Central North).

3.7 Water Quality

3.7.1 Inputs

The final void water balance model includes a salt balance for the void lakes. Table 3-4 presents a summary of the water quality (salinity) parameters adopted for the final void water balance model.

Table 3-4 Water Quality Input Summary

Input	Value	Source
Runoff – Rehabilitated Spoil	1,000 µS/cm	Based on water quality monitoring data for South West Dam (primarily rehabilitated catchment). Similar to nearby mine sites.
Runoff – Natural Catchments	(300 x Runoff(mm) $^{-0.19}$) µS/cm, with maximum of 450µS/cm	Parameters from nearby coal mine sites

Input	Value	Source
Direct Rainfall	4 mg/L	Based on latitude and distance from coast, Salinity Management Handbook (DNR, 1997)
Groundwater Inflow	450 mg/L – Alluvial 17,150 mg/L - Permian coal measures	Averages of ranges presented in the Groundwater Impact Assessment by AGE (2006)

3.7.2 Salinity EC Conversion

The water balance model calculates the TDS for each of the water storages and receiving waterways using a salt mass balance approach. As regulatory compliance and the majority of monitoring is measured using EC, a conversion was required. A TDS–EC conversion factor of 0.67 was adopted for the hydrology assessment.

3.7.3 Runoff Salinity

Runoff ECs presented are based on assessments of measured site water quality data and calibrations. The water quality of the runoff from rehabilitated spoil would be expected to improve over time, as the salts leach out of the surface spoil layers. A constant rehabilitated spoil runoff EC value was conservatively adopted for the post-closure void hydrology predictions.

Runoff entering the final voids was assumed to be completely mixed with the existing stored water. This does not account for the potential stratification of water quality within voids with high depth to surface area ratio in which partial mixing with different layers may occur during the colder months (ACARP, 2017). Assuming complete mixing of the void lake contents will provide an average salinity in the void lake over the simulation period.

3.7.4 Groundwater Quality

The *Groundwater Impact Assessment for Mackenzie South* conducted by AGE in 2006 included an assessment of groundwater samples from monitoring bores installed and monitored by ERM. Groundwater samples collected from the coal seams indicate variable but overall saline water quality, with TDS ranging from 9000 to 25,300 mg/L (AGE, 2006). The water is slightly alkaline with a pH ranging from 7.1 to 7.6 and the predominant ions are sodium and chloride.

The samples of groundwater from the alluvial aquifer at Plains had TDS concentrations of 368 – 536 mg/L. This range is consistent with observed water quality from the dewatering bores at Plains Pit. The average values of these ranges were used in the water balance model. The key input is the adopted alluvial TDS of 450 mg/L, as the inflows from the coal seams are an order of magnitude smaller.

3.8 Model Assumptions

The following key assumptions were applied in the water balance modelling:

- No allowance for flood ingress to Plains North from Mackenzie River has been included in the model. The Plains North levee crest height has been designed to achieve a minimum of 1:1000 AEP flood immunity (regulated structure) and will be modified to achieve a stable final landform. Previous groundwater studies have stated that Mackenzie River is hydraulically isolated from the alluvial aquifer, and so no direct seepage will occur from the river (AGE, 2006).

- Water losses associated with the saturation of the spoil in the backfilled voids (typically during first filling conditions) was excluded. The model results are indicative of void lake behaviour after the backfill material becomes saturated.

- The void lakes are fully mixed (i.e. no stratification). Water quality results indicate the average salt concentration of the entire void lake.

- Rehabilitated spoil runoff salinities are set as constant values based on expected runoff qualities immediately after rehabilitation. Improved runoff quality over time has not been simulated and accordingly the predicted long-term salinities of the void lakes are likely to be upper limiting values.

- Seepage from Plains North or Mackenzie North voids to the alluvium would occur if water is stored for extended periods above the alluvium level. This was not explicitly simulated in the final void water balance model, and instead the seepage potential is discussed in Section 4.1 and 4.2.

- All spoil stockpiles, backfilled areas and regraded pit walls were assumed to be rehabilitated spoil. Only steeper in-situ high-wall areas were modelled as ‘pit’ land-use, with higher runoff parameters.

4. FINAL VOID HYDROLOGY RESULTS

4.1 Overview

The GoldSim model was simulated by looping the 129 years of available SILO climate data, until the volume of each void was observed to reach an equilibrium state.

Table 4-1 summarises the final void water balance results. Final landform arrangements and void equilibrium levels for each void were developed by Minserve and included in Appendix A. The forecast void lake levels and salinities for each final void are presented in Appendix B. No final voids pose an overtopping risk; all final void equilibrium volumes are under 25% total void capacity.

All the final voids are expected to act as ‘sinks’ and will not contribute to sustained baseflow recharge. JBT Consulting (2018) assessed available information on the alluvium at Mackenzie North and Plains, and concluded that these reported final void lake levels will remain below the alluvium.

The salinity of the final voids will continue to slowly increase over time due to the ongoing concentration from evaporation without significant fresh water inflows flushing from rainfall runoff. Stratification is expected to result in lower solute concentrations in the surface layer of the lakes and higher solute concentrations in the deeper layer of the lakes compared to the average concentrations presented fully mixed lake conditions.

Void lake quality is expected to worsen over time for all voids as a result of evapo-concentration – there are no solute outflows from the voids. All final voids become hypersaline salt lakes within the first 100 years except for Plains North.

Table 4-1 Final Void Lake Results Summary

Final Void	Catchment Scenario	Bottom of Pit (m AHD)	Void Spill Elevation (m AHD)	Time to Equilibrium (years)	Void Equilibrium Water Level (m AHD)	Max Level post equilibrium (m AHD)	Void Equilibrium Lake Area (ha)	Equilibrium Volume (GL, % of total volume)	Void EC after 100 years (µS/cm)	Void EC after 400 years (µS/cm)
Mackenzie North	-	5.7	119.5	100	33.4	38.8	17.6	2,370 (2.9%)	42,662	187,852
Plains North	-	-34.6	118	125	57.9	61.4	56.3	21,414 (25%)	5,185	18,537
Plains South	-	113.9	120	0[4]	114.3	117.5	23.0	83 (4.0%)	$>10^6$	$>10^6$
Central-North[1]	Min	-6.2	140[3]	85	39.4	41.2	20.3	4,125 (4.3%)	60,942	134,748
	Max			30	40.0	41.2	22.2	4,254 (4.5%)	25,567	37,047
Central[2]	Min	-60.0	140	70	-25.6	-21.3	49.2	7,332 (3.0%)	86,565	315,072
	Max			90	-9.3	-2.7	71.3	17,283 (7.1%)	36,026	140,221
Max Pit	-	122.7	136.4	20	127.6	131.6	2.7	77 (8.8%)	33,445	284,628
Central-South	-	74.4	153.9	30	113.8	118.2	19.7	2,876 (13%)	46,645	207,017
Jellinbah South	-	54.8	159.9	100	97.3	101.3	10.9	2,437 (13%)	55,466	206,442

1. No seepage to Central assumed (results in largest area and volume).

2. Seepage from Central-North included (results in largest area and volume).

3. Spills to Central first at 41.2 m AHD. Both voids would then overflow to the environment at 140 m AHD.

4. Frequently evaporates to empty during dry periods.

4.2 Plains Sensitivity Analysis

The long-term forecast results for Plains North final void are presented in Figure 4-1. The void is expected to fill to a maximum of approximately 67 m AHD then reduce to a steady-state average level of 58 m AHD once the alluvial ingress reduces to a constant 1.2 ML/day. The deepest area in the base of weathering is at ~RL 75 mAHD, and the base of weathering is generally several metres below the base of alluvium (JBT Consulting, 2018). Based on the provided groundwater estimates, Plains North void is therefore expected to remain over 10 metres below the base of alluvium, and remain a groundwater sink.

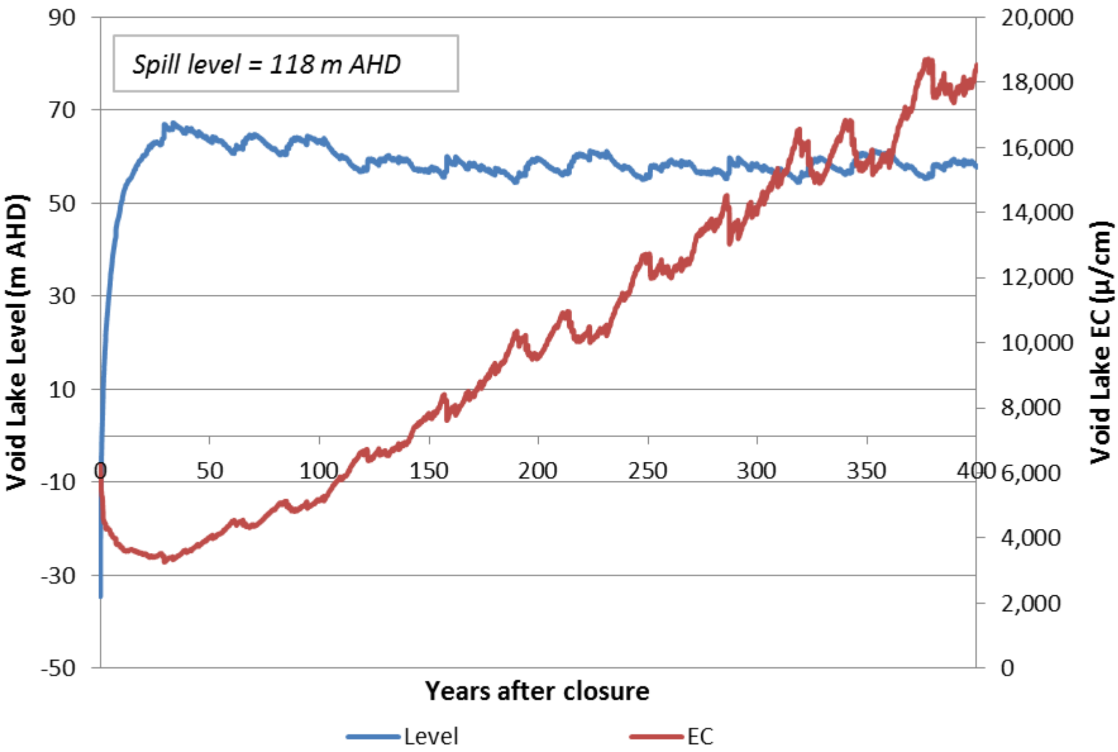

Figure 4-1 Plains North Water Balance Results

The sensitivity of these results to the groundwater estimates was explored, and it was found that a steady-state inflow of 2 ML/day or higher would be required for the void lake surface to exceed the base of alluvium.

Plains North is forecast to remain below stock watering guidelines for the first 60 – 100 years, based on the conservatively high runoff salinities adopted.

Plains South regularly evaporates to empty due to the absence of groundwater inflows, small catchment and large base area. Seepage from Plains North to Plains South was found to be negligible (maximum of 0.022 ML/day) as a result of the consistently low levels in Plains North, and has no impact on the results. The seepage rates were calculated using a conservatively high hydraulic conductivity, so minimal seepage is expected from Plains South to Plains North.

5. RECOMMENDATIONS

Jellinbah Mine is expected to have 8 final voids at mine closure, including the proposed Mackenzie North pit. Final landforms and drainage features will be constructed to provide pit flood immunity and divert external undisturbed catchments. Long-term water balance models were developed for each void using 129 years of historical climate data and final void surfaces provided, indicating the following:

- All voids remain well below spill level (under 25% of void capacity) and do not pose a risk of uncontrolled overflows to the receiving environment.
- None of the final voids present a seepage risk to groundwater systems, based on the water balance results and the assessment by JBT Consulting (2018), and will remain as groundwater sinks.
- Plains South functions as an evaporation pond and frequently evaporates to empty during dry periods. It becomes hypersaline within a few years as a result.
- Seepage from Plains North to South is expected to be negligible. Seepage from Central North to Central may be significant depending on the adopted final landform designs. Worst case scenario results were presented with regard to seepage and void volumes remain well below void capacity.
- Model results indicate that Plains North reaches an EC of 5,000 μS/cm after approximately 100 years, while all other voids have ECs greater than 20,000 μS/cm after 100 years. This is due to the significant alluvial groundwater contribution.
- Plains North could be considered for post-closure beneficial use (stock watering) but all other voids will be non-use areas. If beneficial use of Plains North is further considered, leach testing of rehabilitated spoil at Jellinbah is recommended to accurately predict runoff salinity over time. The results presented do not account for improvement in runoff quality with time, and likely present an over-estimate of void salinity.

6. QUALIFICATIONS

a. In preparing this document, including all relevant calculation and modelling, Engeny Water Management (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b. Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

c. Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

   (i) Additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or

   (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

d. Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the works, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works. All limitations of liability shall apply for the benefit of the employees, agents and representatives of Engeny to the same extent that they apply for the benefit of Engeny.

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f. If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

g. This report does not provide legal advice.

7. REFERENCES

ACARP (2017), *Guidelines for Coal Mine Open Pit Final Void Closure and Relinquishment*

AGE (2006) Mackenzie South Project – Groundwater Impact Assessment. Report prepared by Australasian Groundwater and Environmental Consultants (AGE) for Australasian Resource Consultants Pty Ltd (AARC), February 2006

AGE (2013), Mackenzie North Groundwater Assessment, prepared by Australasian Groundwater and Environmental Consultants (AGE) for Australasian Resource Consultants Pty Ltd (AARC), June 2031

Australian and New Zealand Environment and Conservation Council (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. October 2000.

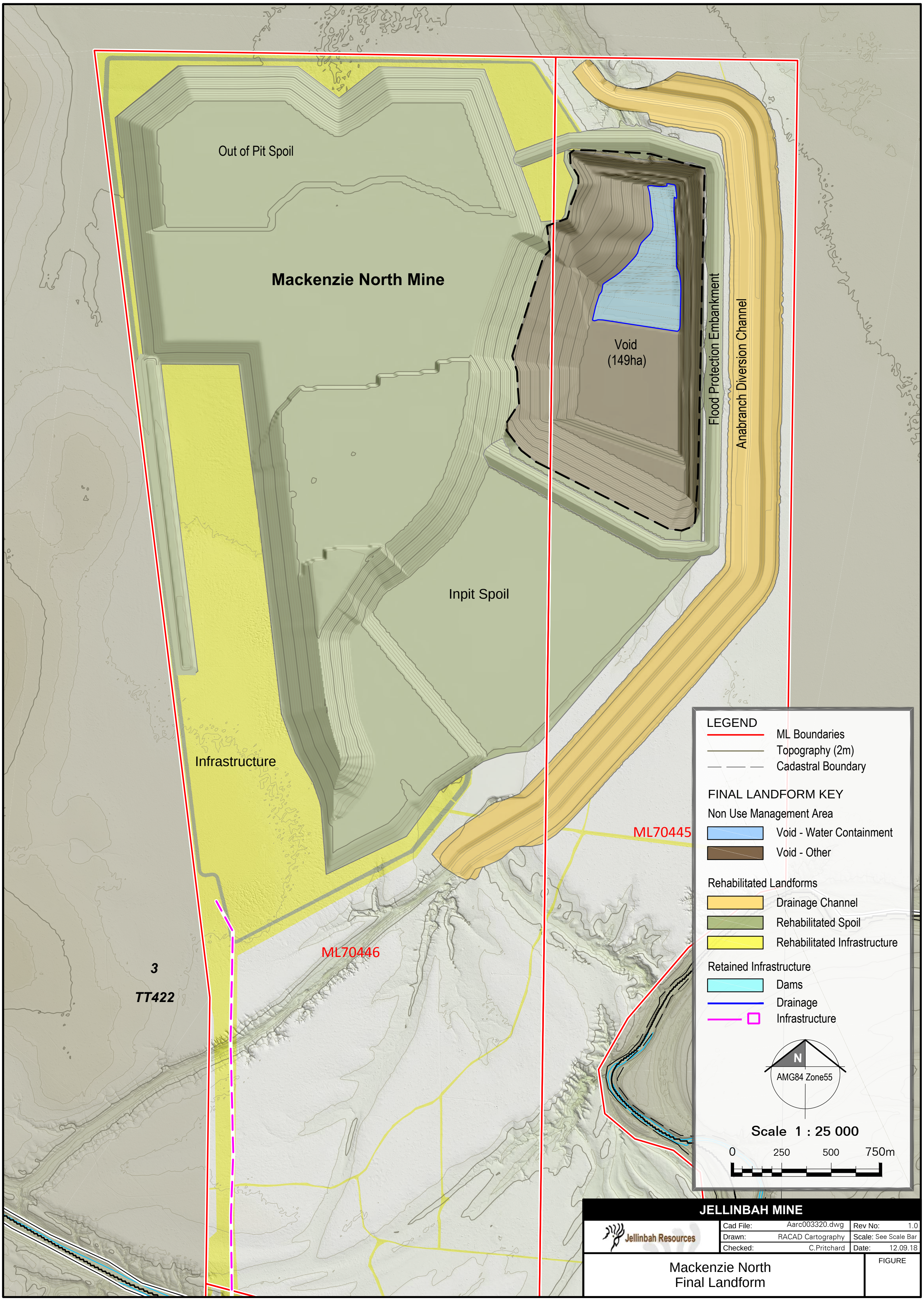
Department of Natural Resources (DNR). (1997). *Salinity Management Handbook*. Scientific Publishing.

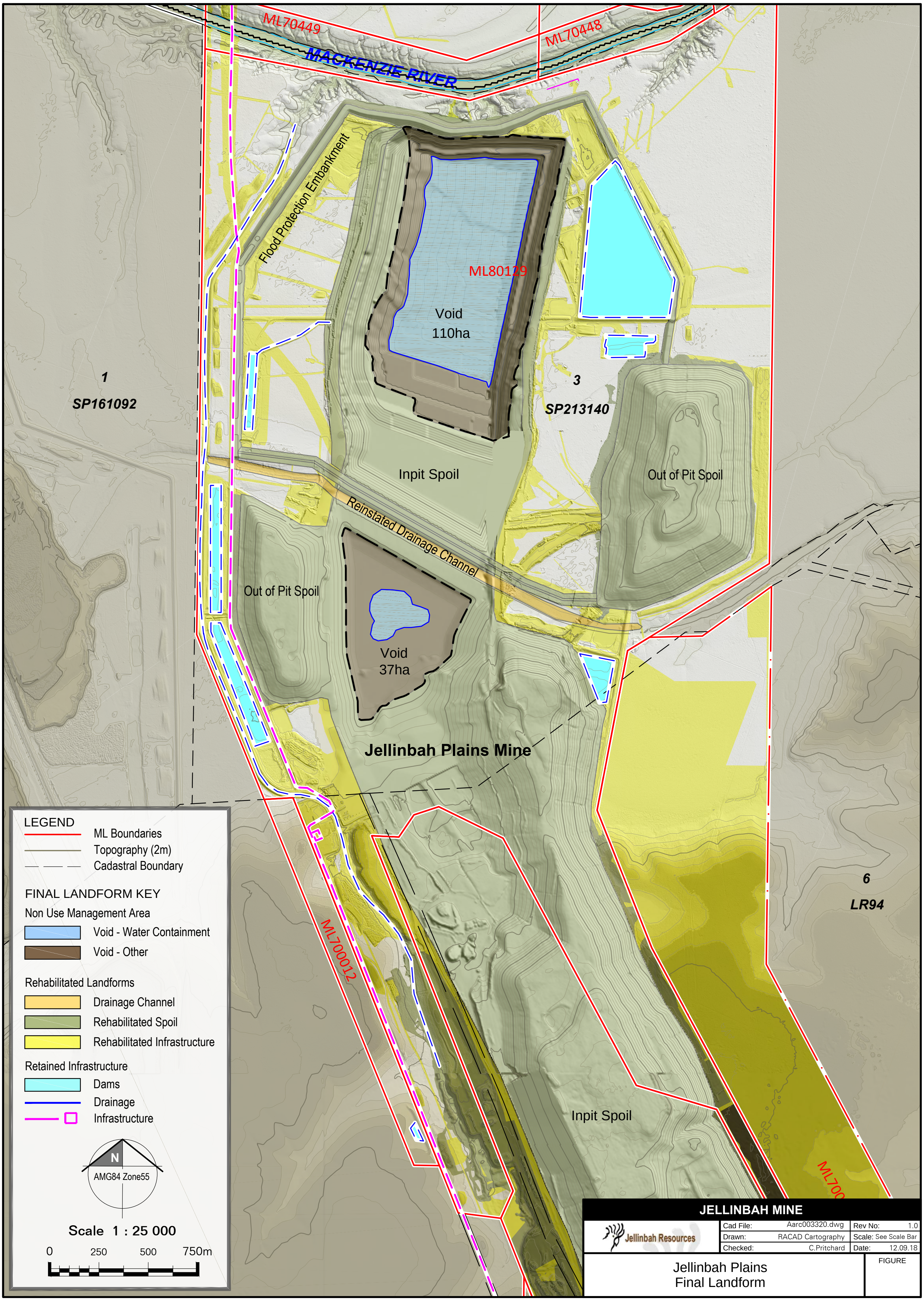
Grayson, R.B., Argent, R.M, Nathan, R.J., McMahon, T.A and Mein, R.G. (1996). *Hydrological Recipes – Estimates Techniques on Australian Hydrology*. CRC for Catchment Hydrology. 1996.

JBT Consulting Pty Ltd (2018), *Groundwater Inflow Rate to Final Voids*, report JBT01-061-003, prepared 12 November 2018.

Appendix A

Final Landform Figures


Out of Pit Spoil
Mackenzie North Mine
Void
(149ha)
Flood Protection Embankment
Anabranch Diversion Channel
Inpit Spoil
Infrastructure
ML70445
ML70446
3
TT422
LEGEND
ML Boundaries
Topography (2m)
Cadastral Boundary
FINAL LANDFORM KEY
Non Use Management Area
Void - Water Containment
Void - Other
Rehabilitated Landforms
Drainage Channel
Rehabilitated Spoil
Rehabilitated Infrastructure
Retained Infrastructure
Dams
Drainage
Infrastructure
N
AMG84 Zone55
Scale 1 : 25 000
0
250
500
750m
JELLINBAH MINE
Jellinbah Resources
Cad File: Aarc003320.dwg
Rev No: 1.0
Drawn: RACAD Cartography
Scale: See Scale Bar
Checked: C.Pritchard
Date: 12.09.18
Mackenzie North
Final Landform
FIGURE


ML70449
ML70448
MACKENZIE RIVER
Flood Protection Embankment
ML80129
Void
110ha
1
SP161092
3
SP213140
Inpit Spoil
Out of Pit Spoil
Reinstated Drainage Channel
Out of Pit Spoil
Void
37ha
Jellinbah Plains Mine
ML700012
6
LR94
Inpit Spoil
LEGEND
ML Boundaries
Topography (2m)
Cadastral Boundary
FINAL LANDFORM KEY
Non Use Management Area
Void - Water Containment
Void - Other
Rehabilitated Landforms
Drainage Channel
Rehabilitated Spoil
Rehabilitated Infrastructure
Retained Infrastructure
Dams
Drainage
Infrastructure
N
AMG84 Zone55
Scale 1 : 25 000
0 250 500 750m
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Jellinbah Resources
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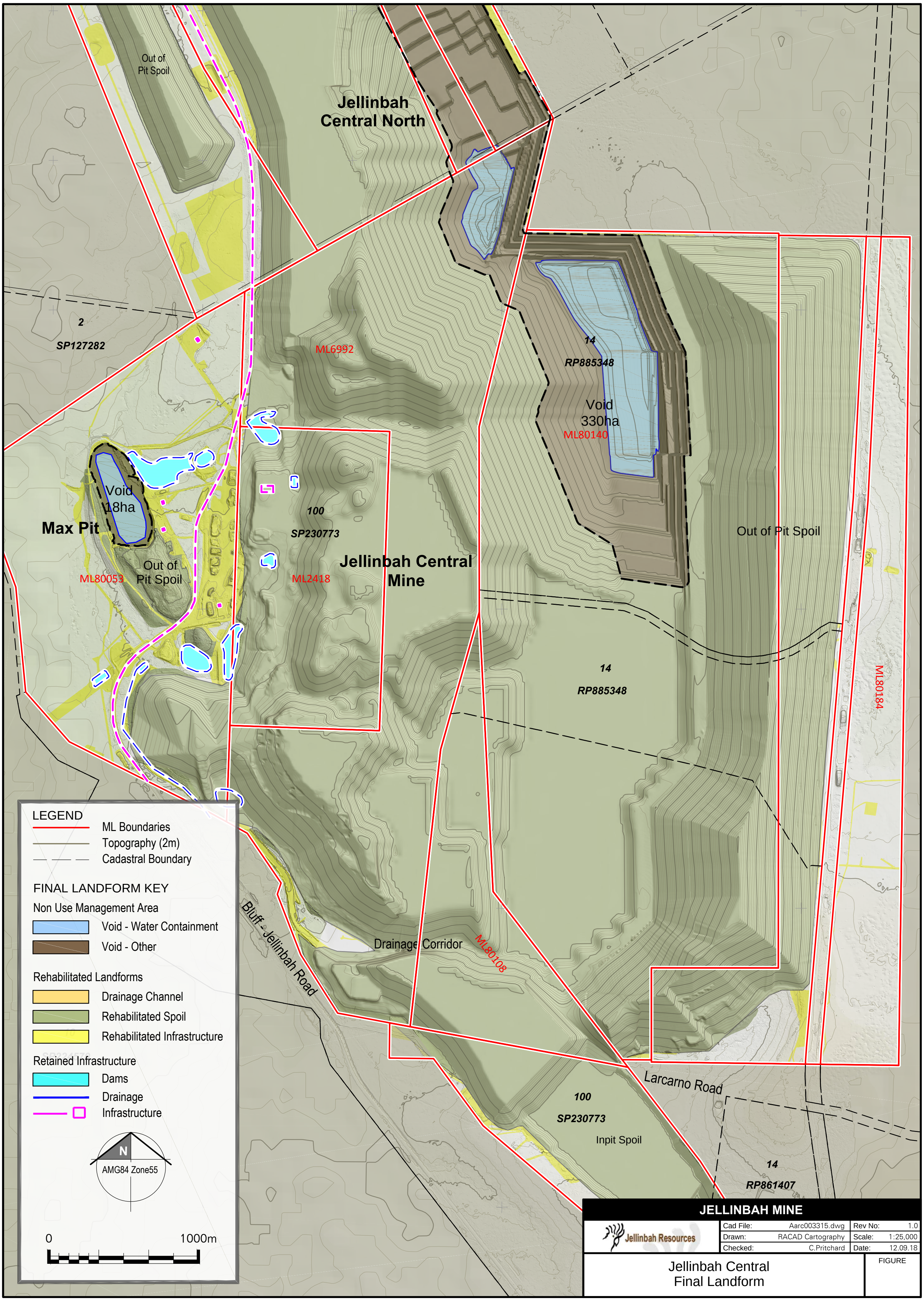
Rev No: 1.0
Scale: See Scale Bar
Date: 12.09.18
FIGURE
Jellinbah Plains
Final Landform


Out of
Pit Spoil
Jellinbah
Central North
2
SP127282
ML6992
14
RP885348
Void
330ha
ML80140
Void
18ha
Max Pit
Out of
Pit Spoil
ML80053
100
SP230773
ML2418
Jellinbah Central
Mine
Out of Pit Spoil
14
RP885348
ML80184
Bluff - Jellinbah Road
Drainage Corridor
ML80108
Larcarno Road
100
SP230773
Inpit Spoil
14
RP861407
LEGEND
ML Boundaries
Topography (2m)
Cadastral Boundary
FINAL LANDFORM KEY
Non Use Management Area
Void - Water Containment
Void - Other
Rehabilitated Landforms
Drainage Channel
Rehabilitated Spoil
Rehabilitated Infrastructure
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Drainage
Infrastructure
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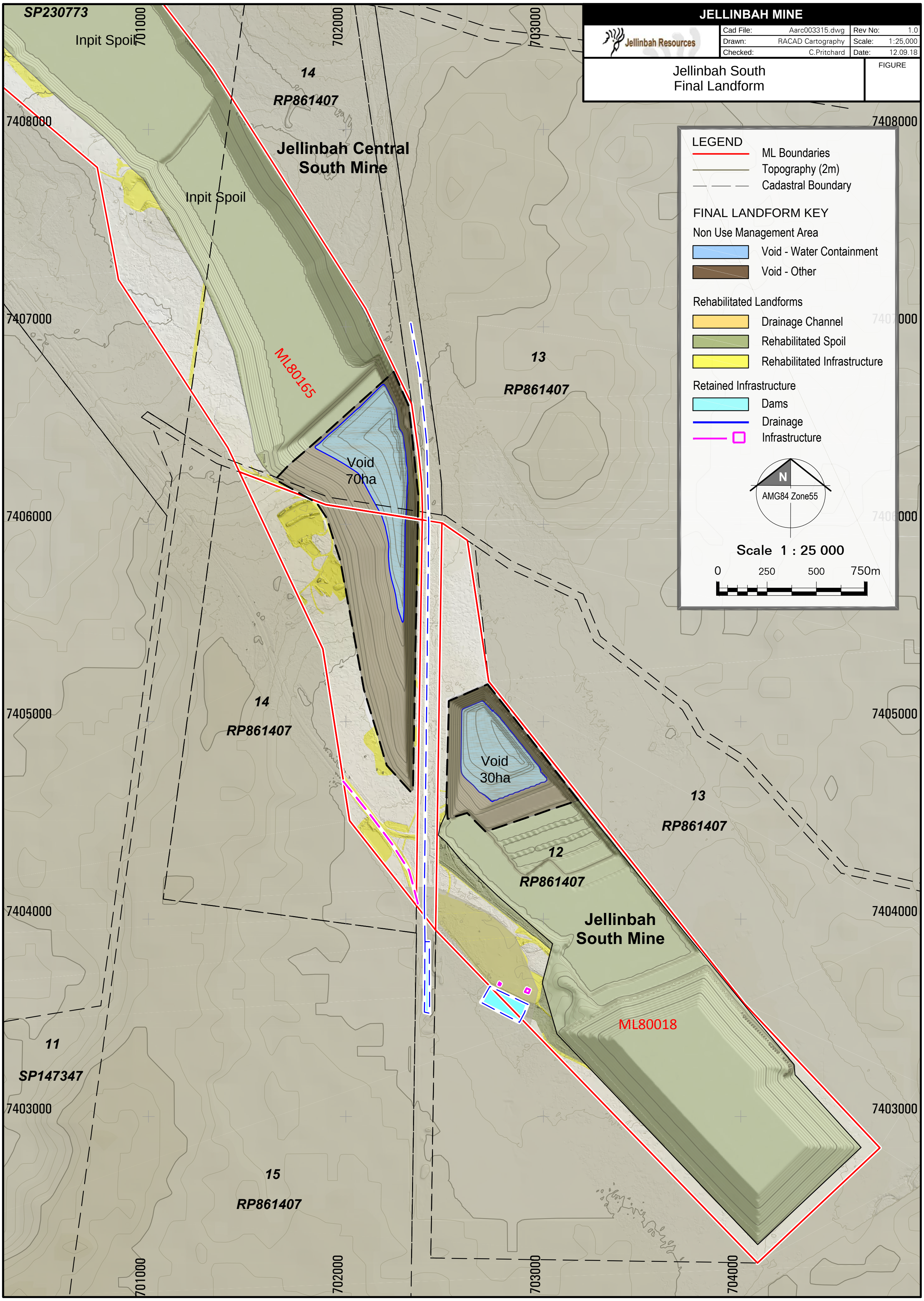
Jellinbah Central
Final Landform
FIGURE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Date: 12.09.18
Jellinbah South
Final Landform
FIGURE
LEGEND
ML Boundaries
Topography (2m)
Cadastral Boundary
FINAL LANDFORM KEY
Non Use Management Area
Void - Water Containment
Void - Other
Rehabilitated Landforms
Drainage Channel
Rehabilitated Spoil
Rehabilitated Infrastructure
Retained Infrastructure
Dams
Drainage
Infrastructure
N
AMG84 Zone55
Scale 1 : 25 000
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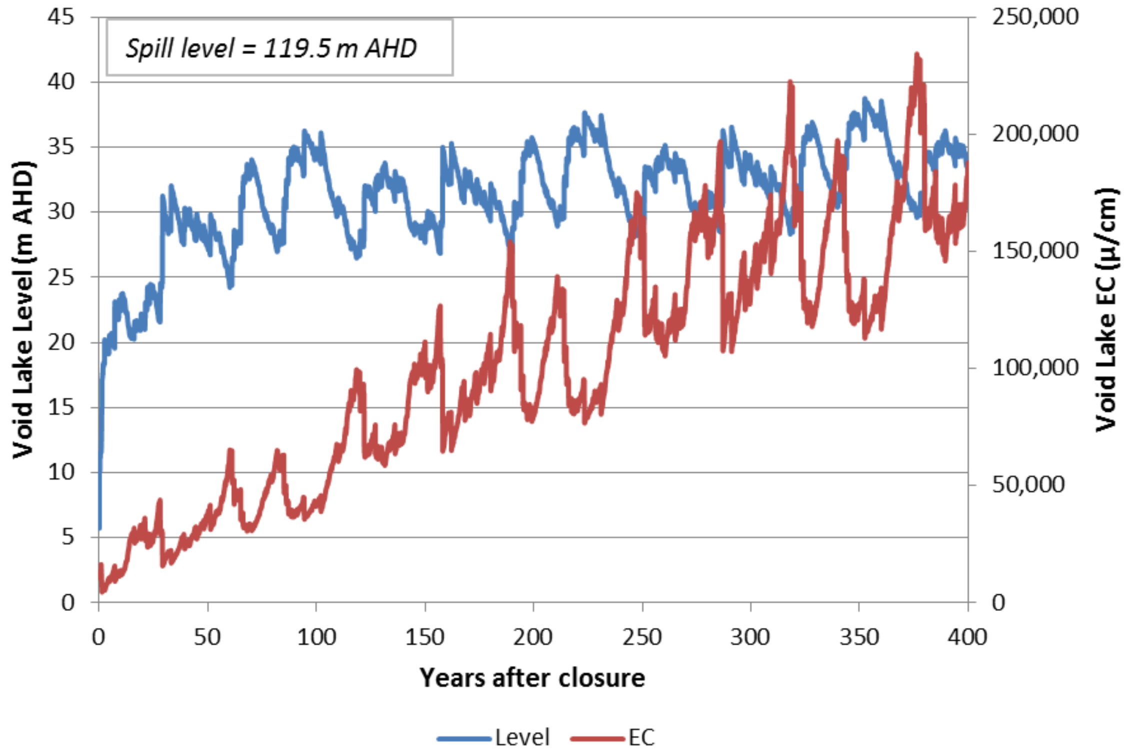
SP230773
Inpit Spoil
Inpit Spoil
14
RP861407
Jellinbah Central
South Mine
ML80165
Void
70ha
13
RP861407
14
RP861407
Void
30ha
13
RP861407
12
RP861407
Jellinbah
South Mine
ML80018
11
SP147347
15
RP861407
7408000
7407000
7406000
7405000
7404000
7403000
701000
702000
703000
704000

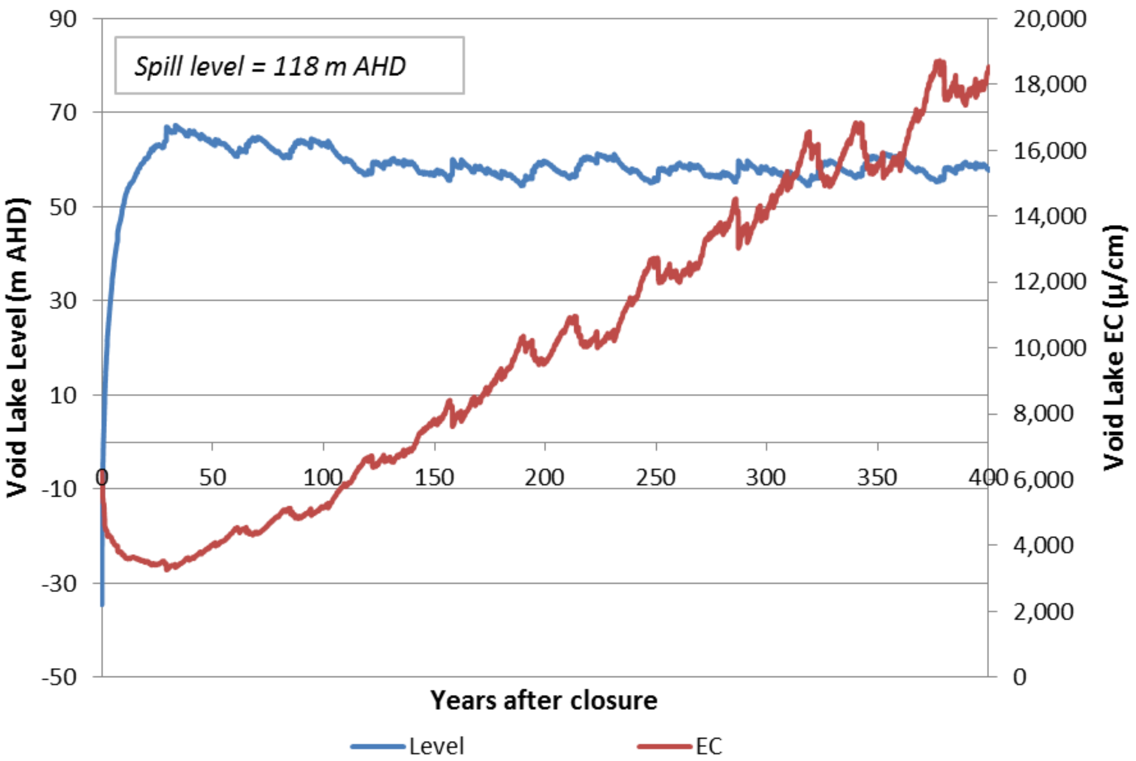
Appendix B

Final Void Water Balance Results

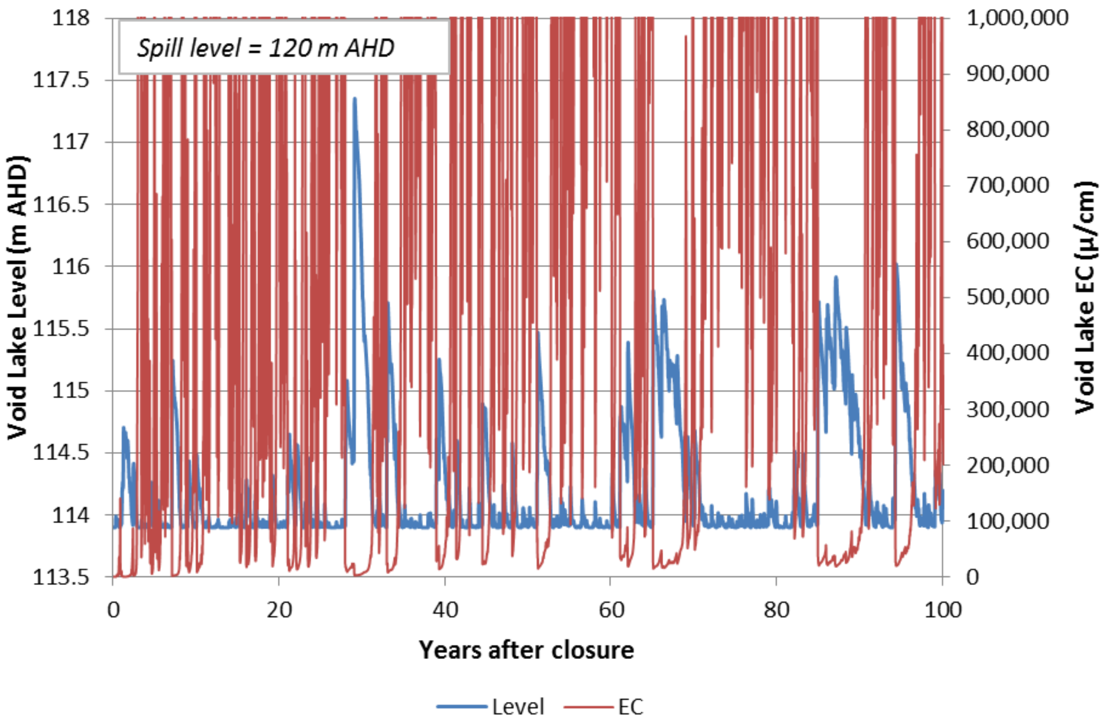
Mackenzie North



Plains North

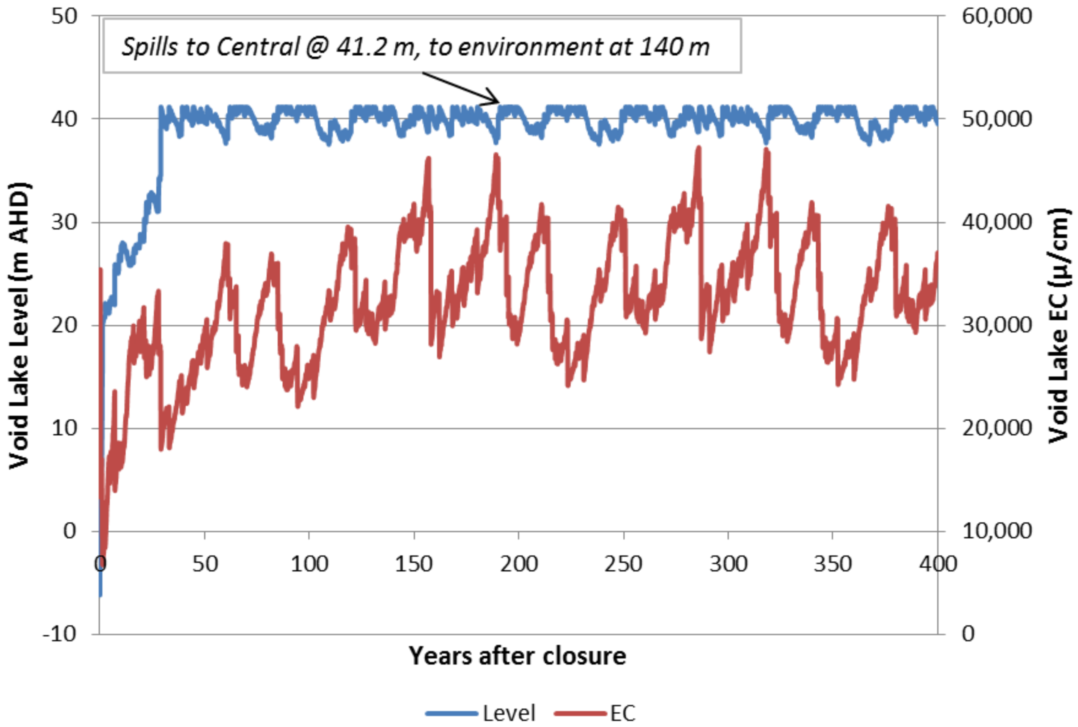


Plains South



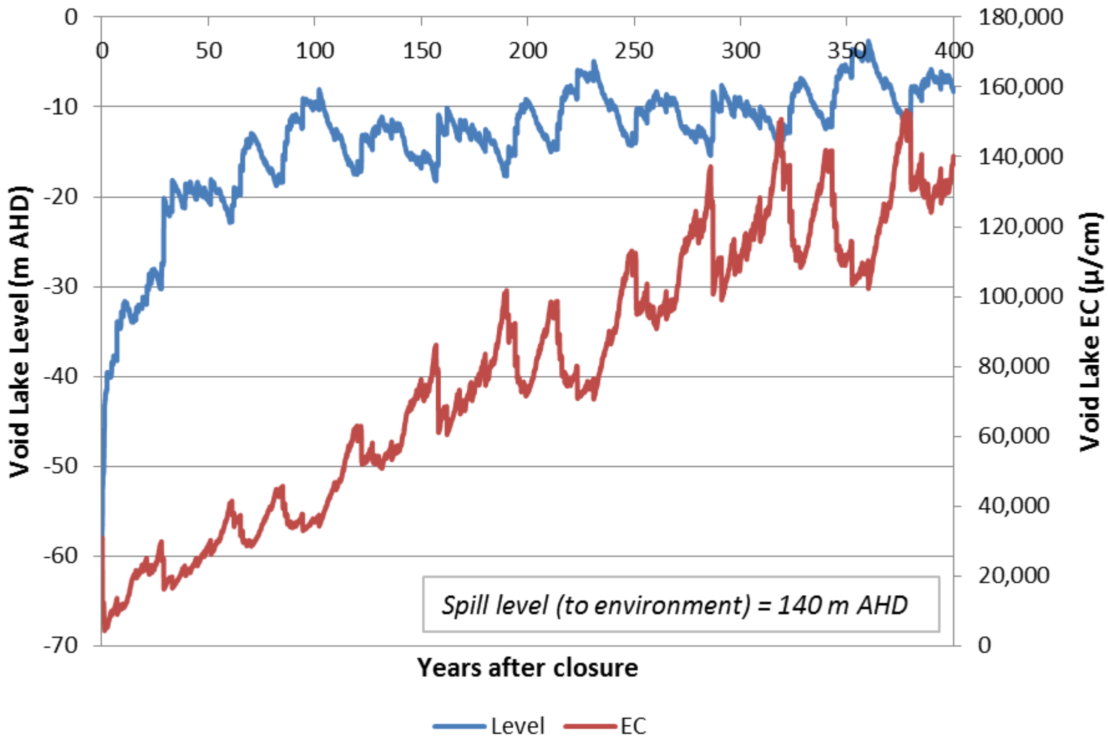
Central North

Maximum catchment, assumes no seepage to Central South (results in highest void level)

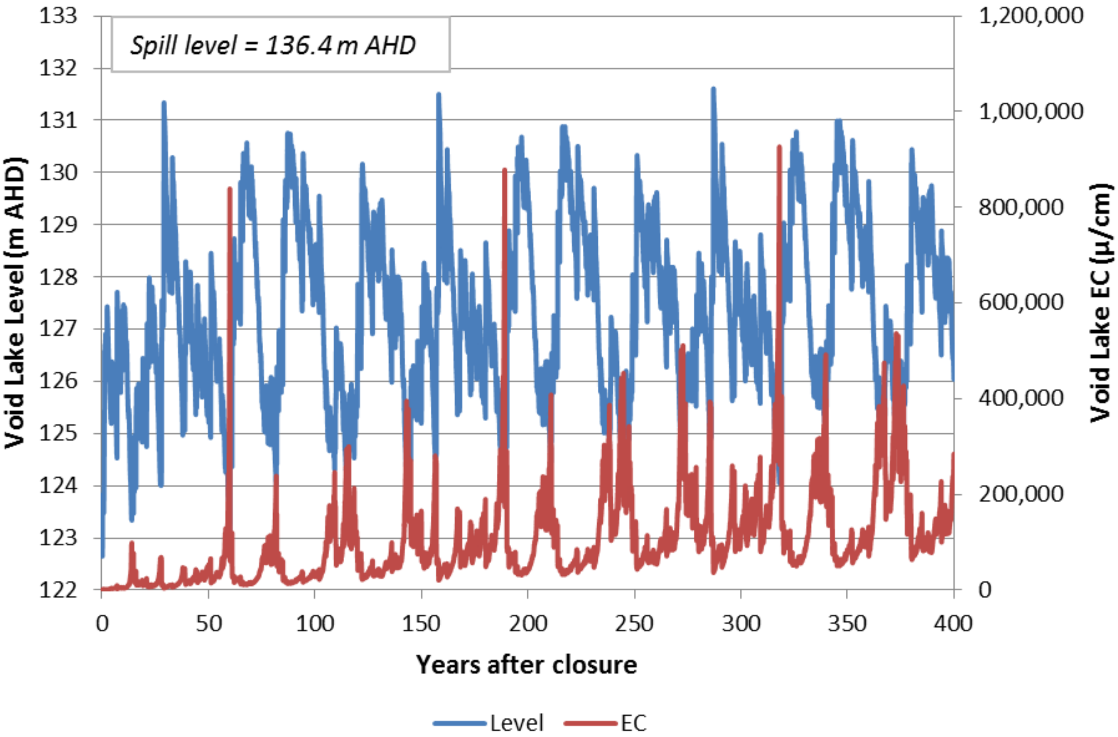


Central

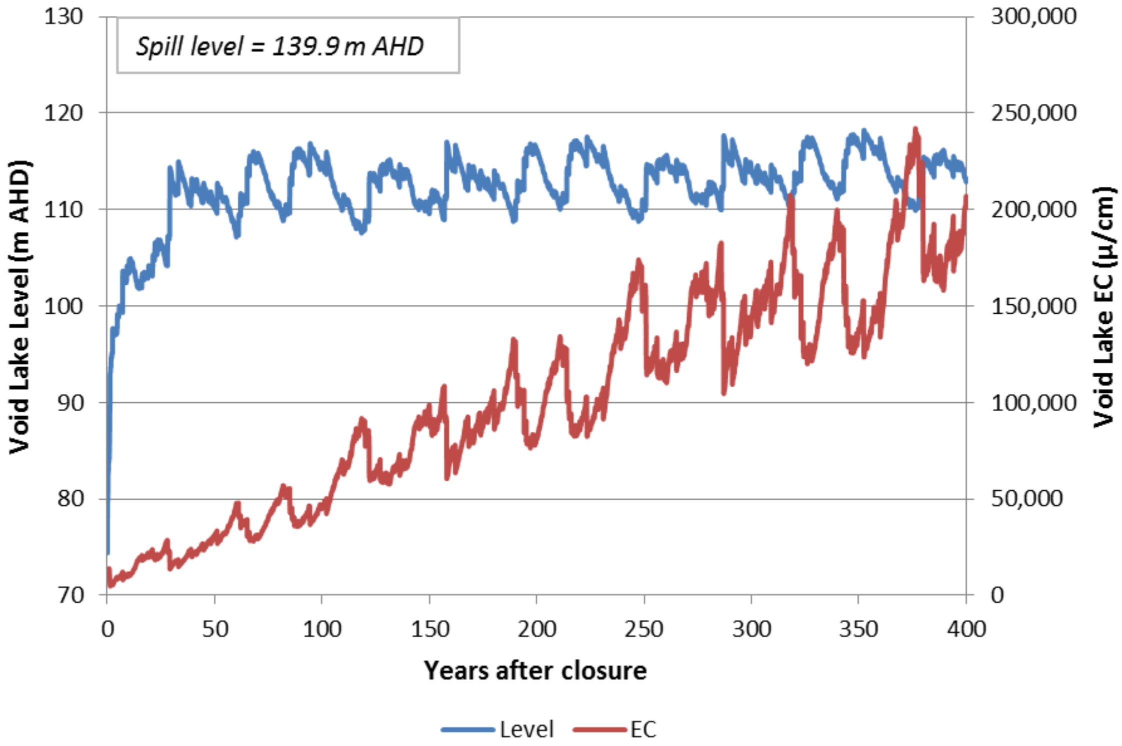
Maximum catchment, assumes seepage from Central North (results in highest void level)



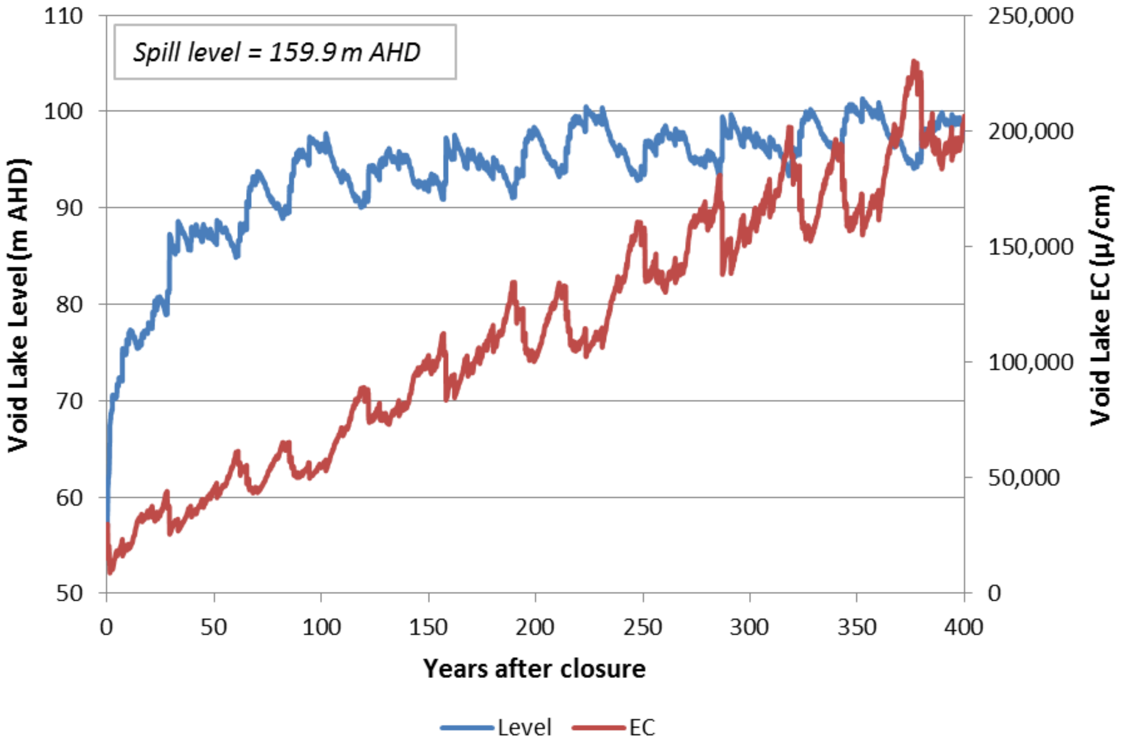
Max Pit



Central South



South



JELLINBAH COAL MINE
WEED AND PEST MANAGEMENT PLAN

PREPARED FOR

JELLINBAH MINING PTD LTD

JANUARY 2018

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2	1	Peter Splatt	1	12/09/2017	NG	
2	2	Heath Carney	1	16/01/2018	NG	HC
2	3	Jellinbah	1	16/01/2018	HC	HC

Project Manager: Gareth Bramston
Name of Client: Jellinbah Mining Pty Ltd
Name of Project: Jellinbah Coal Mine
Title of Document: Weed and Pest Management Plan
Document Version: 2.3

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LIST OF ABBREVIATIONS

AARC	AARC Environmental Solutions Pty Ltd
Act	*Biosecurity Act 2014*
DAF	Department of Agriculture and Fisheries (Queensland)
EA	Environmental Authority
GBO	General Biosecurity Obligation
JEJV	Jellinbah East Joint Venture
Jellinbah	Jellinbah Mining Pty Ltd
km	kilometre(s)
ML	Mining Lease
Plan	Plan of Operations
Project	Jellinbah Coal Mine

1.0 INTRODUCTION

AARC Environmental Solutions Pty Ltd (AARC) was commissioned by Jellinbah Mining Pty Ltd (Jellinbah) to prepare a Final Landform and Rehabilitation Management Plan for the Jellinbah Coal Mine (the Project). The Project is authorised by current Environmental Authority (EA) EPML00516813.

Jellinbah Coal Mine is operated by Jellinbah Mining Pty Ltd on behalf of the Jellinbah East Joint Venture (JEJV). The JEJV participants are: Jellinbah Group Pty Ltd, Marubeni Coal Pty Ltd, and Sojitz Coal Resources Pty Ltd.

1.1 SCOPE OF DOCUMENT

This Weed and Pest Management Plan has been prepared by AARC to provide supporting information to manage the Project's environmental obligations. The plan will outline strategies to minimise the spread of and prevent the introduction of weed and pest species.

The scope of the Weed and Pest Management Plan is to provide:

- A description of weed and pest fauna species previously identified on the Project site;
- Management strategies to minimise the spread of pre-existing weeds and assist in preventing the introduction of new species; and
- Management strategies to control the occurrence of pest faunal species on the Project site. Update this to reflect Plan of operations.

Much of the Project area is used for cattle grazing by entities not associated with the Project. This Weed and Pest Management Plan excludes these areas and is limited to those areas under the direct control of Jellinbah.

1.2 BIOSECURITY ACT 2014

Section 23 of the *Biosecurity Act 2014* (the Act) imposes a 'general biosecurity obligation', which requires everyone to "take all reasonable and practical measures to prevent or minimise the biosecurity risk". Jellinbah therefore has an obligation to manage the impacts of invasive plants and animals at the Project site.

The Act defines the following categories of invasive plants and animals:

- Restricted – an invasive plant or animal that is currently found in Queensland and has a significant impact on human health, social amenity, the economy or the environment. The Act defines seven categories of restricted invasive plants and animals:
    - Category 1 restricted matters include specific species of insects, and specific animal diseases, aquatic diseases and pathogens. A category 1 matter must be reported to Biosecurity Queensland (ph: 13 25 23) within 24 hours of becoming aware of its presence.
    - Category 2 restricted matters include particular weed and pest animal species. A category 2 matter must be reported to Biosecurity Queensland (ph: 13 25 23) within 24 hours of becoming aware of its presence.

- Category 3 restricted matters include weeds and pest animals. These matters must not be distributed (or released into the environment).
- Category 4 restricted matters include specific weeds and pest animals. These matters must not be moved to ensure it does not spread into other areas.
- Category 5 restricted matters include weeds and pest animals. These matters must not be possessed or kept except with an appropriate permit under the Act.
- Category 6 restricted matters include specific invasive animals. These animals must not be fed, with the exception of preparing for or undertaking a control program.
- Category 7 restricted matters include noxious fish.

- Prohibited – an invasive plant or animal that is not found in Queensland, but would have a significant adverse impact on human health, way of life, the economy or the environment if it entered the state.
- Other – all other invasive plants or animals that are neither restricted nor prohibited.

2.0 WEEDS

Detailed flora and fauna surveys have been undertaken prior to Project inception and development of Project extensions. Past flora and fauna survey reports were reviewed to identify weed species known to occur on the Project site. This section discusses the management of weed species listed as 'invasive plants' under the Act.

2.1 WEED SPECIES IDENTIFIED ON THE PROJECT SITE

Eight weed species, listed under the Act, have been identified on the Project site. These species are recognised as 'restricted invasive' plants that pose serious threats to primary industries and livestock, the natural environment, and human health and livelihoods (Queensland Government 2017b).

Table 1 Weed Species Identified on the Project Site

Scientific Name	Common Name	Matter Type	Category	Notes
Mackenzie North				
Cryptostegia grandiflora	Rubber Vine	Restricted invasive	3	All species frequently observed across the site. Most concentrated in riparian woodland areas
Harrisia martinii	Harrisia cactus	Restricted invasive	3	
Parkinsonia aculeata	Parkinsonia	Restricted invasive	3	
Parthenium hysterophorus	Parthenium	Restricted invasive	3	
Opuntia stricta	Prickly Pear	Restricted invasive	3	
Opuntia streptocantha	Westwood Pear	Restricted invasive	3	
Plains				
Harrisia martinii	Harrisia cactus	Restricted invasive	3	Low density throughout the site
Parkinsonia aculeata	Parkinsonia	Restricted invasive	3	Widespread throughout the site
Parthenium hysterophorus	Parthenium	Restricted invasive	3	Abundant around 5 Mile Lagoon
Bryophyllum delagoense	Mother of Millions	Restricted invasive	3	Small infestations
Central North				
Harrisia martinii	Harrisia cactus	Restricted invasive	3	Low density throughout the site
Opuntia tomentosa	Velvety Tree Pear	Restricted invasive	3	Low density throughout the site
Parthenium hysterophorus	Parthenium	Restricted invasive	3	Widespread throughout the site
Bryophyllum delagoense	Mother of Millions	Restricted invasive	3	Small infestations
Central				
Harrisia martinii	Harrisia cactus	Restricted invasive	3	No high densities but present throughout the Central area
Opuntia tomentosa	Velvety Tree Pear	Restricted invasive	3	
Opuntia stricta	Prickly Pear	Restricted invasive	3	
Opuntia streptocantha	Westwood Pear	Restricted invasive	3	
Jellinbah South				
Harrisia martinii	Harrisia cactus	Restricted invasive	3	Thinly dispersed

Figure 2 shows the presence of invasive weed species in the mining leases. The information has been collected from previous ecology surveys carried out in the project area by AARC from 2005 (informal surveys can be conducted as required, refer to section 2.3). The invasive weed species were recorded as opportunistic sightings, but a specific weed survey has never been conducted in the area. The following map does not represent the total extent of the area colonised by weed species, however indicates their presence. For some of the records, there is a brief indication of its abundance but at present there is not enough information to qualify whether the populations are large.

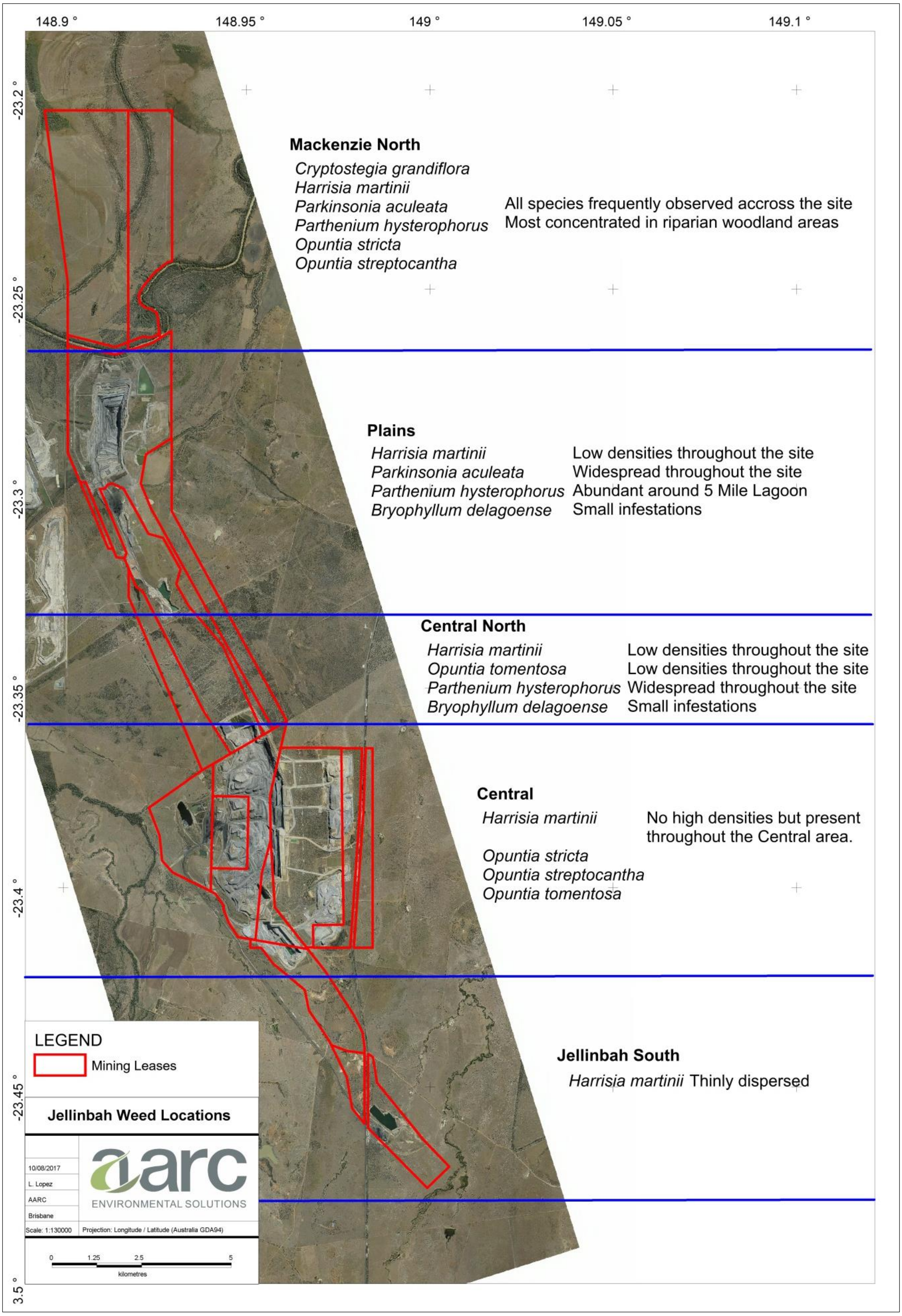


Figure 1 Weed Locations within Jellinbah Coal Mine

2.2 MANAGEMENT STRATEGIES

In accordance with the general biosecurity obligation, Jellinbah must take reasonable and practical steps to minimise or prevent the introduction or proliferation of weed species. Weed management strategies to minimise the spread of existing weeds and assist in preventing the introduction of new species include:

- Conduct annual monitoring of weed presence (i.e. abundance and spatial distribution) in conjunction with the rehabilitation monitoring program. Particular attention should be paid to areas of rehabilitation and riparian vegetation, as these areas are most susceptible to weed species invasion;

- Where weed species are identified on the Project site by the environmental consultant during annual monitoring or site inspections, inform Jellinbah personnel and ensure these areas are treated with control methods recommended by the Department of Agriculture and Fisheries (DAF);

- During subsequent monitoring / inspections, inspect areas treated previously to ensure treatments have been effective;

- Seed re-contoured areas as soon as possible and re-seed rehabilitated areas to prevent the introduction of weeds to these areas;

- Minimise the area of disturbance at the Project site at any given time to discourage the establishment of weed species; and

- Wash down vehicles when travelling from highly populated weed species areas, to areas of minimal weed presence.

Table 2 Weed Control Strategies Recommended by DAF

Species	Mechanical Control	Chemical Control
Mother of Millions (*Bryophyllum delagoense)*	Small areas may be controlled by hand-weeding and either burned on a wood heap or disposed of in a bin, the contents of which are buried at council refuse tips.	Herbicides may be applied at any time of year, although the species is more easily identified when in flower during winter. Treating infestations at this time of year also has the benefit of preventing new seeds from developing. Registered herbicides are listed in DAF Fact Sheet (provided in Appendix A).
Rubber Vine (*Cryptostegia grandiflora)*	Scattered or medium-density infestations may be controlled by repeated slashing close to ground level. Dense infestations may be controlled by stick-raking or blade ploughing during winter. Pasture and burning windrows will kill residual seed. Follow up treatment is necessary.	Herbicides may be applied via a number of methods: • Basal bark spray; • Cut stump treatment; or • Soil application (only in specific situations). Registered herbicides are listed in DAF Fact Sheet (provided in Appendix A).
Harrisia Cactus (*Harrisia martini*)	Mechanical control may include digging out individual plants, including all tubers, and burning.	Herbicide application can be effective in controlling Harrisia Cactus. Registered herbicides are listed in DAF Fact Sheet (provided in Appendix A).
Opuntia spp. (Westwood Pear, Prickly Pear, Velvety Tree Pear)	Use of machinery to remove *Opuntia* spp. is typically ineffective as it can re-establish easily.	Herbicide application is effective in controlling *Opuntia* spp. Registered herbicides are listed in DAF Fact Sheet (provided in Appendix A).
Parthenium (*Parthenium hysterophorus*)	Hand pulling of small areas is not recommended. There is a danger that mature seeds will drop off and increase the area of infestation. Colonisation may be limited by pasture maintained in a good condition with high levels of crown cover.	Herbicide may be applied to non-crop areas. Timing of herbicide application is a key factor. Registered herbicides are listed in DAF Fact Sheet (provided in Appendix A).
Parkinsonia (*Parkinsonia aculeata*)	Infestations may be controlled by stick-raking, ripping or blade ploughing. This method should be restricted to areas away from watercourses. Follow up treatment is necessary.	Herbicides may be applied via a number of methods: • Aerial application; • Foliar spray; • Basal bark treatment; • Cut stump treatment; or • Soil application. Registered herbicides are listed in DAF Fact Sheet (provided in Appendix A).

Source: DAF Fact Sheets – refer to Appendix A.

2.3 PROPOSED WEED MONITORING

Monitoring points have been selected based on vegetation type and its susceptibility of being colonised by weed species (Figure 2). It is recommended that these sites will be visited as part of the annual rehabilitation monitoring program, and quantitative data recorded in a database supported with photographic evidence.

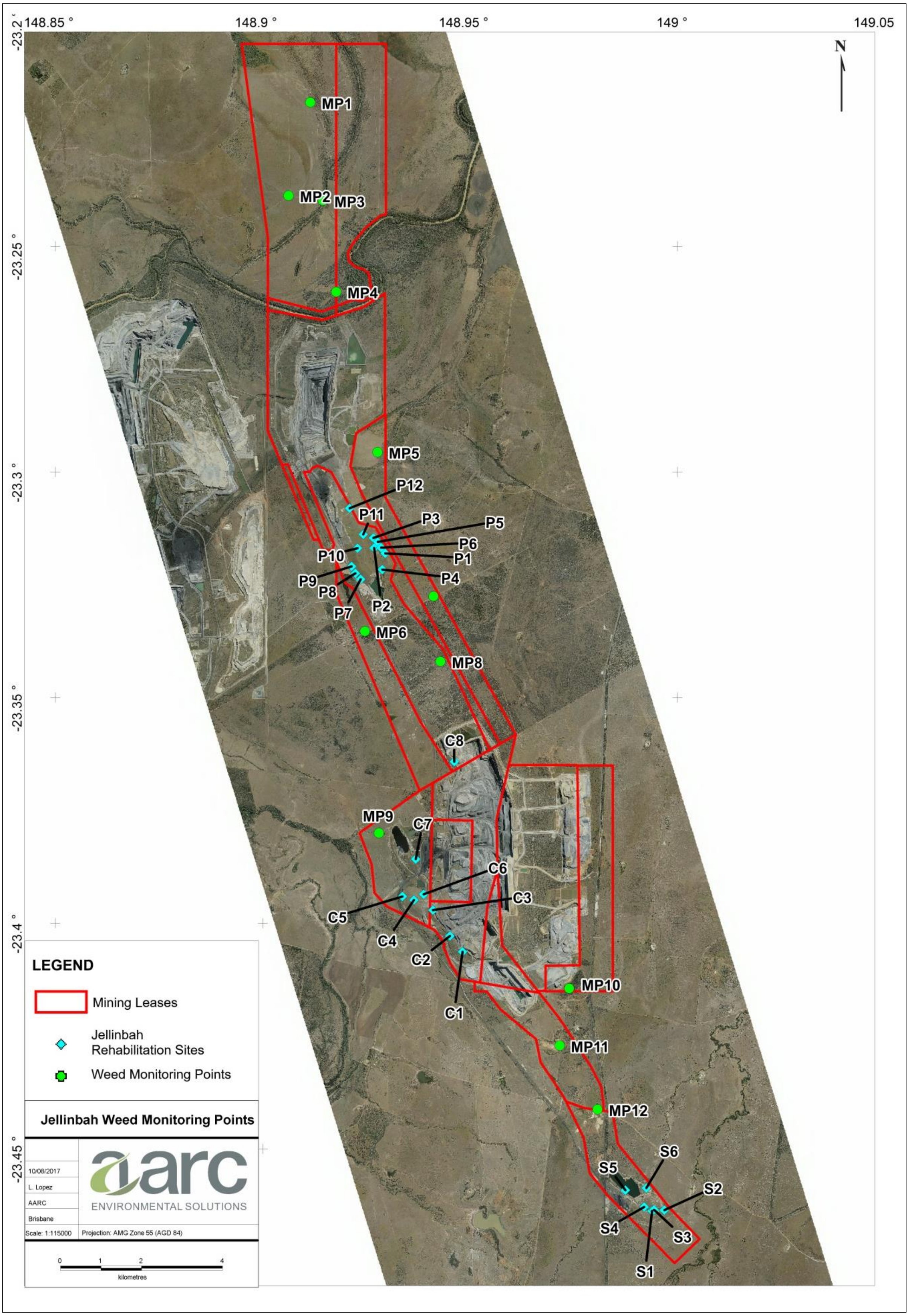


Figure 2 Proposed Monitoring Points for Weed Species in Jellinbah Coal Mine

3.0 PESTS

3.1 PEST SPECIES IDENTIFIED ON THE PROJECT SITE

Seven known pest species have been identified on the Project site in the past. In addition, an unknown deer species has been recorded on one occasion. A number of these pest species are recognised as 'restricted invasive' animals that pose serious threats to primary industries, the natural environment and native wildlife, and human and animal welfare (Queensland Government 2017c). Wild dogs are of particular concern as they are known predators of important native species such as Northern Quoll, Spectacled Hare Wallaby and Rufous Bettong.

Table 3 Pest Animal Species Identified on the Project Site

Scientific Name	Common Name	Matter Type	Category
Mackenzie North			
Rhinella marina	Cane Toad	Invasive	-
Deer	Deer	-	-
Canis lupus dingo	Dingo	Restricted invasive	Categories 3, 4, 5, 6
Oryctolagus cuniculus	European Rabbit	Restricted invasive	Categories 3, 4, 5, 6
Felis catus	Feral cat	Restricted invasive	Categories 3,4,6
Sus scrofa	Feral Pig	Restricted invasive	Categories 3,4,6
Plains			
Rhinella marina	Cane Toad	Invasive	-
Canis lupus dingo	Dingo	Restricted invasive	Categories 3, 4, 5, 6
Oryctolagus cuniculus	European Rabbit	Restricted invasive	Categories 3, 4, 5, 6
Sus scrofa	Feral Pig	Restricted invasive	Categories 3,4,6
Central North			
Rhinella marina	Cane Toad	Invasive	-
Canis lupus familiaris	Dingo	Restricted invasive	Categories 3, 4, 6
Central			
No official records of pest species have been made in the Central area			
Jellinbah South			
No official records of pest species have been made in the Jellinbah South area			

Note: The cane toad is not prohibited or restricted invasive animals under the Biosecurity Act 2014, however everyone has a General Biosecurity Obligation (GBO) to take reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control.

Figure 3 shows the presence of invasive pest species in the mining leases. The information has been collected from previous ecology surveys carried out in the project area by AARC from 2005. The invasive pest species were recorded as opportunistic sightings.

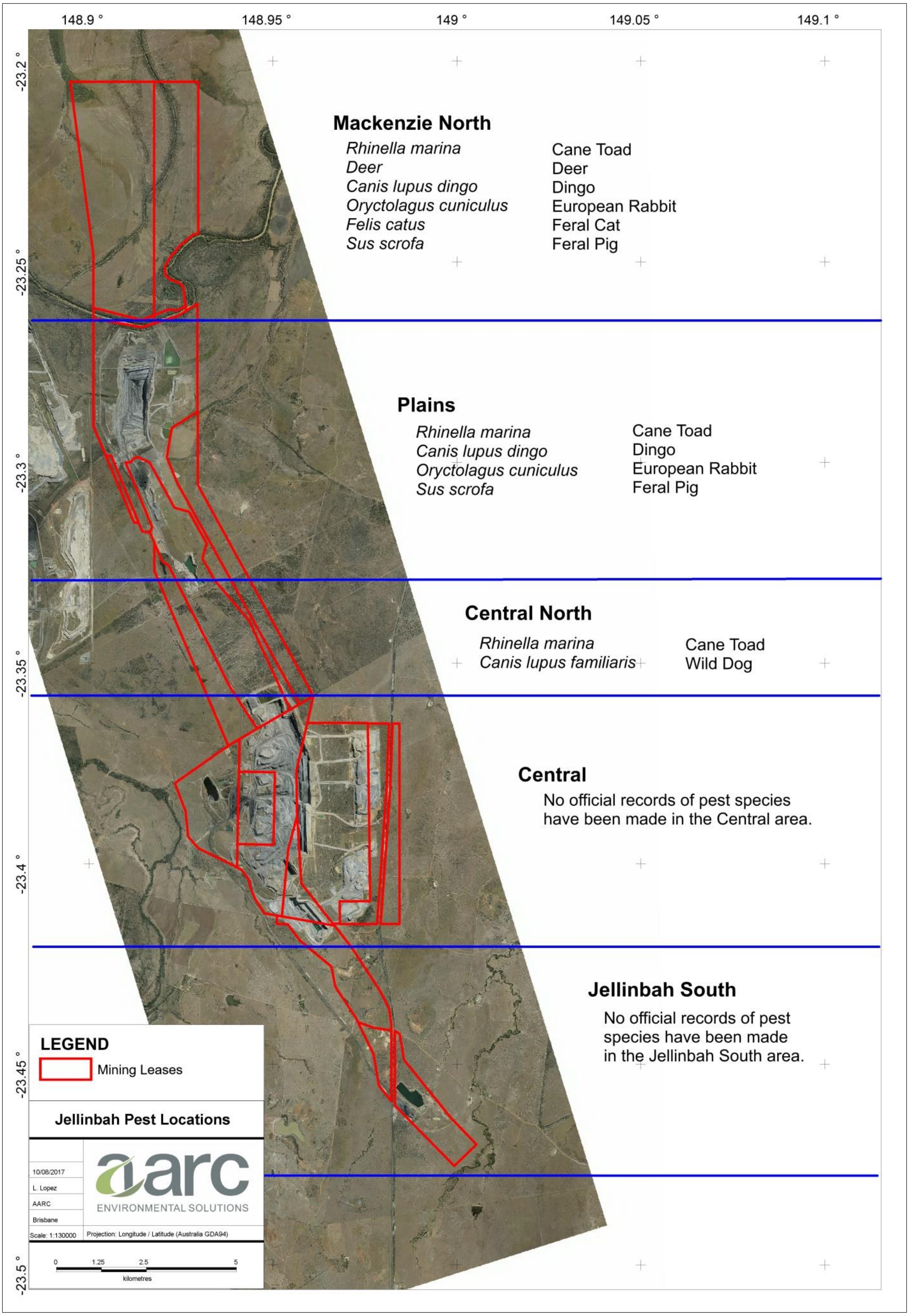


Figure 3 Pest Locations within Jellinbah Coal Mine

3.2 MANAGEMENT STRATEGIES

In accordance with the general biosecurity obligation, Jellinbah must take reasonable and practical steps to minimise or prevent the occurrence of pest fauna species on the Project site. Management strategies to minimise the occurrence of invasive pest species are outlined below:

- Store domestic waste in appropriate receptacles in areas that are inaccessible to fauna species. Ensure stored waste is disposed of in landfill on a regular basis;

- Keep landfill sites covered to reduce the occurrence of feral cats and pigs;

- Formal and informal monitoring and record keeping of weed and pest species observations.

- Avoid allowing the collection of standing water in habitable areas, wherever possible, to mitigate the reproduction of cane toads;

- Conduct visual monitoring and record keeping for pest fauna species in conjunction with annual rehabilitation monitoring. Encourage employees to report incidental sightings; and

- If regular sightings of a certain pest fauna species are reported, further action is recommended in accordance with the government advice that can be found in DAF Fact Sheets in Appendix A.

4.0 REFERENCES

Queensland Government 2017a, Biosecurity Act 2014, (Current as at July 2017), viewed 10th August 2017.

Queensland Government 2017b, *Weed control laws*, viewed 10th August 2017, https://www.business.qld.gov.au/industry/agriculture/land-management/health-pests-weeds-diseases/weeds-and-diseases/controlling-weeds-property/weed-control-laws

Queensland Government 2017c, *Pest animal control laws*, viewed 10th August 2017, https://www.business.qld.gov.au/industry/agriculture/land-management/health-pests-weeds-diseases/pests/controlling-pest-animals-property/pest-animal-control-laws

Appendix A DAF Fact Sheets

Department of Agriculture and Fisheries
Biosecurity Queensland

Invasive animal

Cane toad

Bufo marinus

The cane toad is not a declared pest in Queensland, so there is no legal requirement to control them.

Their original introduction in 1935 was to control agricultural pests, but they proved ineffective.

For the past 60 years, cane toads have been expanding their territory in Australia, and are capable of colonising at least four of the mainland Australian states.

As the toad's geographical range continues to expand, concern has increased about their detrimental environmental effects, particularly on the wetlands of the Northern Territory.

Studies into the feasibility of biological control have commenced.

Legal requirements

The cane toad is not a prohibited or restricted invasive animal under the *Biosecurity Act 2014*, however everyone has a general biosecurity obligation (GBO) to take reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control.

Local governments have a biosecurity plan that covers invasive plants and animals in their area and may require additional actions to be taken on certain species; some of these may be applied under local laws. Refer to your local government for more information.

Queensland Government

History of introduction and spread

The cane toad or giant toad is an amphibian, native to Central and South America. Cane toads have been introduced throughout the world as a biological control for insect pests of agriculture, most notably sugarcane.

A consignment of cane toads from Hawaii was released into Queensland cane fields in 1935. The introduction was surrounded by controversy as to the potential costs and benefits to Australia.

It was hoped that the toad would control Frenchi and greyback beetles—pests of economic importance to the sugarcane industry.

By 1941, however, it had become evident that the cane toad was exerting only limited control over its intended prey. There were two main reasons for this:

- Greyback beetles are only rarely in contact with the ground and Frenchi beetles invade cane fields at a time when the toads are absent due to a lack of protective cover.
- The cane toad has a wide-ranging and indiscriminate diet, and it was not solely dependant upon its intended prey.

The unlimited food source, suitable environment and low rates of predation allowed dynamic reproduction and spread. Toads were recorded in Brisbane only 10 years after release. The toad continues to thrive and has now invaded the Northern Territory and New South Wales (see Map 1).

Map 1. Distribution of the cane toad in Australia

The cane toad's advance is only limited by environmental factors, such as the availability of water for breeding, tolerable temperatures, suitable shelter and availability of food.

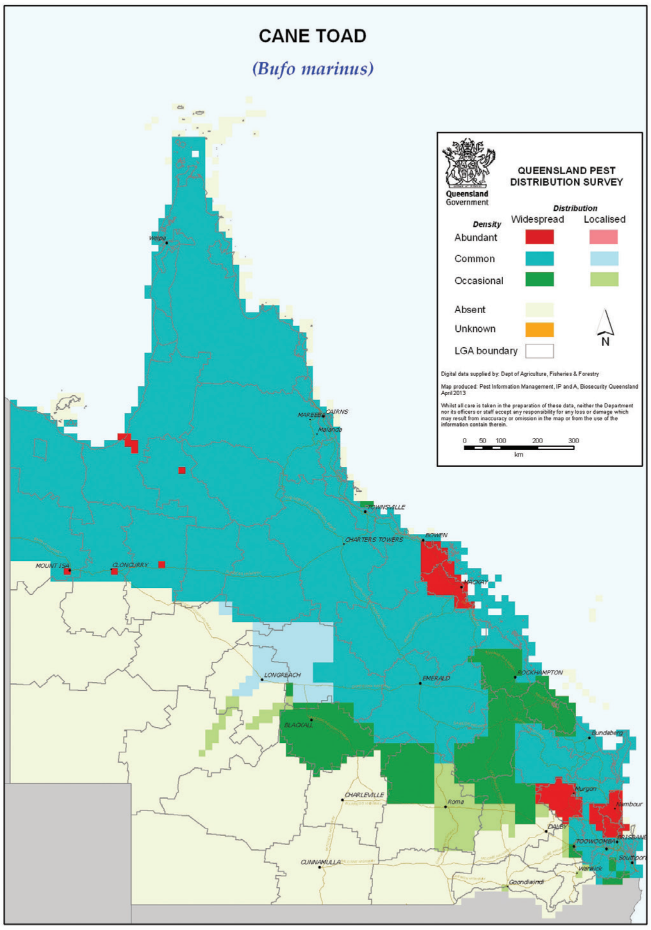
Toads at the frontier of their range of expansion may be larger than those in established populations. This is most probably due to greater food supply, combined with a lower incidence of disease.

Description

In comparison with native frog and toad species, adult cane toads have a distinctive head and face, and are large and heavily built creatures (adults may grow to 20 cm).

Following their aquatic larval stages (eggs and tadpoles), cane toads are generally encountered at night near any

Map 2. Distribution of the cane toad in Queensland

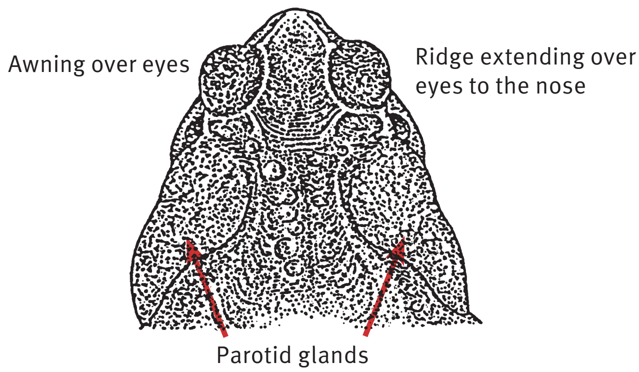


source of light. Cane toads are ground-dwelling—they are poor climbers and unable to jump very high.

A definite visor or awning extends over each eye and a high angular bony ridge extends from the eyes to the nose.

The parotid glands (see Figure 1) are perhaps the most characteristic feature of the adult cane toad. These glands are large, protuberant, and are situated on the head behind each ear. These glands carry a toxin.

Figure 1. Distinguishing features of the cane toad



The cane toad's hands and feet are relatively small and lack discs at the tips of the digits. Webbing is absent between the fingers but is distinct and leathery between the toes.

Colouring on the dorsal (upper) surface may be brown, olive-brown or reddish-brown. The ventral (under) surface varies from white to yellow and is usually mottled with brown.

Warts are present on all cane toads; however, males possess more than females. Warts are dark brown at the caps.

Mating

Mating can occur at any time of the year and depends only on available food and permanent water. The mating call is a continuous purring trill that sounds like a running motor.

In situations where females are scarce or absent, male cane toads may have the ability to undergo a sex change to become fertile females; however, this has not been proved.

Eggs

Both cane toads and native frogs spawn in slow-moving or still water, but their eggs can be easily distinguished.

Cane toad eggs are laid in long, gelatinous ‘strings’ with the developing tadpoles appearing as a row of small black dots along the length. The strings are unique to cane toads, generally appearing as blobs of jelly attached to water plants or debris. Native frogs generally produce egg clusters as mounds of foam floating on the water surface.

Compared with native species, cane toad egg production is dynamic and a single clutch can contain up to 35 000 eggs. Remove any cane toad eggs found in the water and allow to dry out.

Figure 2. Drawing of toad spawn from Wildlife of greater Brisbane

Tadpoles

The cane toad is the only species in Australia that has a pure black tadpole. Native frogs have lighter-coloured undersides with a great range of colours and markings—cane toad tadpoles may turn paler colours to almost transparent at night.

Cane toad tadpoles are small and usually congregate in vast, slow-moving shoals. This ‘shoaling’ behaviour is uncharacteristic of most native species.

Unlike cane toad tadpoles, native species develop lungs at an early stage and periodically rise to the surface in order to exchange their lung gasses. Large groupings of tadpoles that do not break the water surface for air indicate cane toads.

Young toads

Following emergence from the water, the young toadlets usually congregate around the moist perimeter of the water body for about a week before they eventually disperse.

Young toads are very difficult to distinguish from the native *Uperoleiea* species, which also have parotid glands, but all *Uperolelea* species have bright red patches in the groin area.

Under ideal conditions toadlets may reach adult size within a year.

Toxicity

Bufo marinus produce venom in glands occurring in most of the skin on their upper surface. The venom is concentrated in the parotid glands as a creamy-white solution, which is released when the animal experiences extreme provocation or direct localised pressure (e.g. grasped by the mouth of a predator).

The parotid solution is highly toxic and when ingested it produces drastic acceleration of the heartbeat, shortness of breath, salivation and prostration. It is extremely painful if accidentally rubbed into the eye.

Ingestion of toads by domestic and most native animals can result in death. In some recorded cases, death has occurred within 15 minutes.

Field observations suggest that some predatory Australian species have learned how to feed safely on cane toads.

Birds have been observed flipping toads over to avoid the parotid glands. Predatory reptiles may have more trouble adapting, being unable to remove a toad from the mouth once they start feeding.

Impacts on wildlife

The cane toad is poisonous at all stages of its life cycle and most native frog larvae and many aquatic invertebrates are dramatically affected by their presence.

Cane toads are voracious feeders that consume a wide variety of insects, frogs, small reptiles, mammals and even birds. Perhaps the only limiting factor to the prey taken is the width of the cane toad’s mouth.

It has been suggested that cane toad competition for food and breeding grounds has been responsible for reducing the populations of some native frogs. However, many native frogs are arboreal (tree-dwelling) and occupy different niches. Cane toads don’t have the native frogs’ ability to ‘shut down’ during dry seasons when resources are limited.

Pressure from cane toads may displace native animals (frogs and other species) where they are already suffering due to manipulation of their habitat by humans and grazing animals. Animals that use waterholes as retreat sites during the dry season are especially vulnerable—toads will congregate here in large numbers.

Public health

Cane toads readily eat animal and human faecal material and, in areas of poor hygiene, they have been known to transmit disease such as salmonella.

Control

Control of cane toads is not enforced as there is currently no available effective broad scale control. Individuals and community groups have carried out removal campaigns to decrease numbers and slow the invasion front.

Fencing is recommended to keep toads out of ponds intended for native fish and frogs; a height of 50 cm is sufficient. Bird wire with 1 cm holes may keep toads out of an area.

Research indicates that spread can be delayed in semi-arid areas by blocking access to water holes.

Individual toads may be killed relatively humanely using a commercial spray available from hardware stores or may be stunned and decapitated (only by experienced operators). The removal of eggs from small water bodies such as frog ponds can be effective.

Researchers have successfully mitigated impacts in recently colonised areas by 'training' predators however, large scale application of this technique is difficult.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

This fact sheet is developed with funding support from the Land Protection Fund.

Restricted invasive plant

Rubber vine

Cryptostegia grandiflora and *Cryptostegia madagascarensis*

Rubber vine's ability to quickly spread and colonise areas makes it a threat to many areas of northern Australia. Due to this ability, rubber vine is listed as a Weed of National Significance.

Rubber vine generally invades waterways first, where the seeds germinate in moist silt layers after rain. The plant smothers riparian vegetation and forms dense, sometimes impenetrable, thickets.

This decreases biodiversity and prevents access to both stock and native animals. It also creates habitat for feral animals. Infestations expand outward from waterways, hillsides and pastures, resulting in loss of grazing land and increased difficulty in mustering stock.

Rubber vine is poisonous to stock, though seldom eaten. Most deaths due to rubber vine occur after stock have been stressed, or when other feed is scarce.

Legal requirements

Rubber vine (*Cryptostegia grandiflora*) and ornamental rubber vine (*Cryptostegia madagascarensis*) are restricted invasive plants under the *Biosecurity Act 2014*. They must not be given away, sold, or released into the environment without a permit. The Act requires everyone to take all reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control. This is called a general biosecurity obligation (GBO). This fact sheet gives examples of how you can meet your GBO.

At a local level, each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

Description

Rubber vine is a vigorous climber with twining, whip-like shoots that can grow unsupported as an untidy, multi-stemmed shrub 1–2 m high, or it can scramble up to 30 m high in trees. The stems, leaves and unripe pods exude a white, milky sap when broken or cut.

Leaves are dark green and somewhat glossy, 6–10 cm long, 3–5 cm wide, and in opposite pairs.

Flowers are large and showy, with five white to light purple petals arranged in a funnel shape.

The seed pods are rigid and grow in pairs at the end of a short stalk. The pods are 10–12 cm long, 3–4 cm wide and each can contain up to 450 brown seeds. Each seed has a tuft of long, white, silky hairs, which enable easy dispersal by wind and water.

Ornamental rubber vine (*Cryptostegia spilanthoides*) is a shrub up to 3 m tall, if unsupported and stems can climb to 10 m if supported. Bark is sparsely dotted with corky patches. Leaves are dark green, glossy, with pale underside, 2–11 cm long, 1.5–5.5 cm wide, arranged in opposite pairs. Plant produces milky latex sap when leaves, fruit or branches are cut.

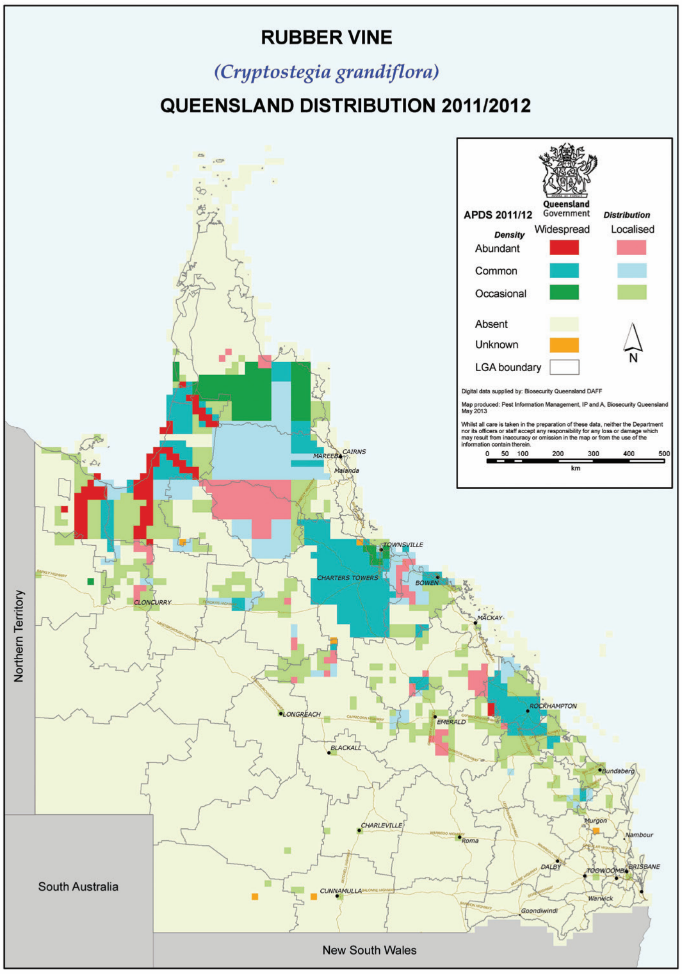
Flowers are pink-purple, 4–6 cm long, found near branchlet ends. Pods are 7–9 cm long, contain seeds 5–5.9 mm long, 1.8–3.5 mm wide, topped with silky tuft of white hairs.

Life cycle

Rubber vine flowers at any time of year if sufficient moisture is available. Usually, June and July are the only non-flowering months. Plant stem diameter must be approximately 20 mm before flowering can occur.

Seed pod formation occurs from spring to late autumn, with peak seed production corresponding to maximum flowering. Eventually, pods dry out and split open, with pod-splitting occurring approximately 200 days after formation.

Map 1. Distribution of rubber vine in Queensland



Seeds are scattered by wind, but also carried downstream by water. Approximately 95% of seed is viable, although germination requires favourable temperature and soil moisture conditions.

Methods of spread

Rubber vine seeds spread by wind and water.

Habitat and distribution

Rubber vine is native to Madagascar, but is now widely distributed throughout tropical and subtropical regions of the world.

The plant was introduced to Australia as an ornamental shrub in 1875 or earlier, and was popular in north Queensland mining settlements due to its luxuriant growth even under harsh conditions. Weedy infestations were recorded around Charters Towers early this century.

Rubber vine prefers areas where annual rainfall is 400–1400 mm, and is well adapted to a monsoonal climate.

Infestations of rubber vine are now found throughout river systems of southern Cape York and the Gulf of Carpentaria, south along the coast to the Burnett River, and isolated infestations occur as far south as Gatton and as far west as the Northern Territory border.

Infestations are common throughout central Queensland, while in western Queensland there are infestations in the Mount Isa, Longreach and Aramac areas. Isolated infestations have been reported in Western Australia.

Control

Managing rubber vine

The GBO requires a person to take reasonable and practical steps to minimise the risks posed by rubber vine. This fact sheet provides information and some options for controlling rubber vine.

Effective control of rubber vine can be achieved by a number of methods, alone or in combination depending on the situation and the severity of infestation. All areas treated must be periodically checked and any regrowth treated or the initial treatment efforts will be wasted.

Rubber vine seed is most commonly spread by wind and running water.

It is thus difficult to prevent seed coming onto uninfested land if there is rubber vine anywhere in the area. Your goal should be to prevent rubber vine from establishing and forming dense infestations. It is essential to regularly inspect all areas of your property, paying particular attention to creeks and gullies.

This is most important where prevailing winds are known to blow from infested areas, or where infestations occur upstream.

Any isolated plants located should be treated promptly.

All control of rubber vine will require follow-up treatments to keep your property clean. As rubber vine spreads quickly, small infestations should be controlled first to prevent them from becoming major problem areas. Dense infestations are difficult and costly to treat.

Follow-up treatment must be budgeted for within the overall control program. Techniques need to be integrated for successful rubber vine management. Consideration should be given to coordinating control over a catchment area.

Five suggested strategies for controlling rubber vine in scattered, medium, and dense infestations are outlined in Table 2.

Fire

Rubber vine infestations can be very effectively controlled by burning. Preparing and managing fuel load prior to burning, and following up in a timely manner after the fires, are critical to the overall success of the program.

It is recommended that you perform two successive annual burns. The first fire will open up the infestation to increase grass growth (fuel load) while killing rubber vine plants. The second fire will clean up the regrowth that occurs after the first fire.

An appropriate fire regime is an effective tool for managing rubber vine over the long term, as well as being an effective follow-up to other control methods.

Mechanical control

Several mechanical techniques are effective in controlling rubber vine. The type of infestation will determine the technique required.

- Scattered or medium-density infestations: Where possible, repeated slashing close to ground level is recommended.
- Dense infestations: During winter, stick-raking or blade-ploughing reduces the bulk of the infestation. Pasture should be sown and windrows burned to kill residual seed. Follow-up treatment is essential. It is important to comply with the relevant state and/or local government native vegetation legislation, and it should be noted that causing even accidental death of vegetation can be a breach of this legislation.

Biological control

Two biological control agents are successfully established, and their impact depends on abundance. Both agents cause abnormal defoliation, creating an 'energy sink', which appears to reduce seed production. These agents usually do not kill established rubber vine plants.

Diseases

Rubber vine rust (*Maravalia cryptostegiae*) is established over a wide area. Yellow spores form under the leaves and are spread mainly by the wind.

It is most active over summer, abundance being directly related to leaf wetness, which is dependent on rainfall and dew. Over summer, a generation is completed every seven days. Rust activity is reduced over the dry season.

Continued heavy infection causes defoliation, appears to reduce seed production, can kill small seedlings and causes dieback of the whip-like stems. Established plants are not killed.

Insects

Also established is the moth *Euclasta whalleyi*, whose larvae are leaf feeders. Observation indicates the moth prefers stressed plants, either from limited soil moisture or high levels of rust infection.

The moth's period of activity is the dry season. A native fly parasite and a disease can reduce the localised abundance of the *Euclasta* larvae.

The larvae are tapered at both ends, grow up to 30 mm long, and are grey-brown with orange dots along their sides. Fine silken threads and black, bead-like droppings are often found near the larval feeding damage.

The creamy-brown moths are active at night and rest at a 45° angle from a surface, with their wings folded. The life cycle from egg to adult takes 21–28 days.

Defoliation reduces the smothering effect on other vegetation and causes an increase in leaf litter and promotes increased grass growth amongst rubber vine, increasing fuel loads required for fire management. Decreased flower and pod production should reduce the ability of rubber vine to spread.

Herbicide control

Basal bark spray

This method gives a high level of control although it is not as effective on multi-stemmed plants as it is difficult to spray each stem completely around the base.

Thoroughly spray around the base of the plant to a height of 20–100 cm above ground level, spraying higher on larger plants.

Optimum results are attained when the plant is actively growing.

Cut stump treatment

This is the most successful method of herbicide control, but also the most labour intensive. The following points should be followed carefully:

- cut the stem off as close to the ground (within 15 cm) as possible; for smaller plants use a machete or similar; larger plants may require a chainsaw
- make sure the cut is horizontal
- immediately spray or swab the cut surface
- a cost-effective method for scattered to medium-density infestations is the use of a brush-cutter.

Soil application

Because of the high risk of killing non-target vegetation, including trees and pasture plants, soil-applied herbicides play a role in controlling rubber vine only in specific situations.

It is important to comply with the relevant state and/or local government native vegetation legislation, and it should be noted that causing even accidental death of vegetation can be a breach of this legislation.

The following points should be followed carefully:

- do not use residual herbicides within a distance of two or three times the height of desirable trees
- do not use Graslan along waterways or land with greater than a 20^0 slope
- a minimum of 50–80 mm of rainfall is required before residual herbicides are taken up by the plant.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

Table 1. Herbicides for the control of rubber vine

Situation	Herbicide	Rate	Comments
Agricultural non-crop areas, commercial and industrial areas, forests, pastures and rights-of-way	Triclopyr 300 g/L + Picloram 100 g/L + Aminopyralid 8 g/L (Grazon Extra) or Triclopyr 300 g/L + Picloram 100 g/L (e.g. Conqueror)	350–500 mL/ 100 L water	High volume spray Actively growing plants not infected with rust Use the higher rate for dense stands higher than 1.5 m tall at flowering (consult label)
Native pastures, rights-of-way, commercial and industrial areas	Metsulfuron-methyl 600 g/kg (e.g. Associate, Ken-Met 600)	15 g/100 L water	High volume spray on actively growing plants Apply to actively growing bushes up to 3 m tall, October through April Wetting agent is critical Complete coverage is essential May damage pasture legumes (consult label)
Agricultural non-crop areas, commercial and industrial areas, forests, pastures and rights-of-way	2,4 D 300 g/L + Picloram 75 g/L (e.g. Tordon 75-D, Commander 75-D)	1.3 L/100 L water	Treat actively growing plants Thoroughly wet leaves and soil around base of plant Less effective than other treatments
Around agricultural buildings and other farm non-crop situations, commercial, industrial, and public service areas, rights-of-way and waster land, away from desirable vegetation	Imazapyr 250 g/L (e.g. Unimaz 250 SL)	4 mL/L water	High volume application to actively growing plants (consult label)
Non agricultural areas (native pastures) commercial and industrial areas and rights-of-way	Aminopyralid 375 g/kg plus Metsulfuron-methyl 300 g/kg (e.g. Stinger)	30 g/100L water plus wetting agent (consult label)	Apply to bushes up to 3 m in height Apply from October to April when bushes are actively growing. Ensure thorough spray coverage of all foliage and leaders Incomplete coverage will result in regrowth
Native pastures, rights-of-way, commercial and industrial areas	Triclopyr 75 g/L + Metsulfuron-methyl 28 g/L (e.g. Zelam Brush Weed)	375 mL/100L	Spray actively growing plants up to 3 m tall, from October to April. Thoroughly spray all foliage and leaders. Incomplete coverage will result in regrowth
Agricultural non-crop areas, commercial and industrial areas, fencelines, forestry, pastures and rights-of-way	Triclopyr 240 g/L + Picloram 120 g/L (e.g. Access)	1 L/60 L diesel	Basal bark plants up to 5 cm basal diameter Treat at any time Thoroughly spray around base of plant
Agricultural non-crop areas, commercial and industrial areas, forests, pastures and rights-of-way	Triclopyr 600 g/L (e.g. Garlon 600, Triclopyr 600)	1 L/60 L diesel	Basal bark Treat at any time Thoroughly spray around base of plant
Agricultural non-crop areas, commercial and industrial areas, fencelines, forestry, pastures and rights-of-way	Triclopyr 240 g/L + Picloram 120 g/L (e.g. Access)	1 L/60 L diesel	Cut stump Apply immediately cut is made
Agricultural non-crop areas, commercial and industrial areas, forests, pastures and rights-of-way	Triclopyr 600 g/L (e.g. Garlon 600, Triclopyr 600)	1 L/60 L diesel	Basal bark size and larger plants
Non-crop areas, including: native vegetation, conservation areas, gullies, reserves and parks	Picloram 44.7 g/L + aminopyralid 4.47 g/L (Vigilant II)	Undiluted	Cut stump as close to the ground as possible. Apply immediately according to label instructions
Pastures, rights-of-way and industrial	2,4-D as amine 700 g/L (e.g. Amicide Advance 700)	145 mL/10L water	Cut stump Apply immediately
Other formulations of 2,4-D are also registered for cut-stump treatment of rubber vine. Consult labels for registration details, rates and critical comments.			
	Hexazinone# 250g /L (e.g. Bobcat®SL, Velpar®L)	2 mL/spot, 3 spots for each bush (tree)	Soil application# prior to rain See warning below. #Must place spots around bush. Less effective on sandy soils
	Tebuthiuron# 200 g/kg (e.g. Graslan, Tebuthiuron 200)	1.5 g/m^2	Soil application# prior to rain Application prior to rain by hand or backpack spreader
	Triclopyr 300 g/L + Picloram 100 g/L+ Aminopyralid 8 g/L (Grazon Extra) or Triclopyr 300 g/L + Picloram 100 g/L (e.g. Conqueror, Grass-up)	3–5 L/ha	Aerial application (helicopter only) to actively growing plants Triclopyr 300 g/L + Picloram 100 g/L
	Tebuthiuron# 200 g/kg registered for aerial application (e.g. Graslan)	7.5–15 kg/ha	Aerial application prior to rain Triclopyr 300 g/L + Picloram 100 g/L

Warning: Soil testing is highly recommended prior to application of these herbicides, as rate and efficacy are dependant on soil type.
DO NOT USE SOIL APPLIED HERBICIDES (HEXAZINONE AND GRASLAN) WITHIN A DISTANCE OF TWO TO THREE TIMES THE HEIGHT OF DESIRABLE TREES.
DO NOT USE GRASLAN NEAR WATERWAYS OR LAND WITH GREATER THAN A 20° SLOPE.

Read the label carefully before use. Always use the herbicide in accordance with the directions on the label.

Table 2. Suggested strategies for the control of rubber vine

Situation	Initial treatment	Follow-up	Comments
Scattered infestations	Basal bark/ cut stump	Follow-up with basal bark/ cut stump as necessary	Cut stump method preferred where possible
	Foliar spray	Follow-up basal bark/ cut stump/foliar spray as necessary	Only foliar spray when there is nil to little rust on the leaves of the plants
	Fire	Follow-up basal bark/ cut stump/foliar spray as necessary	For scattered infestations usually recommended only if herbicides not desired, or if have other weeds can be controlled by fire or if fire is utilised to improve pastures
	Repeated slashing		
Medium infestations	Foliar spray	Treat regrowth, seedlings with basal bark/cut stump/ foliar spray	Fire and follow-up with basal bark/cut stump/foliar spray as necessary
	Fire	Fire 1 year later and follow-up basal bark/cut stump/ foliar spray as necessary	If fuel load is sufficient **CAUTION:** There are some native tree species which are susceptible to fire Check before burning
	Repeated slashing		
Dense infestations previously cleared areas	Stick rake or blade plough	Sow pasture – basal bark/ foliar spray – fire and basal bark/cut stump/foliar spray as necessary	First treatment clears bulk of rubber vine and kills roots; any regrowth or seedlings can then be treated; when grass growth allows fuel build up, fire used as control and individual plants later treated
	Fire	Fire one year later and follow-up basal bark/ cut stump/foliar spray as necessary	If fuel load is sufficient **CAUTION:** There are some native tree species which are susceptible to fire Check before burning
	Aerial spray	Fire 1–2 years later or follow-up with basal bark spray	Bulk of rubber vine killed with aerial spray; allow build up of fuel for fire or treat remaining plants with basal bark spray Contact 13 25 23 before use of this method
	Graslan		Where situation and soil type are suitable
Dense infestations along creeks and rivers	Basal bark/ cut stump	Fire or basal bark/cut stump/foliar spray	When bulk of rubber vine killed, allow fuel build up for fire or treat remaining plants individually
	Fire and sow pasture	Fire one year later and follow-up basal bark/cut stump/foliar spray as necessary	If there is a sufficient fuel load to carry a fire, it can open up dense infestations **CAUTION:** There are some native tree species which are susceptible to fire Check before burning

This fact sheet is developed with funding support from the Land Protection Fund.

Department of Agriculture and Fisheries
Biosecurity Queensland

Restricted invasive plant

Harrisia cactus

Moonlight cactus

Harrisia martinii, Harrisia tortuosa and *Harrisia pomanensis*

Harrisia cactus can form dense infestations that will reduce pastures to a level unsuitable for stock. Harrisia cactus will choke out other pasture species when left unchecked.

The spines are a problem for stock management, interfering with mustering and stock movement.

Harrisia cactus produces large quantities of seed that is highly viable and easily spread by birds and other animals. As well as reproducing from seed, harrisia cactus has long trailing branches that bend and take root wherever they touch the ground. Any broken-off portions of the plant will take root and grow.

Legal requirements

Harrisia cactus (*Harrisia martinii, Harrisia tortuosa* and *Harrisia pomanensis*) are restricted invasive plants under the *Biosecurity Act 2014*. It must not be given away, sold, or released into the environment without a permit. The Act requires everyone to take all reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control. This is called a general biosecurity obligation (GBO). This fact sheet gives examples of how you can meet your GBO.

Queensland Government

At a local level, each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

Description

Harrisia cactus is a perennial. The spiny fleshy stems are jointed and form tangled mats about half a metre high. Many branches often lie flat and take root where they touch the ground. Each section is ribbed lengthwise with six ribs; each rib has low, thick, triangular humps at regular intervals. These humps have cushions of grey felty hairs, three to five short spines lying flat, and one to three erect, stiff, very sharp spines 2.5–3 cm long.

The large flowers open at night. Flowers are pink and funnel-shaped with a tinge of white. These grow singly near the ends of the stems on a scaly but spineless slender grey-green tube 12–15 cm long.

Round, red fruits 4–5 cm across have scattered bumps with hairs and spines. Numerous small black seeds are embedded in the white, juicy pulp of the fruit, which splits open when ripe.

Harrisia cactus roots are of two types. Shallow feeding roots up to 3 cm thick and 30 cm to 2 m long grow mostly horizontally off a crown, up to 15 cm below ground level. Swollen tuberous storage roots descend to a depth of 15–60 cm.

Life cycle

Harrisia cactus bears a bright red fruit containing 400–1000 small black seeds. Plants are easily established from seed and germinate soon after rain.

Seedlings quickly produce a swollen tuberous food storage root that develops as the plant grows. Branches take root where they touch the ground and new plants will grow from broken branches and sections of underground tubers.

Counts of tubers in dense cactus infestations have shown over 125 000 per hectare. Each plant houses many dormant underground buds that are all capable of reshooting when the tip growth dies; any small portion of the tuberous root left in the soil will grow.

Methods of spread

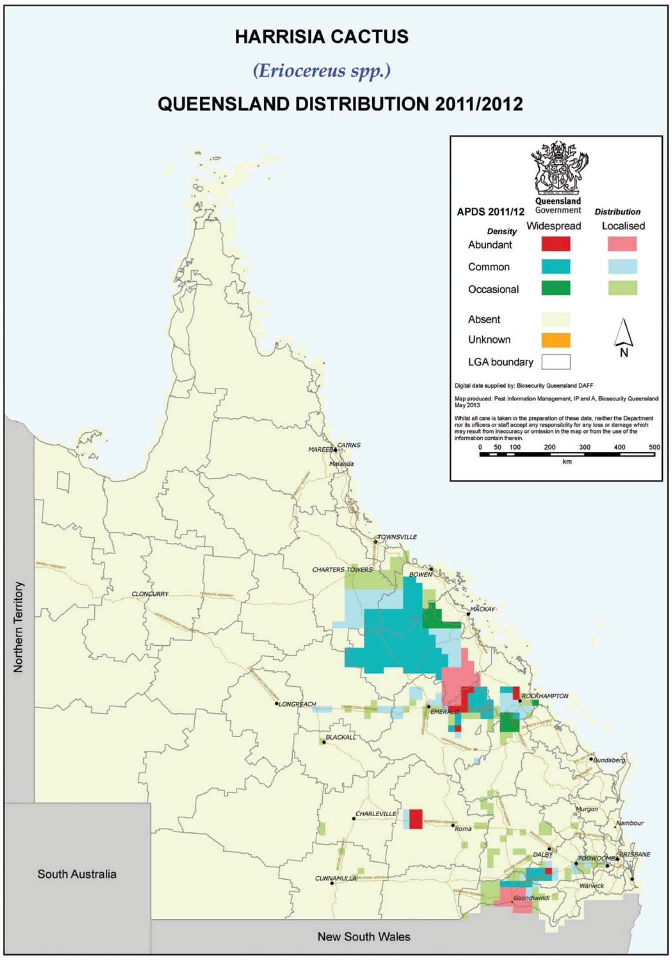
Fruit and seed are readily eaten by birds, mammals and to a lesser extent by feral pigs.

Habitat and distribution

Harrisia cactus is a native of Argentina and Paraguay, South America. It was introduced to Australia as a pot plant in the 1890s. In 1935 it was first recognised as a serious pest in the Collinsville district and by the 1950s was rapidly spreading south.

Harrisia cactus is mainly a pest of brigalow and associated softwood country. However, infestations are now appearing in box and ironbark stands and also in pine forests.

Map 1. Distribution of harrisia cactus in Queensland



The cactus is shade tolerant and reaches its maximum development in the shade and shelter of brigalow scrub, though established infestations can persist once scrub is pulled.

Harrisia cactus is found in the Collinsville, Nebo, Moranbah, Dingo, Blackwater and Goondiwindi districts, with minor infestations occurring at Millmerran, Greenmount, Gatton, Ipswich, Rockhampton, Rannes, Mount Morgan, Alpha and Mitchell.

Control

Managing harrisia cactus

The GBO requires a person to take reasonable and practical steps to minimise the risks posed by harrisia cactus. This fact sheet provides information and some options for controlling harrisia cactus.

Control of this plant is difficult as it has a deep underground tuberous root system and use of a combination of physical, biologic and herbicide controls is recommended.

Physical control

Dig out plants completely and burn. Ensure that all tubers that can grow are removed and destroyed.

Ploughing is not considered an effective means of control unless followed by annual cropping.

Biological control

Two introduced insects have become established in the field:

- a stem-boring longicorn beetle (*Alcidion cereicola)*
- a mealy bug (*Hypogeococcus festerianus*).

The stem-boring beetle only attacks older woody stems. In the Collinsville area, large beetle colonies developed and contributed to the collapse of dense areas of cactus. Populations of *Alcidion cereicola* have declined with the reduction in the cactus in recent years.

The most successful biological control agent is the mealy bug *Hypogeococcus festerianus* which is now present in harrisia cactus in Collinsville, Dingo, Moranbah, Blackwater, Nebo, Charters Towers and Goondiwindi districts, with small colonies established at Alpha, Capella, Rannes, Gatton, Greenmount, Millmerran and Rockhampton.

How mealy bug works

The mealy bug aggregates and feeds in the tips of stems and buds, where it limits growth and causes distortion. This results in the knotting of the stem. The plant's response is to utilise energy reserves within the tuber system to produce new growth. Eventually the plant dies, as it is unable to support the continuous high energy demands.

Dry weather reduces the effectiveness of the mealy bug. When dry, the plant's tuber system becomes dormant. Consequently, mealy bug damage does not result in new growth and the energy reserves within the plant are not affected. Instead the bug may damage all vegetative parts and eventually die out. The tuber will remain dormant until adequate moisture returns, when it will reshoot.

How to spread the bug

Mealy bug disperses naturally via wind, although landholder assistance is necessary for its continuous spread, particularly between patches. The bug is manually spread by cutting infected stems and placing them into healthy plants. The best pieces for starting new colonies are large knobs of twisted and distorted cactus that contain many mealy bugs well protected inside knots. Stem tips covered by white, woolly masses of bug are also good. To collect the bug, cut infected stems approximately 15 cm from the distorted knob and place segments in green, plump sections of the healthy plant. Avoid placing mealy bug in stressed or dried out stems. Small cactus plants require at least one large knot, with larger plants requiring three knots per plant. Where possible, landholders should infest every cactus clump as this ensures a rapid reduction in growth and fruiting potential. When cactus infestations are light, chemical control may be a preferable option.

Cut pieces can be transported in boxes or open vehicles. They are not delicate, but are best kept in the shade. Avoid keeping them in large heaps, in direct sunlight, under tarpaulins or in closed containers for long periods. Such conditions will promote rotting of the stems, leading to poor results or failures. Ideally, stems should be put out within three days and a maximum of five days.

When to infest

Best results come by infesting new areas during spring and early summer, from September to December. Maximum growth and spreading occurs in the summer months of December to February. During the drier and colder months of April to August the mealy bug does not die, but little growth and multiplication occurs. Introduction of mealy bug during autumn and winter will not be lost, but little effect is seen until the following summer.

How soon to expect results

Mealy bugs are generally more active and effective on harrisia cactus growing underneath shrubs and trees, so results will be seen more quickly in these areas than in cactus growing in the open. Best results are obtained when infesting plants that have actively growing new shoots.

During wet summers in northern and central Queensland, the growing points of stems will begin to curl after about six weeks.

By the end of the first summer, damage (severe twisting) will be widespread in infested plants. If the initial infestation was sufficiently heavy, no fruit or growth will occur during the second year, and the cactus will begin to die during the third year. Seedlings and regrowth shoots will continue to be present but by the end of the fourth year there should be very little cactus left.

In the southern portion of the state, where temperatures are lower, the mealy bug still provides control but the process takes longer. However, the mealy bug will do better on cactus in the open, rather than in the shade, as temperatures are higher in the open.

Herbicide control

Foliar application of registered herbicides provides effective control, but can be costly over large areas. Before using any herbicide always read the label carefully. All herbicides must be applied strictly in accordance with the directions on the label (see to Table 1).

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

Table 1. Herbicides for the control of harrisia cactus

Situation	Herbicide	Rate	Comments
Non-crop land and rights-of-way	Dichlorprop as K salt (600 g/L)	1 L/60 L water	Good soil moisture essential Spray plant when actively growing to run-off point A follow-up treatment may be necessary
Native pastures, rights-of-way, commercial and industrial areas	Metsulfuron-methyl (600 g/kg) (e.g. Brush-Off®)	20 g/100 L water + surfactant	Spray plant when actively growing to run-off point A follow-up treatment may be necessary
Agricultural non-crop areas, commercial and industrial areas, fence lines, forestry, pastures and rights-of-way	Triclopyr as butotyl (240 g/L) + Picloram as ioe (120 g/L) (e.g. Access®)	1 L/60 L diesel	Spray plant when actively growing Apply as overall spray, wetting all areas of the plant to ground level
Non-agricultural areas (native pastures), commercial and industrial areas and rights-of-ways	Aminopyralid as K salt 375 g/kg + Metsulfuron methyl 3 g/kg (e.g Stinger)	40 g/100 L water	Spray to thoroughly wet using 1000 to 1400 L/ha Follow-up treatment may be necessary
Commercial and industrial areas, around buildings and rights-of-way	Triclopyr as butotyl 75 g/L + Metsulfuron-methyl 28 g/L (e.g. Zelam Brush Weed®)	500 mL/100 L	Spray to thoroughly wet using 1000 to 1500 L/ha Follow-up treatment may be necessary
Agricultural non-crop areas, commercial and industrial areas, forests, pastures and rights-of-way	Triclopyr as tea 200 g/L + Picloram as tipa 100 g/L (e.g. Slasher) or Triclopyr as tea 200 g/L + Picloram as tipa 100 g/L + Aminopyralid 25 g/L (e.g. Tordon RegrowthMaster) (e.g. Tordon DSH®)	2.5 L/100 L water	Spray plant when actively growing (September–March) Treat all stems thoroughly

Read the label carefully before use. Always use the herbicide in accordance with the directions on the label.

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03/17

Department of **Agriculture and Fisheries**
Biosecurity Queensland

Invasive plant risk assessment

Athel pine

Tamarix spp.

Steve Csurhes

First published 2008
Updated 2016

Queensland Government

Contents

Summary

There are about 54 different species of *Tamarix* native to various parts of the Middle East, China and Europe. A number of species within the genus are very closely related and can hybridise. Several species within the genus are invasive: *T. ramosissima* (salt cedar) is one of the 10 worst weeds in the United States (US), where it infests an estimated 1.5 million acres.

It is also listed by the International Union for the Conservation of Nature (IUCN) as one of 100 of the world's most invasive species. *T. chinensis* and *T. parviflora* are also invasive in the US. In Australia, *T. aphylla* (athel pine) is one of 20 Weeds of National Significance. Currently, athel pine is a major problem along the Finke River in central Australia and is at an earlier stage of population development elsewhere in Australia. Dense, mature stands of *Tamarix* pose a serious threat to natural biodiversity and can cause localised salinity and loss of groundwater. In Queensland, *T. aphylla* has been widely planted to provide shade and ornament for many decades.

However, over the past 5–10 years it has started to spread quite noticeably at a few locations. These infestations need to be eliminated as a matter of urgency if large-scale problems comparable to those being experienced in the Northern Territory and the US are to be prevented. All arid-zone river systems that have sandy banks (and associated floodplains) and a water table that can be reached by the specialised roots of *Tamarix* species appear to be at risk of invasion.

Identity and taxonomy

Taxa: This assessment covers the entire *Tamarix* genus.

Common names: Athel pine (Australia), tamarisk (US), salt cedar (US).

Taxonomy: *Tamarix*, together with two other small Asian genera, *Myricaria* and *Reaumuria*, constitute the family Tamaricaceae (DeLoach et al. 1999). *Tamarix* is an ancient genus in Asia that is taxonomically isolated from other plant families (Baum 1967; Crins 1989).

Tamarix comprises about 54 species (DeLoach et al. 1999).

The taxonomy of the genus is unclear with multiple species being morphologically very similar. This confusion is probably due, in part, to the ability of some *Tamarix* species to interbreed. For example, in the US, DNA studies suggest that *T. chinensis* (and possibly hybrids between it) and *T. ramosissima* occur in some western areas (DeLoach et al. 1999). Some authors continue to distinguish many species, while others consider *T. pentandra, T. tetranda, T. gallica, T. chinensis, T. ramosissima* and *T. parvifolia* to be one variable species or hybridising group best designated by the single name *T. pentandra* (Sudbrock 1993).

T. aphylla, T. petandra, T. ramosissima, T. indica and *T. parviflora* have been recorded by Australian herbaria. However, the accuracy of these identifications is questionable, given the confusion that exists over taxonomy of the genus. Some references deal with the uncertainty by simply referring to a *T. ramosissima/T. chilensis* complex.

In Australia, the most problematic species is *T. aphylla*. The latter species is sometimes confused with *T. ramosissima*, which has also been commonly planted as a shade and ornamental tree.

Description

Tamarix species are spreading, often multi-branched, trees up to 12 m tall with pendulous branches (Figure 1).

T. aphylla is evergreen, whereas other congeners, including *T. ramosissima*, are deciduous. *Tamarix* species are flowering plants and are not true pines (conifers). *Tamarix* species are long-lived (50 to 100 years). Old trees have extensive lateral roots as well as deep roots that tap the water table. The minute leaves are dull grey-green and form a sheath around the fine branchlets, giving them the appearance of pine needles. The flowers are pinkish-white, small and without stalks. They occur in spikes 3–4 cm long at the ends of the previous year's branches. The fruit is bell-shaped, capped with a hairy tuft and contains numerous seeds. The seeds have a pappus and are very small (pollen-sized).

Origin

The genus *Tamarix* is native to a zone stretching from southern Europe and north Africa through the Middle East and south Asia to China and Japan. There are a few species in disjunct parts of Africa (Rodman 1989). Baum (1978) considers that *Tamarix* have one major centre of speciation in the Pakistan–Afghanistan–Iran–Turkmenistan–southern Kazakhstan–western China area and another in the eastern Mediterranean area.

Biology and ecology

While *Tamarix* species can survive when planted in a range of habitat types, they are best adapted to the sandy or gravelly banks of waterways and on sandy floodplains, especially where their roots can access underground water (Figure 1).

Figure 1. *T. aphylla* in Australia only seems to spread along the sandy banks of waterways such as rivers and lakes.

Climatically, *Tamarix* species are best suited to arid and semi-arid zones within subtropical to tropical latitudes. *Tamarix* species have evolved several features that enhance their growth and survival along the banks of waterways, when faced with episodic disturbance events such as drought and flooding. Firstly, *Tamarix* species are hydrophytes (phreatophytes), which means they have specialised roots that can draw water from deep underground. Mature specimens use large quantities of water. Along the Brazos River floodplain in Texas, *T. ramosissima* dominates about 7000 ha and is estimated to use more than 93 million cubic metres of water annually (Busby & Schuster 1971). Secondly, *Tamarix* species tolerate saline water and exude large quantities of salt through their specialised leaves. Lastly, they can survive prolonged periods of inundation (Frasier & Johnsen 1991). *Tamarix* species are well adapted for survival in arid and semi-arid climates and, once established, not even dramatic changes in soil moisture will completely eliminate them, provided abundant groundwater is available (Frasier & Johnsen 1991).

Reproduction and dispersal

Tamarix species reproduce from broken stem fragments and from seeds. Vegetative reproduction is particularly successful when branches are broken up by floodwaters and carried downstream.

Flowering normally starts in about the third year of life and continues annually thereafter (CRC for Weed Management 2005). A single mature specimen can produce hundreds of thousands of seeds each year (Sudbrock 1993). The tiny, hairy, pollen-sized seeds are widely dispersed by wind and water throughout the growing season, and they will germinate within 24 hours of moistening. In Arizona (US), seeds of *T. ramosissima* have been known to germinate while floating on water. They subsequently become established when they float to the shoreline and settle on saturated soil as the water recedes (Frasier & Johnsen 1991). In Queensland, seedlings of *T. aphylla* have been observed emerging in the middle of sandy river beds (Figure 2).

Figure 2. Young *T. aphylla* colonising freshly disturbed sand within the bed of the Flinders River near Hughenden

Seeds are viable for a short time (Zohary 1956; Waisel 1960). Seeds germinate most of the year, provided sufficient moisture is available, with most germination in autumn. Seedlings establish readily on saline and alkaline soils and can reach 60–100 cm in height within the first year. Subsequent growth is rapid with trees increasing in height between 2–5 m per annum under favourable conditions (Parsons & Cuthbertson 1992).

History as a weed overseas

Tamarix species were first introduced into the US in 1823, after which they were widely planted as ornamentals, for windbreaks and for stream bank stabilisation (Brotherson & von Winkel 1986; DiTomasco 1988). Of some 10 species of *Tamarix* that were introduced into the US, *T. ramosissima* is the most invasive. *T. ramosissima* spread explosively after the late 1920s and today occupies an estimate 1.5 million acres of floodplains, riverbanks and lakeshores in western US (Robinson 1965; Horton 1977; DeLoach et al. 1999). Another species, *T. parviflora* is currently invading coastal and central areas of California (DeLoach et al. 1999). Unlike the situation in central Australia, *T. aphylla* is only mildly invasive in North America.

DeLoach et al. (1999) state that *T. ramosissima* is 'one of the worst ecological disasters ever to befall western riparian ecosystems in the United States.' Similarly, Frasier and Johnsen (1991) consider *Tamarix* to be 'one of the 10 worst noxious weeds in the United States.' *T. ramosissima* has become so dense along many river systems and floodplains, especially in western US, that it has completely replaced native vegetation, reduced biodiversity, and currently threatens the survival of several endangered species (DeLoach et al. 1999). In a study of habitat use by birds along the lower Colorado River, Anderson and Ohmart (1977) found that *Tamarix* stands supported only four species per hundred acres, as opposed to 154 species per hundred acres of native vegetation.

Dense, mature stands of *Tamarix* use huge amounts of water and lower water tables below the root zone of locally native tree species (DeLoach et al. 1999). A single large plant can absorb 200 gallons of water a day (Hoddenbach 1987). *Tamarix* species utilise saline groundwater and excrete the excess salts through specialised leaves that accumulate on the soil surface, killing saline intolerant native plants. Fallen foliage of *Tamarix* species is highly flammable and causes increased wildfires (DeLoach et al. 1999). Dense stands of *Tamarix* also alter stream channel morphology, interfere with recreational activities, create potential flood hazards and reduce livestock carrying capacity (DeLoach et al. 1999; Frasier & Johnsen 1991). Even iconic landscapes such as the Grand Canyon have been degraded by *Tamarix* species with dense infestations along its riverbanks.

T. ramosissima and *T. parviflora* are current targets for biological control in the US (DeLoach et al. 1999).

Distribution and history of spread in Australia

Various species of *Tamarix* were introduced into Australia to provide shelter against wind and sun, and for use as ornamantals. They were planted extensively around Broken Hill and Whyalla in the 1930s and 1940s and soon after in other states, particularly around homesteads, stockyards, bores and other hot, exposed sites on grazing properties and towns. Planting in the Northern Territory resulted in naturalisation along the Finke River. Spread appears to have been most rapid soon after extensive flood events in the 1970s. Elsewhere in Australia, spread has been less rapid. For example, in Queensland spread appears to have only started in the last 10–20 years. The reason for the long 'lag time' between planting and noticeable spread is unclear.

The largest infestations of *Tamarix* in Australia are along the banks of the Finke River in the Northern Territory. The material at this site is believed to be *T. aphylla*. An estimated 600 km of the Finke River are infested. Other smaller infestations exist along ephemeral creeks in western New South Wales. A large infestation was found at Starvation Lake in 1990 and Tilcha Flow (a stream flowing from Tilcha Bore) in South Australia. Other sites include the lower Gascoyne (found in 1991) and Avon Rivers in Western Australia. Several other rivers in inland Australia (e.g. Todd River, Ross River and Palmer River) are being, or have the potential to be, invaded (Griffin et al. 1989). The *T. ramosissima*/*T. chinensis* complex is currently spreading on saline flats of the Murray River near Berri, South Australia (Gavin 2002).

Thousands of *T. aphylla* trees have been planted as ornamental and shade trees across Queensland, the vast majority seemingly failing to naturalise.

In Queensland, T. aphylla has naturalised and is spreading at the following locations:

1. on vacant crown land at Gemfields, near Emerald, central Queensland (Figure 3)
2. on a mine near Blackwater, central Queensland (detected 1999)
3. along a drainage line on a degraded landscape on the Mount Isa Mines lease (N March, pers. comm.)
4. along the bed and banks of the Flinders River, Hughenden.

Wild populations of *T. aphylla* probably exist elsewhere in Queensland and the challenge is to detect these populations before they become intractable problems. Since *T. aphylla* has been so commonly planted as shade/shelter trees and ornamentals, there is significant scope for additional wild infestations to develop over time.

Figure 3. *T. aphylla* starting to spread near Emerald in central Queensland.

Existing and potential impacts

Various species of *Tamarix*, especially *T. aphylla* and the *T. ramosissima/T. chinensis* complex, have the potential to dominate sandy riparian habitats and sandy or saline floodplains over much of arid and semi-arid Australia. Inland river systems such as the Finke River appear particularly vulnerable. If permitted to spread, *Tamarix* species could generate impacts comparable to those being experienced in western US. Potential impacts include:

Loss of biodiversity: If permitted to spread, *Tamarix* species can exclude all other vegetation and cause substantial loss of natural biodiversity. Along some parts of the Finke River, native river red gums (*Eucalyptus camaldulensis*), an icon species of central Australia, have been replaced by athel pines (Griffin et al. 1989). Unlike eucalypts, athel pines do not provide nesting hollows or the same quality of food or habitat for native wildlife.

Increased soil salinity: The leaves of athel pine exude salt which raises the salt content of the soil, leading to loss of saline-intolerant native plants and pasture.

Agricultural impact: Dense stands of athel pine can hinder stock mustering and replace pasture grasses.

Localised drop in underground water tables: Extensive mature stands of athel pine use large amounts of water and are capable of lowering the water table, causing waterholes to dry up.

Social impact: At some sites, athel pines are damaging the foundations and walls of historic buildings.

In recognition of these impacts and the potential for further spread, athel pine has been listed as one of 20 Weeds of National Significance (ARMCANZ 2001).

Preferred habitat

A curious feature of athel pine in Australia is its ability to naturalise and spread in some areas but not others, despite being widely planted across the landscape. This variation in 'invasion success' might be due to species-level or biotype-level genetic variation, or it may be a reflection of very specific habitat requirements. It is difficult to determine whether any species within the genus are non-invasive, since most species seem to spread if they are widely planted and if local conditions are suitable.

This study speculates that perhaps seeds of *Tamarix* can only germinate and survive in very specific habitats since most naturalised populations in Queensland and other states seem to exist only on exposed, freshly disturbed sand and gravel where there is an underground moisture supply (e.g. underground water exists below the sands of the Finke River and the Flinders River, and below the dams and mining depressions where athel pines are spreading in central Queensland). *Tamarix* species are well adapted to take advantage of underground water supplies and may even rely on such features for survival.

Successful invasion may also require specific disturbance events such as flooding, since *T. aphylla* only spread explosively along the Finke River after major flood events had disturbed existing riparian habitats and deposited extensive fresh alluvial deposits. Also, certain species of *Tamarix* seem to spread successfully on saline areas (e.g. *T. ramossissima/T. chinensis* complex is invasive on saline flats of the Murray River near Berri, South Australia). Again, saline areas tend to be free of other vegetation, so it may simply be an expression of the exposed nature of these sites. *Tamarix* species are pre-adapted to saline conditions (since they have specialised leaf glands that exude excess salts) and as such, these habitats may be at particular risk of invasion.

References

Anderson, BW & RD Ohmart 1982, *Revegetation for wildlife enhancement along the lower Colorado Rive*r, Final report to the US Bureau of Reclamation, Boulder City, Nevada.

ARMCANZ (2001), *Weeds of National Significance: athel pine (*Tamarix aphylla*), strategic plan*, National Weeds Strategy Executive Committee, Launceston, Tasmania.

Brotherson, JD & Von Winkel (1986), 'Habitat relationships of saltcedar (*Tamarix ramosissima*) in central Utah', *Great Basin Naturalist* 46: 535–541.

Busby, FE & Schuster, J (1971), *Journal of Range Management*, 24: 285–289.

CRC for Weed Management (2005), 'Weed of the month—*Tamarix aphylla*', online, www.weeds.crc.org.au/main/wom_athel_pine.html May 2005.

DeLoach, CJ (1988), *Prospects for biological control of saltcedar (*Tamarix *spp.) in riparian habitats of the south-western United States*, Proceedings of the VII International Symposium on Biological Control of Weeds, 6–11 March 1988, Rome, Italy,

DeLoach, CJ, Carruthers, R, Lovich, J, Dudley, T & Smith, S (1999), *Ecological interactions in the biological control of saltcedar (*Tamarix *spp.) in the United States: towards a new understanding*, Proceedings of the 10th International Symposium on Biological Control.

DiTomasco, JM (1998), 'Impact, biology and ecology of saltcedar (*Tamarix* spp.) in the southwestern United States', *Weed Technology* 12: 326–336.

Duncan, KW & KC McDaniel (1992), 1991 *Summary of range brush control research-demonstration trials in New Mexico*, Range Improvement Task Force, NMSU Ag. Exp. Station, NMSU Coop. Ext. Service, Report 30.

Frasier, GW and Johnsen, TN (1991), '37–Saltcedar (tamarisk): Classification, distribution, ecology and control', in *Noxious range weeds* (eds LF James, JO Evans, MH Ralphs & RD Child), Westview Press, Boulder, San Francisco and Oxford.

Fuller, M (1998), 'Athel pine (*Tamarix aphylla*)', *Agnote* No. F61, Northern Territory Government.

Gavin, J (2002), *Review of progress against the athel pine strategic plan*, unpublished report, Northern Territory Government, Alice Springs.

Hoddenbach, G (1987), Tamarix *control. Tamarisk control in southwestern United States,* Cooperative National Park Resources Studies Unit, Special Report No. 9: 116–125.

Horton, JS (1977), 'The development and perpetuation of the permanent tamarisk type in the phreatophyte zone of the southwest', pp. 123–127, in RR Johnson and DA Jones (technical coordinators), *Symposium on the importance, preservation and management of riparian habitat*, July 1977, Tucson, Arizona, USDA Forest Service, General Technical Report RM-43, Fort Collins, Colorado.

Parsons, WT & Cuthbertson, EG (1992), *Noxious weeds of Australia*, Inkata Press, Melbourne and Sydney, pp. 620–22.

Robinson, TW (1965), *Introduction, spread and aerial extent of saltcedar (tamarix) in the western states*, USDI Geological Survey Professional 491-A.

Rodman, J (1989), 'Reflections on tamarisk bashing', *Proceedings of the First Annual Meeting of the Society for Ecological Restoration*.

Sudbrock, A (1993), 'Tamarisk control—fighting back: an overview of the invasion, and a low-impact way of fighting it', *Restoration and Management Notes* 11: 31–34.

Waisel, Y (1960), 'Ecological studies on *Tamarix aphylla* (L.) Karst. I. distribution and reproduction', *Phyton* (Argentina) 15(1): 7–17.

Zohary, M (1956), 'The genus *Tamarix* in Israel', *Tropical Woods* 104: 24–60.

Restricted invasive animal

Feral pig

Sus scrofa

Pigs were introduced to Australia by early settlers. Subsequent accidental and deliberate releases resulted in the wild (feral) population establishing throughout Australia.

Feral pigs cause environmental and agricultural damage, spread weeds and can transmit exotic diseases such as leptospirosis and could spread foot-and-mouth disease.

Legal requirements

The feral pig is a restricted invasive animal under the *Biosecurity Act 2014*. It must not be moved, fed, given away, sold, or released into the environment without a permit. The Act requires everyone to take all reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control. This is called a general biosecurity obligation (GBO). This fact sheet gives examples of how you can meet your GBO.

At a local level, each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

An animal ceases being considered an invasive restricted animal (feral) if a person is keeping it and has become a registerable biosecurity entity (RBE) to keep that designated animal. Feral pigs can be considered as designated animals if a person keeps them.

Description

Feral pigs are typically smaller, leaner and more muscular than domestic pigs with well developed shoulders and necks, and smaller, shorter hindquarters.

The body is usually covered in sparse, coarse hair and they have a longer, larger snout, longer tusks, a straighter tail and narrower back than domestic pigs. Feral pigs are mostly black, buff-coloured or spotted black and white.

Growth potential is similar to domestic pigs, although harsh environmental conditions tend to stunt development. Adult female feral pigs usually weigh 60–75 kg, while males usually weigh 90–110 kg. Older boars (razorbacks) can have massive heads and shoulders and a raised and prominent back bone that slopes steeply down to small hams and short hind legs. Some boars develop a crest or mane of stiff bristles extending from their neck down the middle of their back.

Life cycle

Under good seasonal conditions, breeding occurs all year and sows can produce two litters per year. Adult females have a 21–day oestrus cycle, with a gestation period of about 113 days, producing a litter of 4–10 piglets. Sows can make nests of available vegetation just before farrowing. Nests sometimes have a domed roof and are usually less than 2 km from available water. Piglets normally spend the first 1–5 days of life inside the nest, with the sow nearby. Weaning occurs after 2–3 months. Sexual maturity is reached when sows weigh about 25 kg, usually around six months of age.

Mortality of juveniles is high if the mother's dietary protein intake is low (up to 100% mortality in dry seasons). Adult mortality does not vary as much with seasonal conditions, but few animals live more than five years.

Social behaviour

Feral pigs are generally nocturnal, spending daylight hours sheltering in dense cover. Pigs are omnivorous, eating plants and animals and are extremely opportunistic feeders, exploiting any temporarily abundant food.

They prefer green feed and will eat grains, sugarcane and other crops, fruit and vegetables. They root extensively for tubers, worms and soil invertebrates.

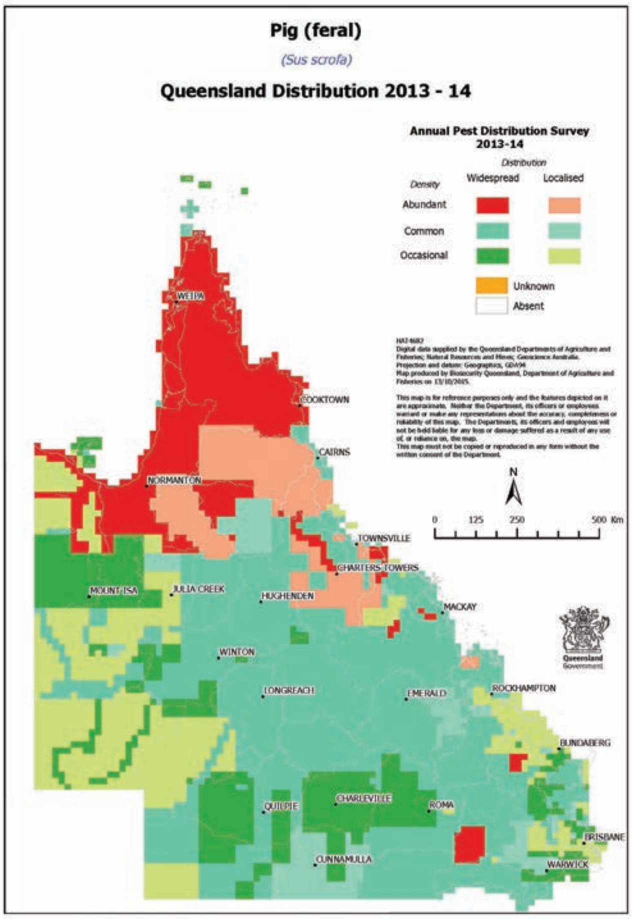
Feral pigs have relatively high energy and protein requirements, particularly during pregnancy and lactation and often move to other parts of their home range during pregnancy.

Habitat and distribution

Feral pigs are found in all habitat types in Queensland. The greatest concentrations of feral pigs are on the larger drainage basins and swamp areas of the coast and inland. In hot weather, pigs need to remain near water.

Population estimates can be achieved by spotlighting, aerial survey or the use of motion cameras.

Map 1. Distribution of feral pigs in Queensland



Evidence of feral pigs includes fresh digging or rooting of the ground, tracks and faeces on and off pads, mud or hair at holes in fences where pigs have pushed through, wallows, tusk marking and mud rubs on trees and fence posts and nests in vegetation made by sows before farrowing.

Female and juvenile pigs usually live in small family groups with a home range of 2–20 km^2. Adult males are typically solitary, with a home range of 8–50 km^2. Range size varies with season, habitat, food availability and disturbance. Herds of 400 pigs have been recorded in Cape York.

Impacts

Pigs can damage almost all crops from sowing to harvest, starting with uprooting seed and seedlings to feeding on or trampling mature crop.

They feed on seed, sugar cane and grain crops (except safflower), fruit (especially banana, mango, papaw, macadamia and lychee) and vegetable crops. Research has shown feral pigs can take up to 40% of lambs.

Pastures are damaged by grazing and rooting and pigs can also transport weeds. Wallowing pigs damage and foul the water in tanks and bore drains and silt up troughs. They can also damage fences and dam walls.

Pig activity degrades water quality and the habitat for small terrestrial and aquatic animals. It also creates erosion and allows exotic weeds to establish. Predation of native fauna does occur and examination of faeces has shown remains of marsupials, reptiles, insects, and ground-nesting birds and their eggs.


Feral pig wallow


Feral pig rooting


Feral pig damage to river banks


Feral pig damage to sugar cane

Diseases and parasites

Feral pigs can carry many infectious diseases and internal and external parasites. Some are endemic (already present), while others are exotic to Australia.

Many of the diseases can spread to domestic pigs, other livestock and humans. Feral pigs can transmit sparganosis, melioidosis, leptospirosis, Q fever and brucellosis to humans.

To prevent contracting these diseases it is advisable to either avoid handling feral pigs or use suitable protective clothing (mask, goggles, strong rubber gloves and plastic apron and boots) to minimise contamination with blood, urine and faeces. Rare or undercooked meat should not be eaten; thoroughly cook meat to avoid contracting pathogens. Raw feral pig meat and offal should not be fed to dogs as dogs can be infected with swine brucellosis. Dogs infected with swine brucellosis can also transmit the disease to humans.

Control

Managing feral pigs

The GBO requires a person to take reasonable and practical steps to minimise the risks posed by feral pigs. This fact sheet provides information and some options for controlling feral pigs.

Feral pigs are difficult to control because they are primarily nocturnal, breed rapidly, are generalist omnivores and have large home ranges and thus control programs need to be conducted over a wide area (often including several properties) to be effective.

Effective control requires an integrated, collaborative approach where all stakeholders participate in planning, implementation and evaluation of the actions taken.

Fencing

Though an expensive option, fencing can offer successful pig control especially for high value crops grown on small areas. Research has indicated that the most successful pig-proof fences are also the most expensive.

The most effective pig-proof fences use fabricated sheep mesh held close to the ground by plain or barbed wire and supported on steel posts.

Electrifying a conventional fence greatly improves its effectiveness if used before pigs have established a path through the fence.

Pigs will often charge an electric fence and unless the fence incorporates fabricated netting they often successfully breach the fence.

For crop protection or to avoid lamb predation, pig-proof fences need to be constructed before the pigs become a problem. Once pigs have adjusted to feeding on grain or lambs in a particular paddock fencing may be ineffective.

Trapping

Trapping is an important technique that is most useful in populated areas, on smaller properties (‹5000 ha), and where there are low pig numbers. Trapping can be particularly useful in 'mopping up' survivors from baiting programs. It is most successful when food resources are limited.

Trigger mechanisms for pig traps can be made pig-specific and therefore pose little danger to wildlife or domestic animals.

Advantages

- This is the safest form of control and can be safely undertaken on closely populated areas.
- It's flexible and can be incorporated into routine property activities, making economical use of labour and materials.
- Carcasses can be safely disposed.
- Traps can be moved and re-used; good trapping makes use of opportunities as they arise.
- Normal pig behaviour is not altered, which allows a greater number of the total population in an area to be targeted.
- More humane to pigs and non-target species.
- The number of animals removed can be easily monitored.

Disadvantages

- Can be time consuming and expensive to construct and maintain.
- Must be checked regularly.
- Not practical for large-scale control.
- Some pigs are trap shy.

Tips

- Stop all activities that will disturb normal feeding (i.e. do not undertake any shooting or dogging).
- Pre-feeding (i.e. ensure that pigs are visiting trap and consuming bait) prior to activating traps is an essential part of successful trapping.
- Feeding sites should be placed where feral pigs are active (i.e. water points, holes in fences, areas containing old carcasses on which pigs have been feeding).
- Bait for traps must be food that pigs usually eat in that area. Pigs feeding on one crop (e.g. sugarcane) will often not take to alternative foods. However, new, novel baits are sometimes attractive (e.g. fermented grains).
- The trap can be built around the feeding site, with feeding within the trap undertaken for several nights before it is set.
- Set the trap every night and check each day. If the trap cannot be checked daily then shade and water must be provided.
- Continue to trap until no more pigs are caught. A change of bait can be tried. Again, feed for one or two nights before re-setting the trap.
- Traps may be left permanently in locations used by pigs and can be utilised when fresh signs of pigs appear.
- If the trap is to be moved, start feeding at the new site before re-locating the trap.

Design

There are several trap designs but all are principally an enclosed area with one-way gates (see Figure 1).

The main area of the trap can be any shape and be made from materials on the property. The best material is steel mesh with a grid 100 × 100 mm, with a minimum height of at least 1.5 m. Star pickets need to be placed no more than 1.5 m apart and imbedded far enough to ensure that adult pigs cannot push them over or lift them up out of the ground.

Alternative trap entrances

Funnel entrance

Formed by the two ends of the mesh forming a funnel, the ends are tied together at the top with wire or rope. The pig moves through the funnel forcing the bottom of the mesh ends apart and once it is in the trap the ends spring back together (see Figures 1 and 2).

Tripped gate entrance

A side-hinged gate is pulled shut by springs and is held open by many systems that can be triggered to allow the gate to swing shut. Often trip wires or other systems are used; most of these systems are not selective for feral pigs and can be triggered by any animal attracted to the bait. Once triggered the trap is no longer effective in trapping pigs.

Pig-specific trigger

By far the simplest and most effective trigger system has the gate held open by a bar (often a branch or piece of wood) which is hooked over the wire on the gate and on the side panel (see Figure 3). For a close up of the pig specific trigger (see Figure 4).

Pigs rooting for feed in the trap lift the bar allowing the gate to swing shut. The specific feeding habit of pigs insures they are the only animals that lift the trigger bar.

The gate may be latched to prevent pigs from opening the door once triggered. However, this will prevent more pigs pushing their way in to join those inside.

Shooting

Shooting pigs by helicopter is effective in areas where pigs exist in reasonable numbers and are observable from the air.

Ground shooting is not effective in reducing the pig population unless intense shooting is undertaken on a small, isolated and accessible population of pigs.

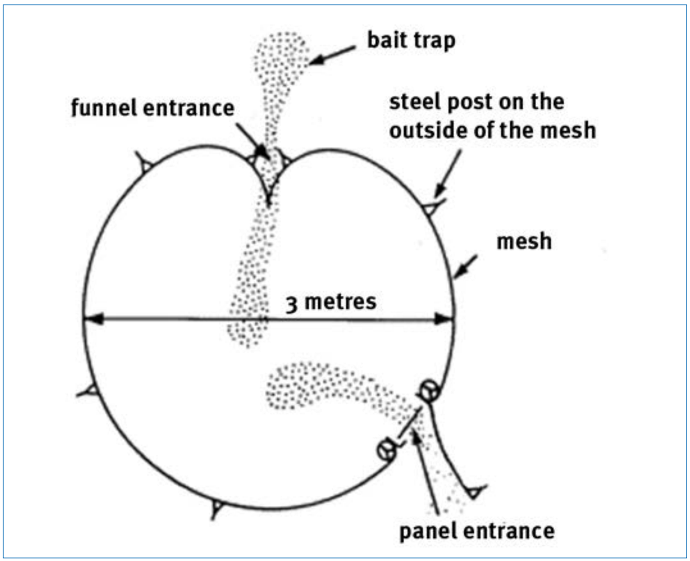


Figure 1. Alternative trap entrances – funnel entrance

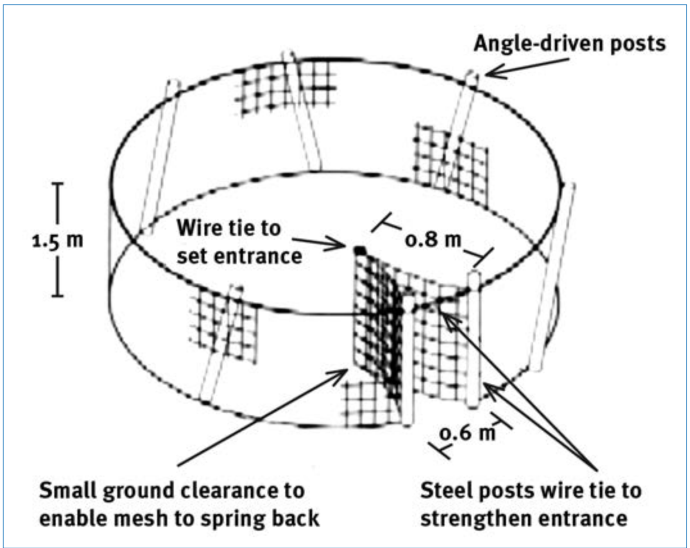


Figure 2. Silo trap with funnel entrance (14 m of silo mesh diameter about 4.5 m

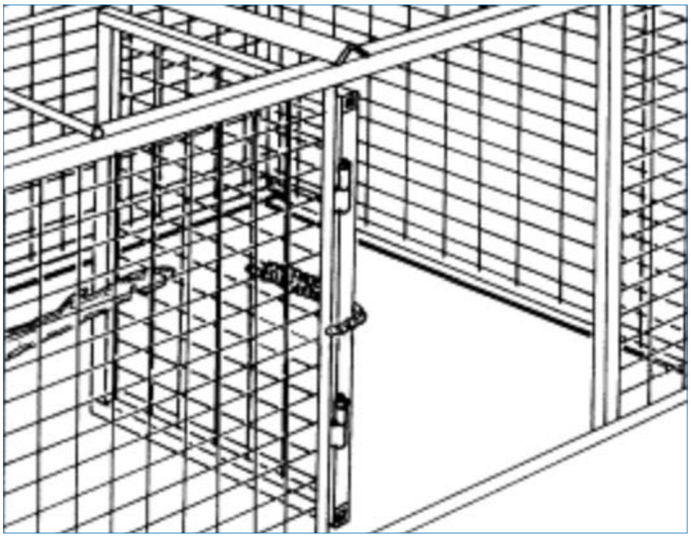


Figure 3. Pig-specific trigger

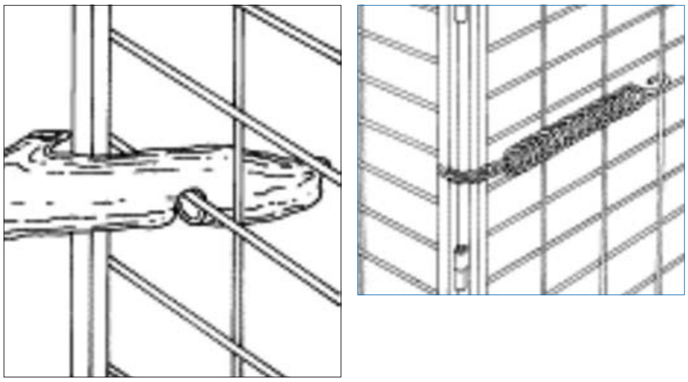


Figure 4. Close up of pig-specific trigger

Feral pig trap

Trapped feral pigs

Hog hopper – pig specific bait station

Poisoning

Poisoning is the most effective control method available that can quickly reduce a pig population.

Sodium fluoroacetate (1080) can only be supplied by people approved under the Health (Drugs & Poisons) Regulation 1996 for the purpose of controlling declared pest animals. Your local government office should be able to assist you.

Pre-feeding is the most important step in ground-based poisoning operations. Free feeding with non-poisoned bait should be performed for several days prior to laying poisoned baits.

By selecting bait wisely, landholders can be species-selective in their poisoning program and avoid many of the unintentional effects of secondary poisoning.

Bait material such as fermented grains are very attractive to pigs. It is a good idea to establish a free feeding routine so that pigs are the only animals feeding, which helps to keep other non-targets away from the feeding site.

Other options (like pig-specific feeders) are now commercially available, and can assist in reducing non-target species access to bait. Other options include burying baits; feral pigs are one of the few animals that will dig up bait.

Aerial poisoning is also available and typically used for broadscale control in western and northern regional areas. Bait is distributed from an aircraft. This is particularly useful for covering large, remote, areas or restricted ground access. Aerial poisoning is a proven and cost-effective method for reducing pig populations.

A phosphorous-based poison is also available for use in Queensland.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

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Feral pig exclusion fencing

This fact sheet is developed with funding support from the Land Protection Fund.

Restricted invasive animal

Dingo

Canis familiaris dingo

The dingo is a primitive canid related to wolves and coyote. The dingo was not a part of the ancestral fauna of Australia. Though its origins are not clear, it is thought to have arrived in Australia 3500–4000 years ago.

It is the largest mammalian carnivore remaining in mainland Australia, and as such fills an important ecological niche. Females weigh about 12 kg and males 15 kg.

The dingo has been regarded as a serious predator of domestic stock since early European settlement in Australia.

Since European settlement domestic dogs have been released or escaped into the environment to cross with dingoes. These hybrids or crosses are colloquially call wild dogs (*Canis lupus familiaris*). Often the term wild dog covers both dingoes and dingo hybrids.

Wild dogs predate on livestock, native fauna and domestic pets.

Queensland Government

Legal requirements

The dingo is a restricted invasive animal under the *Biosecurity Act 2014*. It must not be moved, kept, fed, given away, sold, or released into the environment without a permit. The wild dog must not be moved, fed, given away, sold, or released into the environment without a permit.

The Act requires everyone to take all reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control. This is called a general biosecurity obligation (GBO).

At a local level, each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

Description

Red, ginger and sandy-yellow are the dominant coat colours, though dingoes can also be pure white, black and tan or solid black.

It is not difficult to distinguish between most dingoes and hybrids. The presence of domestic genes is suggested by broken colours—brindling and patchiness in the normally pure white feet and chest patch and sable colouration (black hairs along the back and sides).

Dingoes have a more heavily boned skull and larger teeth (especially the canine) than domestic dogs of similar size.

Life cycle

Dingoes have only one breeding season per year (usually April to June), whereas domestic bitches have two or more oestrus cycles per year. However, unless seasons are particularly favourable, or human sources of food are intentionally or inadvertently provided, feral domestic dogs are unlikely to successfully rear two litters per year.

After a nine-week gestation, dingo pups (usually four to six) are born in a hollow log or cave den. Bitches tend to use the same den each year. Pups are suckled at four to six weeks and generally weaned at four months. When large enough to travel, pups are taken from the den to kills, and other dens many be used. The range of pups is increased as they are moved from den to den. In this way the pups are gradually moved around the bitch's home range.

Independence may occur as early as six months of age when parents abandon them, but this results in high juvenile mortality. Pups that become independent around 12 months appear to disperse voluntarily. Being larger and more experienced, mortality is then usually low.

Where dingoes live alone or in small groups (most pastoral and semi-settled areas), mature females will breed successfully each year.

By contrast, dominant female infanticide results in only one litter being successfully raised each year within groups containing several adult females (e.g. undisturbed areas such as the Simpson Desert). The dominant (alpha) female will kill all pups of the other females, and then use subordinate females to suckle and rear her litter.

Methods of spread

Dingoes in an undisturbed area generally belong to discrete packs (3–12 members), which occupy long-term, non-overlapping territories. The group rarely moves as a pack—rather, members meet and separate again throughout the day. Dingoes are most gregarious during the breeding season.

There is overlap of home ranges within a group. In contrast, boundaries between groups are more rigid, actively defended and infrequently crossed.

Olfactory communication (smell) is important in dingo social organisation. Dingo droppings are deposited along pads in specific areas where other dingoes will encounter them (creek crossings, intersections of roads and fences).

These 'scent posts' appear to delineate the home range boundary and act as a warning to neighbouring groups and individuals.

This strong site attachment of dingoes is contrary to the notion commonly held by property owners that dingoes will travel large distances to kill stock.

Habitat and distribution

Dingo numbers are believed to be higher today than in pre-European times. This is thought to be due to increased food availability via the introduced rabbit and cattle carcasses, and the development of permanent waters in arid areas of the state.

Dingoes/wild dogs are present in all parts of the state.

The distribution of the wild dog in relation to purebred dingoes varies throughout the state. In far western areas, most dingoes sighted appear to be 'pure', with characteristic white points and broad heads. Closer to settled areas a greater number of feral domestic dogs produce a generally hybrid population. It has been estimated that dingoes are 50% pure in south-eastern Queensland and 90–95% pure in south-western and central Queensland.

Radio tracking studies show dingoes occupy a discrete area known as a 'home range'. The dingo visits the edge of this area frequently.

The home range can vary in size according to the productivity of the country—from 9 km^2 in rainforest areas to 300 km^2 on the Nullarbor Plain.

The edge of the home range is commonly associated with a major topographic feature (e.g. an escarpment, a major ridge or stream).

The home range is not used uniformly. Activity is centred on areas with highest food density.

Hunting movement is slow and exploratory, in contrast to frequent rapid movement around the home range boundary.

Pads follow well defined paths and are most likely associated with sociality and home range boundary maintenance. Activity is highest at dusk and dawn.

Diet

Dietary research of stomach content and faecal scats has shown dingoes are opportunistic predators.

Medium-size animals such as kangaroos, wallabies, rabbits and possums consistently form the major part of the dingo diet.

Studies by the Western Australia Agriculture Protection Board show dingoes in undisturbed refuge areas killed and ate kangaroos strictly according to need.

On grazing country, however, 'dingoes harassed, bit or killed sheep in large numbers, often without eating any'. The consumption of these sheep carcasses was the exception rather than the rule. Even kangaroos in these areas were sometimes killed in 'play' type behaviour rather than for food.

Such dietary studies could suggest dingo predation of domestic stock is low. There is, however, a need for caution in using such studies to assess dingo impact on stock.

Grouping increases foraging efficiency and appears necessary to exploit larger prey. Dingoes cooperating in groups are more successful in hunting kangaroos than lone dingoes are. While lone dingoes can easily kill sheep, it is less likely a solitary dingo would successfully attack a calf in the presence of a defending cow.

Disease threat

Dingoes are vectors of canid diseases (e.g. distemper, parvovirus) and parasites. The hydatid parasite *Echinococcus granulosus* is a major problem of dogs and domestic stock. It can cause illness and occasionally death in humans.

The dingo could pose a serious risk if the exotic disease rabies was introduced to Australia.

Beneficial considerations

The establishment of watering points during post-European settlement has resulted in a huge increase in the kangaroo population, with consequent strong pasture competition with domestic livestock.

Though it is widely accepted that sheep production is near impossible in the presence of dingoes, many cattle producers will tolerate dingoes because of their believed suppression of kangaroo numbers.

Research has shown that in some cases the dingo has the potential to mitigate population growth of native species during abundant seasons and it could also be an important limiting factor for many feral animal populations (e.g. feral pigs and goats).

There is some evidence that destruction of the dingo could cause increases in other pests to the grazing industry and result in widespread degradation of environmentally sensitive areas. However, this has not been proven.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

This fact sheet is developed with funding support from the Land Protection Fund.

Restricted invasive animal

Wild dog

Canis familaris

The term wild dog refers collectively to purebred dingoes, dingo hybrids and domestic dogs that have escaped or been deliberately released.

Wild dog control methods include baiting, trapping, shooting, fencing, and the use of guardian animals to protect stock. A planned strategy using a combination of these methods that also considers wild dog behavior will enable effective management.

Legal requirments

The wild dog is a restricted invasive animal under the *Biosecurity Act 2014*. It must not be moved, kept (if a dingo), fed, given away, sold, or released into the environment without a permit. The Act requires everyone to take all reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control. This is called a general biosecurity obligation (GBO). This fact sheet gives examples of how you can meet your GBO.

Queensland Government

At a local level, each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

Control

Managing wild dogs

To increase wild dog control effectiveness, it is essential that control programs are coordinated among adjoining properties. This fact sheet provides information and some options for control.

Queensland research has shown that in some situations wild dogs can quickly re-colonise baited areas due to a number of factors including inconsistent bait programs which do not provide comprehensive wild dog control across the landscape. Such programs may alter the dynamics of wild dog populations in the area. To prevent livestock attacks and enhance wild dog management, it is important for producers to work together using a variety of control methods.

Wild dog ecology and seasonal variations can also influence the likelihood of wild dogs coming into contact with a control tool. The timing of control should consider seasonal variations and the availability of water (where water is restricted) and then target watering points. Many land owners bait using 1080 twice a year to target wild dogs during peaks in activity associated with breeding (March/May) and then again in September/November to target pups and juveniles. However, baiting and trapping is recommended at all times when wild dogs are active.

Fencing

Property fencing suitable to exclude wild dogs is expensive to build and requires continual maintenance to repair damage caused by fallen timber, fire, floods, feral and domestic animals, as well as vegetation regrowth. However, a properly maintained fence can restrict movement into an area where wild dogs have been controlled.

Electric fences suitable for wild dogs have been developed. Electrifying a fence creates a fear of the fence itself and deters wild dogs from approaching.

For property fencing to be successful, the fence must be maintained in good order and ongoing wild dog control conducted within the protected area to limit livestock impacts.

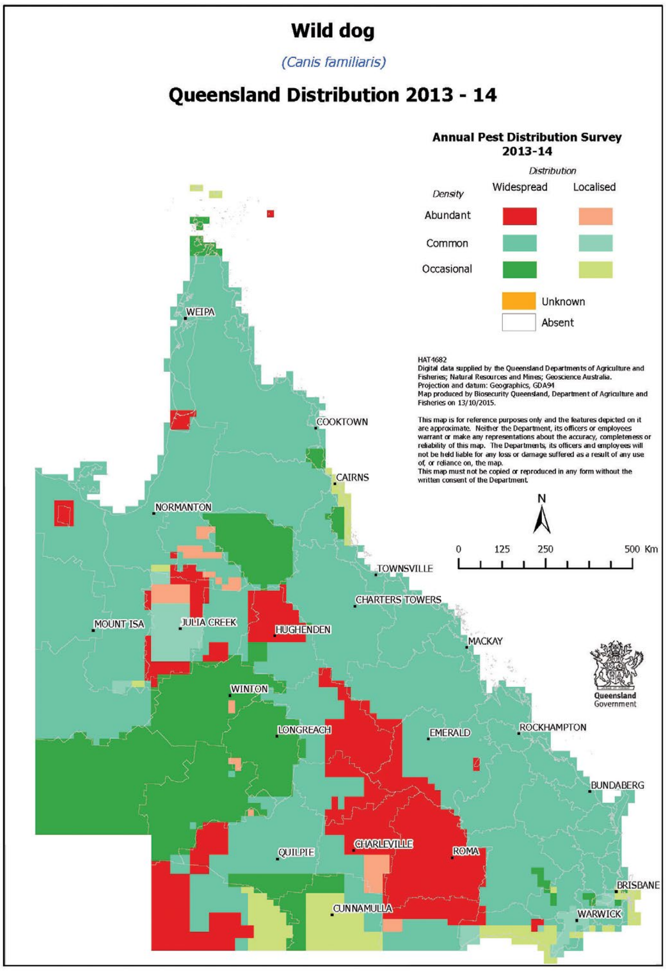
Fencing is the most effective method of protecting livestock and pets from wild dog attack on small acreage blocks.

A fence can also be a good area to place baits and traps when wild dogs are active.

Trapping

A key success to trapping wild dogs (using foot-hold traps) depends on the skill of the operator. Visit www.feral.org.au to watch a PestSmart video on best practice techniques for wild dog trapping.

Map 1. Distribution of wild dogs in Queensland



For humane reasons and to prevent escape, poisoning traps with strychnine is recommended to quickly kill captured wild dogs. A properly poisoned trap becomes a lethal device rather than a holding device.

A mixture of dog faeces and urine is a popular lure used by trappers. Attractiveness of lures varies with seasons and locations. No single lure has yet been found that is consistently attractive to all wild dogs and repeated use of one lure can lead to aversion amongst remaining dogs.

Traps are best placed in areas of high wild dog activity (known as leads). Here the wild dog is most likely to find and investigate the decoy/odour.

A wild dog scent post (an area where urine or faeces have been deposited) can be found by walking with a domestic dog on a lead along a known pad. Trap placement in relation to the scent post can be optimised by observing the domestic dog's behaviour as it approaches. Factors to consider are:

- where on the bush it smells
- placement of feet while urinating/defecating/sniffing
- how it approaches and where it scratches in relation to the pad and scent post.

Padded, laminated or offset foot-hold traps, in a well tuned and functioning state are recommended.

Shooting

Shooting is an opportunistic method, mostly used for control of small populations or individual problem animals.

Livestock guardian animals

Livestock guardian animals have been used to protect livestock from predators in Europe, Asia and America. Some producers in Queensland have decreased predation on sheep and goats using this method. The use of trapping and poisoning in conjunction with guardian animals must be well planned and managed to ensure guardian animal safety.

Baiting

Poison baits are the most economic, efficient and effective method of controlling wild dogs, especially in inaccessible or extensive areas. Baits can be laid quickly by hand, from vehicles and from aircraft.

Currently there are three poisons legally available for wild dog control. These are 1080 (sodium fluoroacetate), strychnine and para amino propiophenone (PAPP).

Subject to restrictions, 1080 baits, either manufactured or prepared from fresh meat can only be obtained from authorised persons. PAPP can only be supplied as a manufactured bait. A permit from the Queensland Department of Health is required for land owners to purchase strychnine. Strychnine can be used both in baits and on traps. The use of both 1080 and strychnine require adherence to the associated conditions of supply. The use of poison baits will control some but not all wild dogs. Baits should be used in conjunction with all other control tools and not be relied on as a total control method.

Meat baits are attractive both to wild dogs and a range of non-target species. When using meat baits, they can be strategically positioned as wild dogs' keen sense of smell enables them to find baits intentionally buried in sand or otherwise hidden under bushes or in hollow logs. Meat baits may also be tied to prevent their loss to non-target species.

These meat bait placement techniques help to:

- reduce the risk of poisoning non-target species
- increase wild dog contact, hence receiving a lethal dose
- minimise bait removal by non-target scavengers
- deter ants (ant-covered baits are believed to be less attractive to wild dogs).

Heavy rain within two weeks of baiting can leach 1080 from baits, but baits may still remain toxic for a considerable time.

Ejectors are a new tool in the delivery of 1080. They require a wild dog or fox to pull the ejector head to be activated. This is done by attaching a lure reward to the ejector head. A capsule of lethal dose 1080 is burst into the wild dog's or the foxes mouth. Ejectors are fixed in one stop and are only able to be activated by foxes and dogs.

Further information

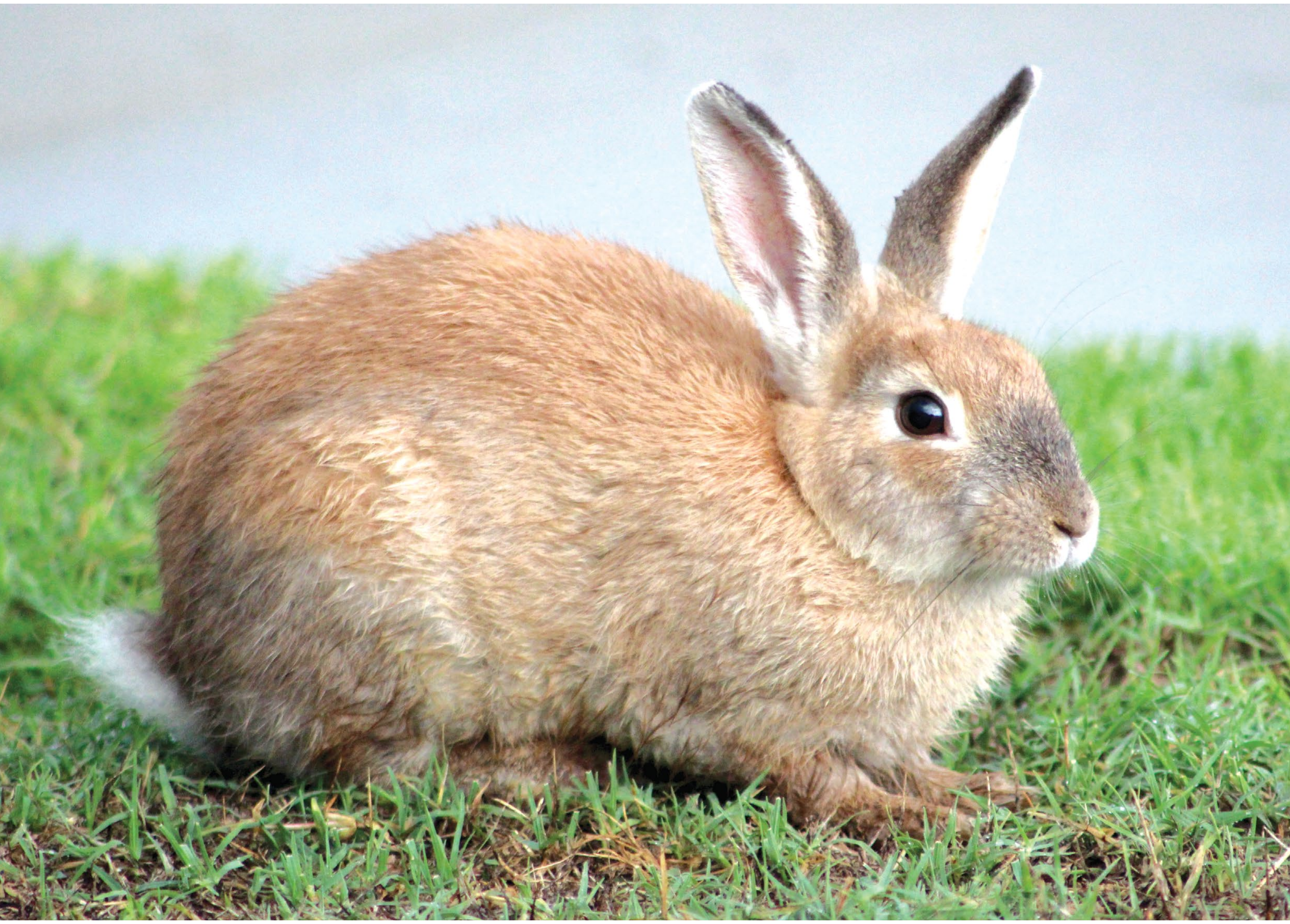
Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

This fact sheet is developed with funding support from the Land Protection Fund.

Restricted invasive animal

Rabbit

Oryctolagus cuniculus



Rabbits are one of Australia's major agricultural and environmental animal pests, costing the country between $600 million and $1 billion annually. They compete with native animals, destroy the landscape and are a primary cause of soil erosion by preventing regeneration of native vegetation.

Legal requirements

The rabbit is a restricted invasive animal under the *Biosecurity Act 2014*. It must not be moved, kept, fed, given away, sold, or released into the environment without a permit. The Act requires everyone to take all reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control. This is called a general biosecurity obligation (GBO). This fact sheet gives examples of how you can meet your GBO.

At a local level, each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

Queensland Government

Pet rabbits

Introducing and selling rabbits in Queensland is not permitted (penalties apply). Limited numbers of permits for domestic rabbits are only available from Biosecurity Queensland for research purposes, public display, magic acts or circuses. Before a permit is granted, a number of guidelines need to be fulfilled.

Description

Rabbits are small mammals around 34–45 cm in length usually grey brown with pale belly fur, other colours include piebald, black and ginger. They have long ears 10 cm long and big eyes. They have long hind legs with hind feet measuring 9–11 cm and shor t front legs. The tail is fluffy brown with white underneath, 4–8 cm. Adult rabbits usually weigh around 1–2.1 kg. The male is called a buck, the female a doe and her young are called kittens.

Life cycle

Does (females) are pregnant for 28–30 days, but are able to mate within hours of giving birth. The average litter is 3–4 kittens but varies from two in a young doe, up to eight or more in a mature doe, and depends on the amount and quality of food available.

Five to six litters are possible in a good season. Young does can breed at four months of age if conditions are suitable.

Habitat and distribution

Rabbits prefer to live in warrens as protection against predators and extremes in temperature. However, they will sur vive in above-ground harbours such as logs, windrows and dense thickets of scrub (e.g. blackberr y and lantana) or under built harbour, old sheds and machiner y etc.

In newly colonised areas without warrens, rabbits tend to live in 'scrapes' (or 'squats')

Rabbits are adaptable and sometimes live in close association with people. They live in built environments such as:

- in and under buildings
- old machinery and storage containers
- in old dumps.

In rural environments rabbits frequently live in:

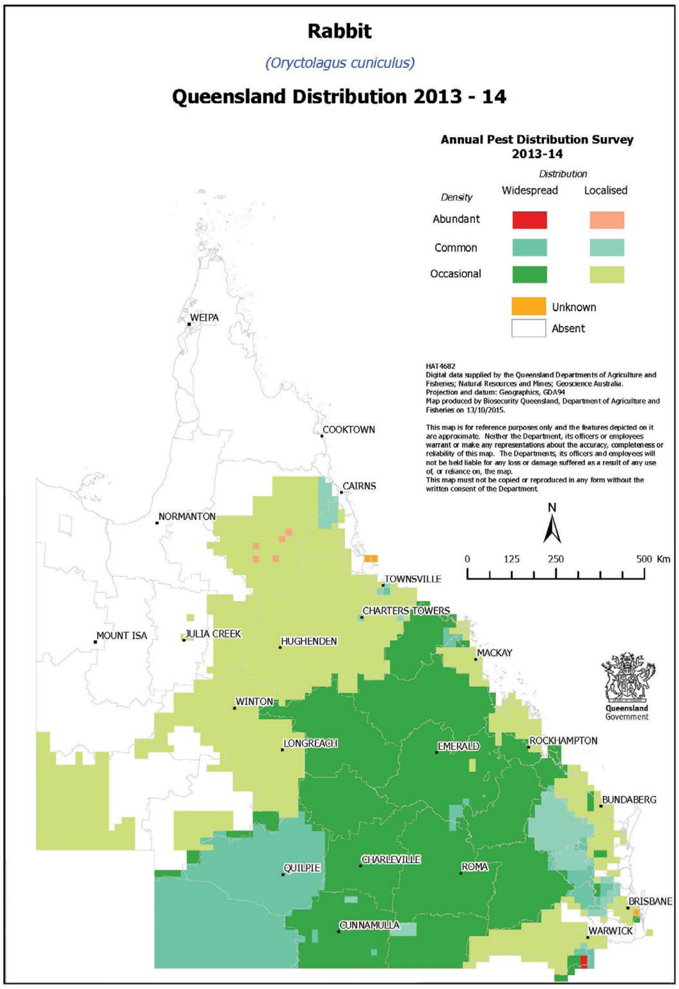
- felled timber and associated windrows
- tussock grasses and rocky areas
- warrens (if soils are easy to dig).

Control

Managing rabbits

The GBO requires a person to take reasonable and practical steps to minimise the risks posed by rabbits. This factsheet information and some options for controlling rabbits.

Map 1. Distribution of rabbits in Queensland



Effective rabbit control cycle

Rabbit control is best done as a joint exercise involving all land managers in the district. Integrated control methods, such as fumigating, ripping warrens and harbour destruction, are essential for the continued long-term reduction of rabbit numbers. Cost-effective, long-term results can be achieved in rabbit control by following a combination of the methods outlined below.

Prevention and early detection

Rabbits will generally eat around 15% of their body weight per day—approximately 250 g. This compares dramatically with the averages for stock—sheep and cattle eat around 3% of their body weight per day. So even a low number of rabbits can be removing large amounts of livestock feed.

For effective long-term rabbit control, concentrate on destroying source areas. Source areas will all have well-established warrens or ready-made structures that are cool and provide protection from predators. A source area must also have a good supply of green feed during the cooler seasons.

Manual control

Harbour destruction

Where there is abundant surface harbour, a high proportion of rabbits may live above ground rather than in underground warrens. Rabbits can make their homes in windrows, dense thickets of shrubs (such as blackberries and lantana) and even in old machinery.

To eliminate these above-ground breeding areas, it may be necessary to:

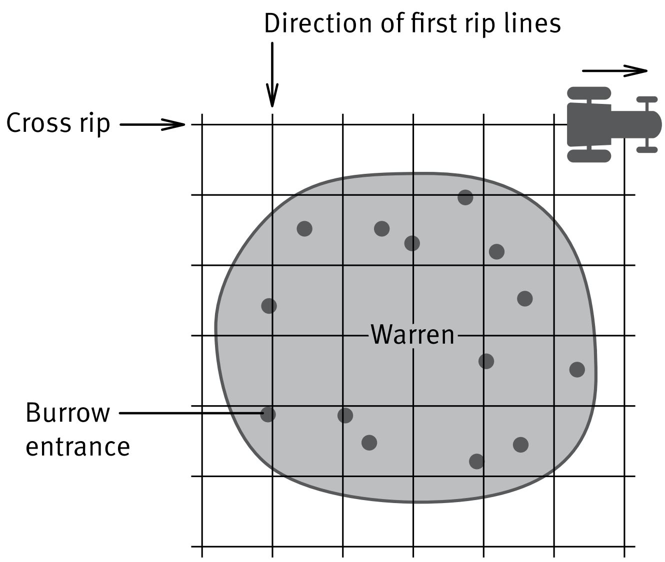
- burn windrows and log piles
- remove noxious weeds through chemical and physical control
- remove movable objects (such as old machinery) from paddocks.

Sometimes removing harbour can expose warrens underneath. If this happens, the warrens need to be ripped.

Mechanical control

Warren ripping

In areas where rabbits live in warrens, ripping is the most effective method of long-term control. Ripping is so successful because warrens can rarely be reopened and rabbits are unable to recolonise these areas.

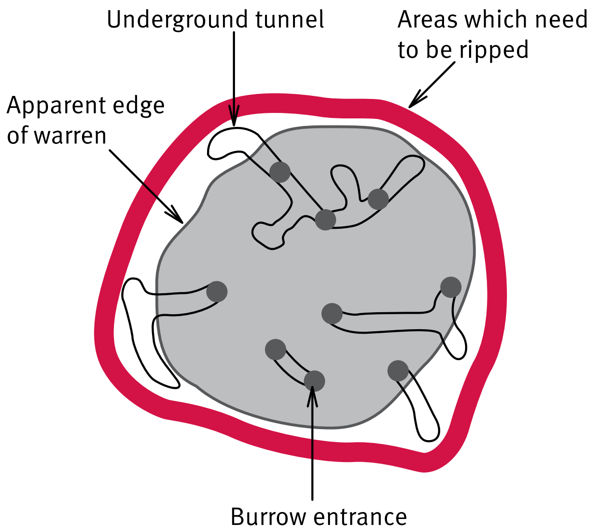


Direction to rip warrens (illustration courtesy Will Dobbie)

Tyne for ripping warrens (photo courtesy Mark Ridge)

To get the best results it is important to chase as many of the rabbits inside the warren as possible. Dogs can be used to drive rabbits into the warren before ripping starts.

The aim of ripping is to completely destroy the warren. It involves using a tractor with a tyned (sharp-pronged) implement—one tyne or many—that rips through the warren and collapses it. Larger tractors and dozers are more appropriate for properties with many warrens as they are able to move faster and rip wider.



Extent to rip warrens (illustration courtesy Will Dobbie)

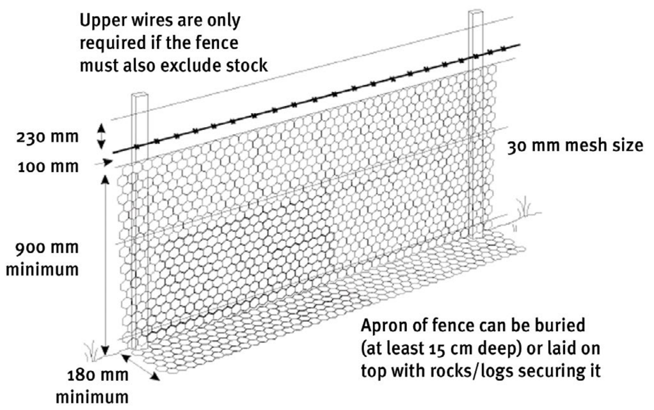
Obviously, ripping is not suitable for warrens located underneath buildings or on steep rocky country. In such cases, other methods (poison baiting, releasing virus or fumigating burrows) should instead be used to reduce rabbit numbers. Warrens should then be either filled in or covered to stop rabbits from re-establishing. Burrows can be blocked with small boulders or rocks.

Rock blocking rabbit hole

Exclusion fencing

Rabbit exclusion fences are built with the aim of keeping rabbits out of a particular area. It is appropriate for small, high-value areas that require protection. A fully fenced area will only remain rabbit-free in the long term if all rabbits are removed from the enclosed area after fencing and the fence is regularly maintained and checked for holes.

Electric fencing is a cheaper alternative, but it is not a complete physical barrier and is also prone to damage from other pest animals and stock.



Exclusion fence for rabbits (illustration courtesy DEWHA)

A rabbit-proof fence should be made of wire mesh netting (40 mm or smaller) and needs to be at least 900 mm high. The netting should also be buried to depth of at least 150 mm. Gates into the fenced area need to be rabbit-proof as well.

Trapping

Trapping is an extremely labour-intensive control method and requires a skilled operator to set the traps to successfully capture rabbits.

If you do plan to trap rabbits on your property, common sense and respect for animal welfare are essential. While there are currently no strict guidelines for the use of traps in Queensland, it is an area of growing concern for animal welfare advocates.

Cage trap

A cage trap has a lever that closes the cage when a rabbit steps on it. The rabbits are lured into the cage with bait—usually diced carrot. Traps need to be disabled and left open for two or three nights with bait leading into the cage. This entices rabbits to enter. A trap can be set once a rabbit has consumed a trail of bait all the way into that trap. Traps should be checked and emptied regularly—usually a couple of times a night.

This effective and humane technique is most useful for removing any remaining rabbits from places like hay sheds and after the shed has been fenced to prevent additional rabbits from entering and leaving. Free-feed then trap, and keep the shed rabbit-proof to prevent rabbits recolonising.

Barrel trap

A barrel trap is designed specifically for rabbits. It is cylindrical, made of light mesh, and is about 1 m long and 15 cm in diameter. The trap has one open end with two hinged trap doors along its side. The open end is placed in the burrow, and the hinged gates close and trap the rabbit after it enters from the burrow.

The trap can be left in the burrow entrance for a number of days. However, it must be checked at least daily so that if a rabbit has been caught it does not suffer and animal welfare responsibilities are met.

Barrel rabbit trap in hole

Biological controls

Rabbit hemorrhagic disease virus (also known as rabbit calicivirus disease)

RHDV is a virus specific to rabbits which works by infecting the lining of the throat, lungs, gut and liver.

RHDV relies primarily on direct rabbit-to-rabbit contact in order to spread. High rabbit numbers are therefore needed before this control method will be effective.

After RHDV has infected an area, it is important to use another method for follow-up control to increase the likelihood that the population is eradicated before it is able to develop resistance and increase its numbers again.

Resistance to RHDV depends primarily on the age of the rabbit. Therefore, it is better for RHDV to go through a rabbit population after rabbits have bred and the young are old enough to be affected by the virus. Rabbits that survive RHDV develop antibodies against the virus. Breeding females can also pass these antibodies on to the young (through antibodies in their milk), conferring temporary protection on rabbits up to 12 weeks old.

Myxomatosis

Myxomatosis is no longer produced as a laboratory strain but field strains are still known to recur and affect rabbit populations.

RHDV1-K5

Recent research by state and federal agencies has identified a new strain of RHDV (called RHDV-K5) that will aid in controlling rabbits that have immunity to current strains.

Shooting

Shooting is most useful when used to 'mop up' after other control methods (such as ripping). To get the best results, shoot at the time of day when rabbits are active. This is usually in the early morning, late afternoon or at night. The best and most economical firearm to use is a .22 calibre rifle.

If your property is within an urban area, you will need to comply with local government regulations and the *Police Powers and Responsibilities Act 2000*, which restrict the use of firearms.

Poison baiting

Baiting is not effective as a sole control method and will not eradicate an entire rabbit population. Numbers will quickly increase again, and you will have to continue baiting year after year with no permanent overall change in the rabbit population.

Rabbits can also become 'bait shy' and this method becomes less and less effective over time. Ideally, baiting is best used either before ripping/fumigation to reduce a population, or after ripping/fumigation as a 'mop-up'.

Baiting works best when rabbits are not breeding. During breeding season the majority of the population feeds over a larger-than-normal area, and it is the young rabbits that are most likely to take baits. While numbers will be reduced, animals of breeding age are not likely to be affected.

1080—sodium fluouroacetate

Pre-feeding is required when using 1080 because rabbits will not readily take new feed. The poison-free bait should be laid at least three times over a one-week period before the poisoned bait is laid. (1080-impregnated carrot baits are the most common form of bait used.) The practice helps to ensure that, when the poisoned bait is laid, it will be eaten by most of the rabbit population.

1080 can only be supplied through persons authorised under the Health Act. Your local Biosecurity officer or your local government office should be able to assist you.

Pindone

Pindone is an anticoagulant registered for rabbit control. This poison works by preventing blood from clotting. In Queensland, it is not recommended for broadacre use and is mainly used in urban areas and near farm buildings.

Pindone works best when given as a series of small doses/feeds over a period of three days. Although pre-feeding is not essential, it does enhance the bait uptake by shy rabbits as they get used to the feed prior to any poison bait being laid. To be effective, pindone requires multiple feeds so that the poison can build up to fatal levels in the rabbit's body. Feeding over a number of nights provides plenty of opportunity for most of the rabbit population to consume the required lethal dose. Rabbits poisoned with pindone will usually die within 10–20 days.

Pindone baiting does not work well when there is a lot of green pick around for rabbits.

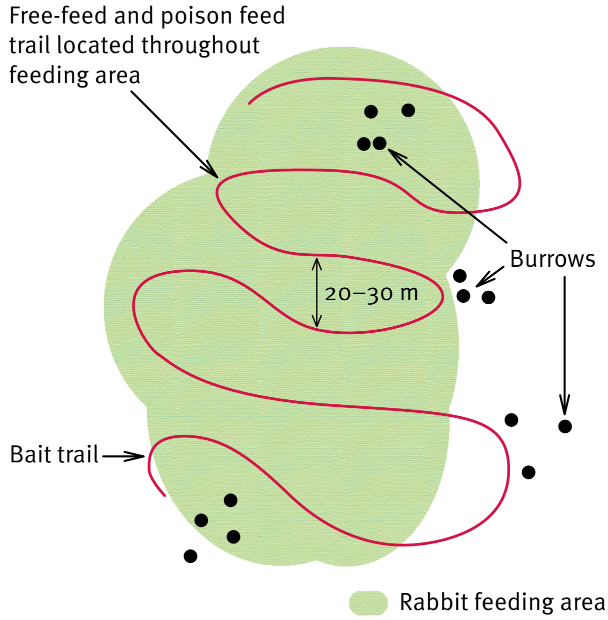
Poison bait trails

It is important that bait trails are laid properly to ensure the best results. 'Baitlayers' make it easier to put out bait trails at the correct rate, and they can be towed behind most 4WD vehicles, quad bikes and tractors.

When scratching and laying a trail, consider the following:

- Rabbits like freshly scratched/disturbed soil—this may be because rabbits are territorial and inspect newly disturbed soil, and/or the disturbed vegetation smell attracts them.
- Lay trails around warrens and in the areas where rabbits most often feed.
- Laying trails on slopes and hills requires care—it can cause erosion in some soils types (e.g. granite and traprock). Trails are best laid in a zigzag pattern in steep terrain to minimise erosion.
- A trail that has been scratched for the first feed is easy to follow for the rest of the baiting program.
- The soil should be turned only enough to scratch the surface—don't plough the ground.
- A trail that has been scratched too deep will spook the rabbits because they will not have full sight of their predators.
- Where vegetation is thick, or it is difficult to find the main feeding areas, lay bait trails in a grid pattern across the site.

As a general rule, avoid crossing the bait trail—it can cause confusion when you try to follow the same trail on subsequent occasions.



Method for laying a bait trail (illustration courtesy Animal Control Technologies)

Bait trials will be most effective if you follow these guidelines:

- Use good quality, non-contaminated bait material. (Simple rule: if you wouldn't eat it, the rabbit won't either.)
- Use enough feed to bait all the rabbits in the area. (The pre-feed will give an indication of the potential bait take.)
- Expect a greater uptake of pre-feed and bait material when vegetation is scarce, dried off or soured.
- Ensure that all the preparation equipment is clean and free of any chemical residues or smells—rabbits can be very shy of unusual odours.
- When there are kittens in a warren, lay the bait trail close to the warrens.

Fumigation

Fumigation is labour intensive and time consuming, and is not usually an effective method if used alone. However, as a 'mop-up' technique or control method for use in areas where ripping is not practical (e.g. steep and rocky terrain), it may be a good alternative.

Because this technique relies on directly affecting the rabbits, and does not affect the structure of the warren, it is crucial that as many rabbits as possible are underground when fumigation is carried out. Rabbits usually take refuge in their burrows from mid-morning to mid-afternoon and during hot weather so these are the best times to fumigate. Dogs can also be used to drive rabbits into their warrens.

For best results, fumigation should be carried out in two stages—initially, before the breeding season starts (as this reduces the breeding stock), and then again during the breeding season.

There are two types of warren fumigation—static and pressure. In Queensland, static fumigants are a more popular and safer option for controlling rabbits and will be explained below.

Static fumigation

This method is easy to use, and time- and cost-effective. Static fumigation comes in the form of aluminium phosphide (phosphine) tablets, which can be purchased from most agricultural suppliers. These tablets are small and round (about the size of a marble), and weigh 3 g. Trade names for phosphine include Pestex®, Quickphos® and Gastion®. General directions for the use of phosphine tablets appear below, but always refer to the manufacturer's specific recommendations for use.

To fumigate warrens using phosphine tablets:

1. Find all warren entrances—both active and inactive.
2. Cut back the warren entrance at right angles using a shovel.
3. Separately wrap two tablets in moistened absorbent paper (toilet paper/paper towels).
4. Insert the tablets as far down into the entrance as possible (polypipe and a push rod can be used to help push the tablets down).
5. Push some scrunched-up newspaper down the hole to block the entrance and then cover it up with soil and, if possible, a rock.
6. Treat all entrances to the warren (active and inactive) the same way.
7. Check warrens about a week after fumigation and re-fumigate any reopened entrances.

Once in the warren, the moistened tablets react with air to release a toxic gas, which spreads quickly throughout the warren. The phosphine gas itself is invisible and odourless but leakages from the warren can be detected by the smell of ammonia. (This is a safety mechanism that is built into the tablet.) Any leakages need to be blocked immediately.

Shooting

Shooting is most useful when used to 'mop up' after other control methods (such as ripping). To get the best results, shoot at the time of day when rabbits are active. This is usually in the early morning, late afternoon or at night. The best and most economical firearm to use is a .22 calibre rifle.

If your property is within an urban area, you will need to comply with local government regulations and the *Police Powers and Responsibilities Act 2000*, which restrict the use of firearms.

Further information

For further detailed reading information on specific rabbit control techniques or costing your rabbit control please refer to Rabbit control in Queensland; a guide for land managers. Download from the Biosecurity Queensland website at www.biosecurity.qld.gov.au

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

Wild rabbit

Escaped or dumped pet rabbits

This fact sheet is developed with funding support from the Land Protection Fund.

Restricted invasive animal

Feral cat

Felis catus

A descendant of the African wild cat (*Felis silvestris lybica*), the common 'house' cat (*Felis catus*) has now been domesticated for about 4000 years. Although the domestic cat has a long history of association with humans, it retains a strong hunting instinct and can easily revert to a wild (feral) state when abandoned or having strayed from a domestic situation.

Semi-feral cats live around dump sites, alleys or abandoned buildings, relying on humans by scavenging rubbish scraps and sheltering in abandoned structures. The true feral cat does not rely on humans at all, obtaining its food and shelter from the natural environment.

Legal requirements

The feral cat is a restricted invasive animal under the *Biosecurity Act 2014*. This is a cat that is not domesticated. The feral cat must not be moved, fed, given away, sold, or released into the environment without a permit. The Act requires everyone to take all reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control. This is called a general biosecurity obligation (GBO). This fact sheet gives examples of how you can meet your GBO.

Queensland Government

At a local level, each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

Description

The feral cat differs little in appearance from its domestic counterpart; however, when in good condition, the feral cat displays increased overall muscle development, especially noticeable around the head, neck and shoulders, which gives the animal a more robust appearance. The average body weight of male feral cats is 3–6 kg, while females weigh 2–4 kg. Body weights vary with condition, with some extremely large specimens documented.

Australian feral cats are predominantly short-haired, with coat colours that range between ginger, tabby, tortoiseshell, grey and black. White markings may be present on the feet, belly, chest and throat; completely white feral cats are extremely rare. In established populations, coat colours are the result of a natural, genetically selective process. Terrain, predators and the ability to capture prey limit coat colours to those that provide the most suitable camouflage and cause a predominance of these colours in subsequent offspring. Ginger cats are more likely to be found in the semi-arid and desert areas, while grey and black specimens generally predominate in scrub and more heavily timbered habitats.

The feral cat is most active at night, with peak hunting activity occurring soon after sunset and in the early hours before sunrise. At night the cat displays a distinctive green eyeshine under spotlight, making it easily distinguishable from other animals. During the day it will rest in any number of den sites, which may include hollow logs, dense clumps of grass, piles of debris, rabbit burrows, and even the hollow limbs of standing trees.

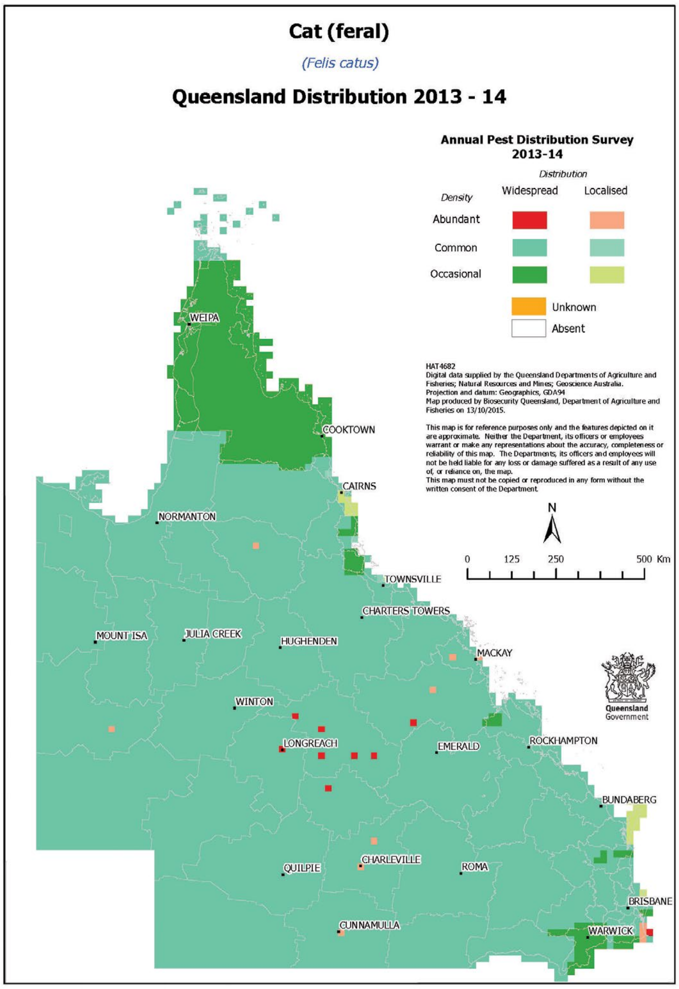
The most obvious and characteristic field signs of feral cats are their scats (droppings). Unlike the domestic cat, the feral cat does not bury its scats, but leaves them exposed at prominent sites to warn other cats of its territorial boundary.

Life cycle

Male cats attain sexual maturity at about 12 months, whereas females are capable of reproduction at approximately seven months. Annually, and under ideal conditions, an adult female can produce up to three litters—each of usually four kittens, but varying from two to seven.

As the breeding instinct is triggered by the increasing length of daylight, litters are less frequent in winter. Most reproduction occurs during the spring and summer months, and is generally limited to two litters per year. Birth follows a gestation period of 65 days, and kittens may be reared in a single den site or may be frequently shifted to other sites within the female's home range. Family and litter bonding begin to break down when the kittens are approximately seven months old. The female's ability to bear litters does not decrease with age, so reproduction continues for the course of her life.

Map 1. Distribution of feral cats in Queensland



Habitat and distribution

There is some evidence to suggest that the cat was present in Australia long before European settlement. This may have occurred as a result of Dutch shipwrecks and regular visits to northern Australia by early South-East Asian vessels as long as 500 years ago.

Post-settlement dispersal resulted from cats straying from areas of early colonisation. In the late 19th and early 20th centuries, large numbers of cats were purposely released in many rural areas to combat plague numbers of rabbits. Unwanted cats continue to be released into urban and rural areas by irresponsible pet owners.

The feral cat is now present Australia-wide, thriving under all climatic extremes and in vastly different types of terrain.

Feral cats maintain stable home ranges, the sizes of which depend upon the relative abundance of food and the availability of suitable den sites. Dominant male cats may have territories of up to 8 km^2, while the territories of females are smaller and may even be halved while kittens are being reared.

Scent glands are present on the chin, at the corners of the mouth, and in the anal region. Territorial boundaries are maintained by scent marking with the cheek glands, pole-clawing, urinating and leaving exposed faecal deposits.Although feral cats are often thought of as being solitary animals, studies show this behaviour is generally limited to hunting activities. At other times feral cats display a degree of social interaction that peaks during the breeding season. Group behaviour has been observed in semi-feral populations, and it has been suggested that such behaviour is exhibited also in feral populations.

Groups usually comprise several related adult females, their young of both sexes, and an adult male—whose range may include other groups of females. Young females usually remain in a group, while young males either leave or are driven from the group as they reach sexual maturity.

Impacts

Effects on wildlife

The energy expended by an adult male cat requires it to consume 5–8% of its body weight in prey per day, while females raising kittens require 20%. Based on these figures, one study concluded that 375 feral cats on Macquarie Island would consume 56 000 rabbits and 58 000 sea birds per year. Where present on the mainland, rabbits may comprise up to 40% of a feral cat's diet. Cats are successful as a control mechanism only when rabbit densities are low. At other times cat predation does little to halt the build-up or spread of rabbit populations; rabbits merely help to support a larger number of cats. When seasonal shortages of rabbits occur there is a corresponding rise in the number of native animals taken by cats.

The feral cat is an opportunistic predator, and dietary studies have shown that small mammals, birds, reptiles, amphibians, insects and even fish can be taken as prey. Cat predation is particularly harmful in island situations, and a number of species have become extinct due to the introduction of cats by early sealers and lighthouse keepers. On the mainland, native animals—which already suffer due to the destruction of their habitats by man and other introduced animals—may be endangered further by cat predation. Actual competition for prey can cause a decline in the numbers of native predatory species such as quolls, eagles, hawks and reptiles. Not only do native animals bear the brunt of predation, but they also suffer the effects of a parasite that reproduces only in the intestine of the cat. This disease (toxoplasmosis) is particularly harmful to marsupials, which may develop blindness, respiratory disorders, paralysis, and suffer the loss of offspring through abortion and stillbirths.

Exotic disease—rabies

Due to their widespread distribution, feral cats may prove to be a major vector for this fatal viral disease if it ever enters Australia. Overseas studies have revealed that wounds inflicted by rabid cats are more dangerous than those caused by rabid dogs. While the bites of rabid dog are generally inflicted on the arms and legs, the cat attacks the head of its victim, biting and clawing viciously. These head and facial bites reduce the time taken for the virus to enter the central nervous system, lessening the chance of success from subsequent remedial treatment.

Control

Managing feral cats

The GBO requires a person to take reasonable and practical steps to minimise the risks posed by feral cats. This fact sheet provides information and some options for controlling cats.

Exclusion fencing

Fencing is the only feasible method of control when special areas need protection from cats. Feral cats have been successfully prevented from climbing over netted fences that use an electrified wire mounted 15 cm from the top and 10 cm outward from the fence. Non-electrified fencing should incorporate a netted ceiling, or a curved overhang, which prevents the cat from climbing straight up and over the fence.

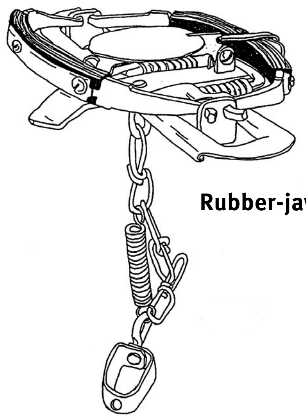
Trapping

Rubber-jawed, leg-hold traps (see below) can be laid in the same manner as they are laid for dingoes and foxes. Leg-hold traps can work well with true feral cats, which would normally avoid the live-capture box traps.

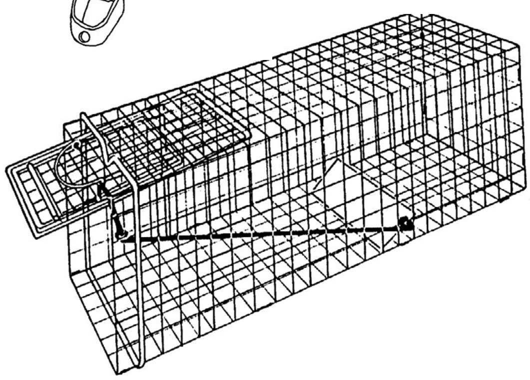
Ideal sites are those where territorial markers, such as faecal deposits and pole-clawing, are noticed. Tuna fish oil has shown some success as an attractant; however, feral cats seem more readily attracted to a site by some visual stimulus such as a bunch of bird feathers hung from a bush or stick.

Semi-feral urban cats are easily trapped in wire 'treadle-type' box traps (see diagram at right). Attractants/lures may be of meat or fish and should be placed so that they cannot be reached through the wire and be retrieved by clawing.

A number of local governments hire cat traps for the purpose of removing stray and feral cats in urban situations.



Rubber-jawed leg-hold trap



Treadle box trap

Lures

Audible recorded lures for feral cats and other predators are available through a number of sources. These recordings mimic the distress call of a small animal and can be used to draw a predator to a bait or trap site.

Shooting

Night shooting is assisted by the cat's distinctive, green eyeshine. Cats have been successfully attracted by the use of a fox whistle.

Poisoning

Fresh meat baits containing 1080 may be used for controlling feral cats under APVMA PERMIT14015.
To obtain a copy of this permit visit www.apvma.gov.au.

Only authorised persons can supply 1080 baits to landholders.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

This fact sheet is developed with funding support from the Land Protection Fund.

Restricted invasive plant

Mother-of-millions

Bryophyllum delagoense (syn. *B. tubiflorum, Kalanchoe delagoensis*) and *Bryophyllum × houghtonii*

Mother-of-millions are native to Madagascar and are escaped ornamental plants. Five species are commonly naturalised in Queensland. It is well adapted to dry areas because of its succulent features.

As the name suggests, one plant can reproduce a new generation from masses of embryoids (plantlets) that are formed on the leaf edges. This makes these plants hard to eradicate and follow up controls are essential.

These plants, especially their flowers, are poisonous to stock and occasionally cause a significant number of cattle deaths. The plant flowers from May to October (during the drier months of the year) and the scarcity of feed at this time may cause cattle to consume lethal amounts of mother-of-millions.

Legal requirements

Mother-of-millions is a restricted invasive plant under the *Biosecurity Act 2014*. It must not be given away, sold, or released into the environment without a permit.

Bryophyllum pinnatum (resurrection plant, live-leaf) is not a restricted invasive plant. However the Act requires everyone to take all reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control. This is called a general biosecurity obligation (GBO). This fact sheet gives examples of how you can meet your GBO.

At a local level, each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

Description

Mother-of-millions are erect, smooth, fleshy succulent plants growing to 1 m or more in height.

All species form tall flower spikes in winter with clusters of bell-shaped flowers. Each species has a distinctive leaf shape, but all produce small plantlets along the edges of the leaves. These plantlets drop readily, develop roots and establish quickly to form a new colony.

Bryophyllum delagoense syn. *B. tubiflorum* and *Kalanchoe delagoensis* (common mother-of-millions, mission bells, Christmas bells) has grey-brown, fleshy, tubular-like leaves with up to seven projections at the tip of each leaf. The flowers are orange-red and occur in a cluster at the top of a single stem. Seeds can germinate for some years.

Bryophyllum × houghtonii syn. *B. daigremontianum × B. delagoense, Kalanchoe × houghtonii* (hybrid or crossbred mother-of-millions) has similar flowers arranged in a branched cluster at the top of the stem. Its leaves are boat shaped with thick stalks and notches along the edges of the leaves.

A third species, *Bryophyllum pinnatum (*resurrection plant, live-leaf) has yellow-green, oval, fleshy leaflets with wavy edges and up to five leaflets per leaf. Its flowers are yellowish-green, often tinged with pink, and occur in loose clusters on stalks growing at intervals along the upper portion of the stem.

Life cycle

Mother-of-millions flowers in Winter and reproduces by seed and by tiny plantlets that are produced at the tips of its fleshy (succulent) leaves. Dislodged leaves and broken leaf parts can also take root and give rise to new plants.

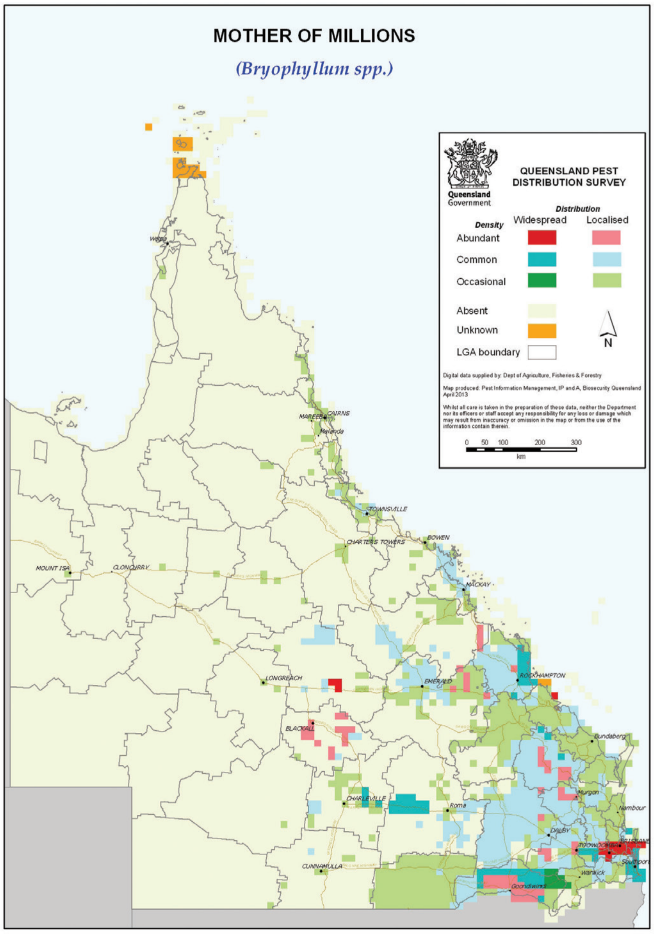
Methods of spread

Mother-of-millions is commonly spread by garners and in garden waste. The tiny seeds are probably wind and water dispersed and its leaves and plantlets may also be dislodged and spread by animals, vehicles, machinery, soil and slashers.

Habitat and distribution

Native to Madagascar, these popular succulent garden plants have escaped culitvation and spread in various areas of Queensland. They have become a problem in pasture lands in the central highlands around Clermont, Emerald and Dingo, and the Burnett, Moreton and Darling Downs scrub regions. The plants establish well in leaf litter or other debris on shallow soils in shady woodlands, and often grow on roadsides, along fence lines and around old rubbish dumps. They can spread from these areas, especially in flood, and establish if pastures are run down.

Map 1. Distribution of mother-of-millions in Queensland



They are adapted to dry conditions and can survive long periods of drought.

Toxicity

These plants are toxic, especially their flowers, and occasionally cause a significant number of cattle deaths. When cattle are under stress or in unusual conditions they are more likely to eat plants that they would not normally eat. Shifting cattle to new paddocks, moving stock through infested rubbish dumps and wastelands, and reduction of availability of feed due to flood or drought can all contribute to cattle eating mother-of-millions and being poisoned.

Poisoned cattle show signs of dullness, loss of appetite, diarrhoea and heart failure. Some cattle may drool saliva or dribble urine. There are two responses to poisoning:

- acute—where cattle die within a day
- chronic—where cattle may take up to five days to die.

Some cattle may make a slow recovery if insufficient plant material was eaten.

Poisoned cattle must be treated within 24 hours of consuming the plant. The treatment is intense and needs to be given by a veterinarian, or under their direction, because of the drugs and materials used.

Control

Managing mother-of-millions

The GBO requires a person to take reasonable and practical steps to minimise the risks posed by mother-of-millions. This fact sheet provides information and some options for controlling mother-of-millions.

Prevention and early detection

The best form of weed control is prevention. Always treat weed new infestations when small—do not allow weeds to establish. Weed control is not cheap, but it is cheaper to do it now rather than next year, or the year after. Proper planning ensures better value for each dollar spent.

Permanent control of mother-of-millions infested areas is best ensured by establishing more desirable plants in that location to compete successfully with future mother-of-millions seedlings and plantlets. This is best achieved through soil preparation, replanting, fertilising and using the area more productively.

Ensure scattered infestations and small dumping areas on properties are regularly checked and cleaned up. Day-today hygiene management will help prevent establishment of these weeds.

Co-operative control upstream and downstream of problem areas will help prevent re-infestation from other areas.

To prevent poisoning, keep stock (especially hungry stock) away from infested areas until the plants are controlled.

Mechanical control

For small areas, pull up plants by hand and burn on a wood heap. Alternatively, bag the plants and dump them in a bin, the contents of which are buried at council refuse tips rather than being recycled into mulch.

Fire

When suitable (e.g. after grading firebreaks), burn infestations and the accompanying debris on which mother-of-millions plants thrive. This is the most economical form of control, encourages grass competition and lessens the problem for following years, requiring only spot spraying with selective herbicides.

Biological control

The South African citrus thrip is present in Queensland and is quite widespread through the south of the state. The thrip damages the outer tissue of the mother-of-millions plant and also lays its eggs under the outer tissue. Where high populations of thrips exist, the number of viable plantlets and flowers forming on mother-of-millions is reduced.

The thrips populations vary from year to year, according to mother-of-millions populations and climate. The South African citrus thrips should not be seen as a long term control strategy—only a control option to complement other techniques such as herbicide treatment and burning.

The department is undertaking further research to identify potential biological control agents to support with management.

Herbicide control

Before using any herbicide always read the label carefully. All herbicides must be applied strictly in accordance with the directions on the label. Where the addition of a wetting agent is recommended, always use a commercial wetting agent or surfactant.

Mother-of-millions may be controlled with herbicides at ny time of the year, but infestations are easiest to see in winter when the plants are in flower. Treating infestations at this time of year also has the benefit of preventing new seeds from developing on common mother-of-millions.

Table 1 details the herbicides registered for mother-of-millions control.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

Bryophyllum x *houghtonii* (left) and *Bryophyllum delagoense* (right)

South African citrus thrips damage to mother-of-millions

Table 1. Herbicides for the control of mother-of-millions

Situation	Herbicide	Rate	Comments
Pastures and non-crop land	2,4-D acid (e.g. Affray 300)	7 L/1000 L water per ha 70 mL/10 L water	High volume foliar spray (handgun) High volume foliar spray (knapsack)
Pastures, rights-of-way and industrial	2,4-D amine 700 g/L (e.g. Amicide Advance 700)	360 mL/100L water	Hand gun and knapsack only. Thorough coverage is essential. Use a surfactant (e.g. Nufarm Activator) (consult label).
Pastures, rights-of-way, non-crop land, forests, non-agricultural land and commercial and industrial areas	Triclopyr 300 g/L + Picloram 100 g/L (e.g. Conqueror) or Triclopyr 300 g/L + Picloram 100 g/L + Aminopyralid 8 g/L (e.g. Grazon Extra)	500 mL/100 L water 50 mL/10 L water	High volume foliar spray (hand gun, knapsack). Always add a wetting agent (e.g. BS-1000 or Chemwet 1000) at 100 mL/100 L water. Apply at flowering.
	Fluroxypyr 200 g/L (e.g. Flagship 200)	600 mL/100 L water + sufactant (consult label)	Apply to seedlings and young plants before flowering.
	Fluroxypyr 333 g/L (e.g. Starane Advanced)	360 mL/100 L water + sufactant (consult label)	
	Fluroxypyr 400 g/L (e.g. Comet 400)	300 mL/100 L water + sufactant (consult label)	

Notes

Thorough, even coverage of leaves and plantlets is necessary.

Note that many 2,4-D products are not registered for control of mother-of-millions in Queensland. Only use products registered for the purpose.

Read the label carefully before use. Always use the herbicide in accordance with the directions on the label.

This fact sheet is developed with funding support from the Land Protection Fund.

Department of Agriculture, Fisheries and Forestry
Biosecurity Queensland

Fact sheet

DECLARED CLASS 1 AND 2 PEST PLANT

PP22 November 2013

Harrisia cactus

Moonlight cactus

Harrisia martinii, Harrisia tortuosa and *Harrisia pomanensis*




Harrisia cactus can form dense infestations that will reduce pastures to a level unsuitable for stock. Harrisia cactus will choke out other pasture species when left unchecked.

The spines are a problem for stock management, interfering with mustering and stock movement.

Harrisia cactus produces large quantities of seed that is highly viable and easily spread by birds and other animals. As well as reproducing from seed, harrisia cactus has long trailing branches that bend and take root wherever they touch the ground. Any broken-off portions of the plant will take root and grow.

Control of this plant is difficult as it has a deep underground tuberous root system.

Declaration details

Harrisia cactus (*Harrisia martinii*, *Harrisia tortuosa* and *Harrisia pomanensis*) are Class 2 declared pest plants under the *Land Protection (Pest and Stock Route Management) Act 2002*. All other harrisia species are Class 1 declared pest plants.

Declaration requires landholders to control declared pests on the land and waters under their control. A local government may serve a notice upon a landholder requiring control of declared pests.

It is an offence to introduce, keep or supply Class 1 or 2 pests without a permit issued by Biosecurity Queensland. Penalties apply.

Description and general information

Dense infestations of harrisia cactus choke out pasture. The sharp spines, even in light infestations, make pasture unfavourable to stock and interfere with operations such as mustering.

The plant fruits prolifically and seeds are spread widely by birds and animals. Harrisia cactus can also reproduce by stem sections taking root. A deep underground tuberous root system allows the plant to survive even if the above-ground parts are killed.

Harrisia cactus is a perennial. The spiny fleshy stems are jointed and form tangled mats about half a metre high. Many branches often lie flat and take root where they touch the ground. Each section is ribbed lengthwise with six ribs; each rib has low, thick, triangular humps at regular intervals. These humps have cushions of grey felty hairs, three to five short spines lying flat, and one to three erect, stiff, very sharp spines 2.5–3 cm long.

The large flowers open at night. Flowers are pink and funnel-shaped with a tinge of white. These grow singly near the ends of the stems on a scaly but spineless slender grey-green tube 12–15 cm long.

Round, red fruits 4–5 cm across have scattered bumps with hairs and spines. Numerous small black seeds are embedded in the white, juicy pulp of the fruit, which splits open when ripe.

Harrisia cactus roots are of two types. Shallow feeding roots up to 3 cm thick and 30 cm to 2 m long grow mostly horizontally off a crown, up to 15 cm below ground level. Swollen tuberous storage roots descend to a depth of 15–60 cm.

Life cycle

Harrisia cactus bears a bright red fruit containing 400–1000 small black seeds. Fruit and seed are readily eaten by birds and to a lesser extent by feral pigs. Plants are easily established from seed dropped by these animals. Seeds germinate soon after rain.

Seedlings quickly produce a swollen tuberous food storage root that develops as the plant grows. Branches take root where they touch the ground and new plants will grow from broken branches and sections of underground tubers.

Counts of tubers in dense cactus infestations have shown over 125 000 per hectare. Each plant houses many dormant underground buds that are all capable of reshooting when the tip growth dies; any small portion of the tuberous root left in the soil will grow.

Habitat and distribution

Harrisia cactus is a native of Argentina and Paraguay, South America. It was introduced to Australia as a pot plant in the 1890s. In 1935 it was first recognised as a serious pest in the Collinsville district and by the 1950s was rapidly spreading south.

Harrisia cactus is mainly a pest of brigalow and associated softwood country. However, infestations are now appearing in box and ironbark stands and also in pine forests. The cactus is shade tolerant and reaches its maximum development in the shade and shelter of brigalow scrub, though established infestations can persist once scrub is pulled.

Harrisia cactus is found in the Collinsville, Nebo, Moranbah, Dingo, Blackwater and Goondiwindi districts, with minor infestations occurring at Millmerran, Greenmount, Gatton, Ipswich, Rockhampton, Rannes, Mount Morgan, Alpha and Mitchell.

Control

Mechanical control

Dig out plants completely and burn. Ensure that all tubers that can grow are removed and destroyed.

Ploughing is not considered an effective means of control unless followed by annual cropping.

Biological control

Two introduced insects have become established in the field:

- a stem-boring longicorn beetle, *Alcidion cereicola*
- a mealy bug, *Hypogeococcus festerianus*.

The stem-boring beetle only attacks older woody stems. In the Collinsville area, large beetle colonies developed and contributed to the collapse of dense areas of cactus. Populations of *Alcidion cereicola* have declined with the reduction in the cactus in recent years.

The most successful biological control agent is the mealy bug *Hypogeococcus festerianus* which is now present in harrisia cactus in Collinsville, Dingo, Moranbah, Blackwater, Nebo, Charters Towers and Goondiwindi districts, with small colonies established at Alpha, Capella, Rannes, Gatton, Greenmount, Millmerran and Rockhampton.

How mealy bug works

The mealy bug aggregates and feeds in the tips of stems and buds, where it limits growth and causes distortion. This results in the knotting of the stem. The plant's response is to utilise energy reserves within the tuber system to produce new growth. Eventually the plant dies, as it is unable to support the continuous high energy demands.

Dry weather reduces the effectiveness of the mealy bug. When dry, the plant's tuber system becomes dormant. Consequently, mealy bug damage does not result in new growth and the energy reserves within the plant are not affected. Instead the bug may damage all vegetative parts and eventually die out. The tuber will remain dormant until adequate moisture returns, when it will reshoot.

How to spread the bug

Mealy bug disperses naturally via wind, although landholder assistance is necessary for its continuous spread, particularly between patches. The bug is manually spread by cutting infected stems and placing them into healthy plants. The best pieces for starting new colonies are large knobs of twisted and distorted cactus that contain many mealy bugs well protected inside knots. Stem tips covered by white, woolly masses of bug are also good. To collect the bug, cut infected stems approximately 15 cm from the distorted knob and place segments in green, plump sections of the healthy plant. Avoid placing mealy bug in stressed or dried out stems. Small cactus plants require at least one large knot, with larger plants requiring three knots per plant. Where possible, landholders should infest every cactus clump as this ensures a rapid reduction in growth and fruiting potential. When cactus infestations are light, chemical control may be a preferable option.

Cut pieces can be transported in boxes or open vehicles. They are not delicate, but are best kept in the shade. Avoid keeping them in large heaps, in direct sunlight, under tarpaulins or in closed containers for long periods. Such conditions will promote rotting of the stems, leading to poor results or failures. Ideally, stems should be put out within three days and a maximum of five days.

When to infest

Best results come by infesting new areas during spring and early summer, from September to December. Maximum growth and spreading occurs in the summer months of December to February. During the drier and colder months of April to August the mealy bug does not die, but little growth and multiplication occurs. Introduction of mealy bug during autumn and winter will not be lost, but little effect is seen until the following summer.

How soon to expect results

Mealy bugs are generally more active and effective on harrisia cactus growing underneath shrubs and trees, so results will be seen more quickly in these areas than in cactus growing in the open. Best results are obtained when infesting plants that have actively growing new shoots.

During wet summers in northern and central Queensland, the growing points of stems will begin to curl after about six weeks.

By the end of the first summer, damage (severe twisting) will be widespread in infested plants. If the initial infestation was sufficiently heavy, no fruit or growth will occur during the second year, and the cactus will begin to die during the third year. Seedlings and regrowth shoots will continue to be present but by the end of the fourth year there should be very little cactus left.

In the southern portion of the state, where temperatures are lower, the mealy bug still provides control but the process takes longer. However, the mealy bug will do better on cactus in the open, rather than in the shade, as temperatures are higher in the open.

Where to obtain mealy bugs

If you cannot obtain mealy bugs from your own property or neighbour, contact the vegetation management, weed control, or environmental officer at your local government.

Foliar application of registered herbicides provides effective control, but can be costly over large areas. Before using any herbicide always read the label carefully. All herbicides must be applied strictly in accordance with the directions on the label.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland (call 13 25 23 or visit our website at www.biosecurity.qld.gov.au).

Map 1. Distribution of harrisia cactus in Queensland

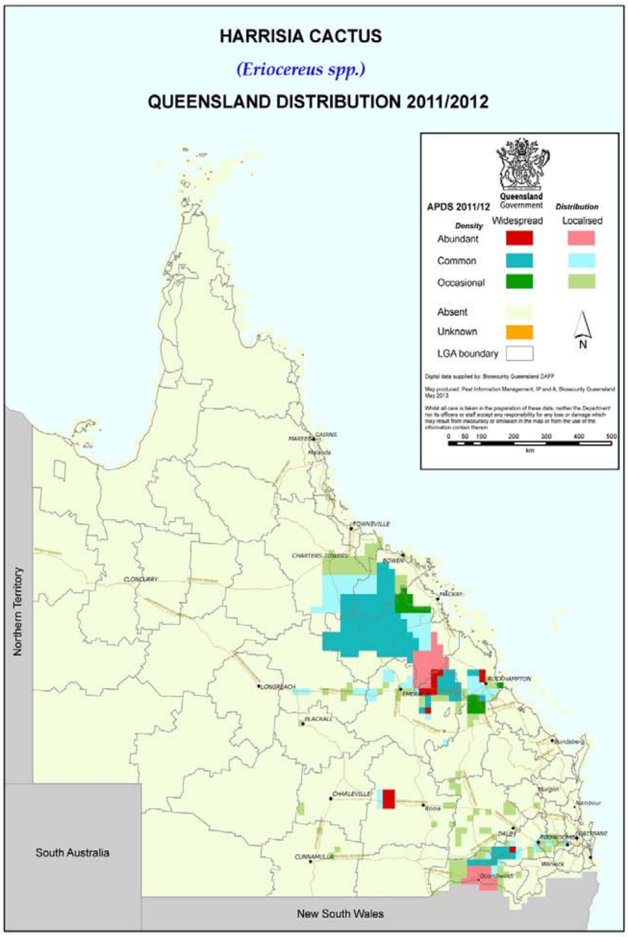


Table 1 Herbicides registered for the control of harrisia cactus

Situation	Herbicide active ingredient	Rate	Comments
Land – non-agricultural land Land – rights of way	dichlorprop as K salt (600 g/L)	1 L/60 L water	Good soil moisture essential. Spray plant when actively growing to run-off point. A follow-up treatment may be necessary.
Land – commercial/industrial/public Land – rights of way, pastures Pastures – native	metsulfuron-methyl (600 g/kg) (e.g. Brush-Off®)	20 g/100 L water + surfactant	Spray plant when actively growing to run-off point. A follow-up treatment may be necessary
Agricultural land – non-crop Forests – timber production Land – commercial/industrial/public Land – rights of way, pastures	triclopyr as butotyl (240 g/L) + picloram as ioe (120 g/L) (e.g. Access®)	1 L/60 L diesel	Spray plant when actively growing. Apply as overall spray, wetting all areas of the plant to ground level
Land – around buildings Land – commercial/industrial/public Land – rights of way	triclopyr as butotyl (75 g/L) +metsulfuron-methyl (28 g/L) (e.g. Ultimate®)	0.5 L/100L	
Agricultural land – non-crop Forests – timber production Land – commercial/industrial/public Land – rights of way, pastures	triclopyr as tea (200 g/L) + picloram as tipa (100 g/L) (e.g. Tordon DSH®)	5 L/100 L water 2.5 L/100 L water	Spray plant when actively growing. Treat all stems thoroughly

Read the label carefully before use. Always use the herbicide in accordance with the directions on the label.

This fact sheet is developed with funding support from the Land Protection Fund.

Restricted invasive plant

Parthenium

Parthenium hysterophorus

Parthenium is a vigorous species that colonises weak pastures with sparse ground cover. It will readily colonise disturbed, bare areas along roadsides and heavily stocked areas around yards and watering points. Parthenium can also colonise brigalow, gidgee and softwood scrub soils. Its presence reduces the reliability of improved pasture establishment and reduces pasture production potential.

Parthenium is also a health problem as contact with the plant or the pollen can cause serious allergic reactions such as dermatitis and hay fever.

Parthenium is listed as a Weed of National Significance.

Legal requirements

Parthenium is a restricted invasive plant under the *Biosecurity Act 2014*. It must not be given away, sold, or released into the environment without a permit. The Act requires everyone to take all reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control. This is called a general biosecurity obligation (GBO). This fact sheet gives examples of how you can meet your GBO.

At a local level, each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

Queensland Government

Description

Parthenium is an annual herb with a deep tap root and an erect stem that becomes woody with age. As it matures, the plant develops many branches in its top half and may eventually reach a height of 2 m.

Its leaves are pale green, deeply lobed and covered with fine soft hairs.

Small creamy white flowers occur on the tips of the numerous stems. Each flower contains four to five black seeds that are wedge-shaped, two millimetres long with two thin, white scales.

Life cycle

Parthenium normally germinates in spring and early summer, produces flowers and seed throughout its life and dies around late autumn. However, with suitable conditions (rain, available moisture, mild temperatures), parthenium can grow and produce flowers at any time of the year. In summer, plants can flower and set seed within four weeks of germination, particularly if stressed.

Methods of spread

Parthenium seeds can spread via water, vehicles, machinery, stock, feral and native animals and in feed and seed. Drought conditions aid the spread of seed with increased movements of stock fodder and transports.

Habitat and distribution

Parthenium is capable of growing in most soil types but becomes most dominant in alkaline, clay loam soils.

The plant is well established in Central Queensland and present in isolated infestations west to Longreach and in northern and southern Queensland.

Infestations have also been found in northern and central parts of New South Wales and it is capable of growing in most states of Australia.

Control

Managing parthenium

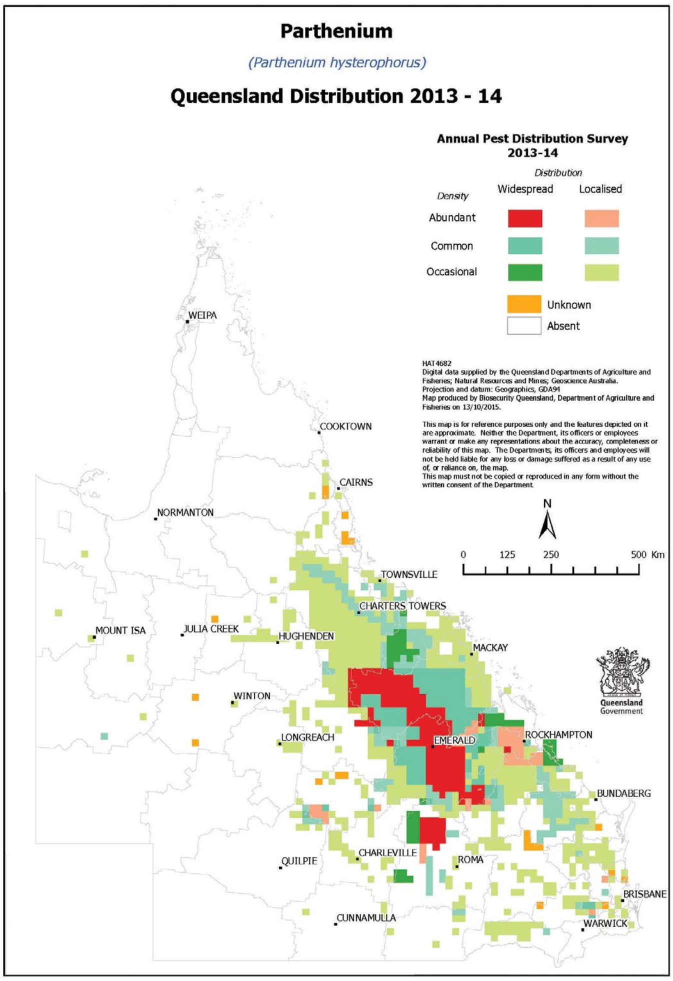
The GBO requires a person to take reasonable and practical steps to minimise the risks posed by parthenium. This fact sheet provides information and some options for controlling parthenium.

Prevention and weed seed spread

Pastures maintained in good condition, with high levels of grass crown cover, will limit parthenium colonisation. Drought, and the subsequent reduced pasture cover, creates the ideal window of opportunity for parthenium colonisation when good conditions return.

Vehicles and implements passing through parthenium infested areas should be washed down with water. Particular care should be taken with earthmoving machinery and harvesting equipment. The wash down procedure should be confined to one area, so that plants that establish from dislodged seed can be destroyed before they set seed.

Map 1. Distribution of parthenium in Queensland



Extreme caution should be taken when moving cattle from infested to clean areas. Avoid movement during wet periods as cattle readily transport seed in muddy soil. On arrival, cattle should be held in yards or small paddocks until seed has dropped from their coats and tails prior to their release into large paddocks. Infestations around yards can be easily spotted and controlled whereas infestations can develop unnoticed in large paddocks.

Particular care should be taken when purchasing seed, hay and other fodder materials. Always keep a close watch for the emergence of parthenium or other weeds on areas where hay has been fed out.

Property hygiene is important. Owners of clean properties should ensure that visitors from infested areas do not drive through their properties. If your property has parthenium on it, ensure that it is not spread beyond the boundary or further within the property.

Manual control

Hand pulling of small areas is not recommended. There is a health hazard from allergic reactions and a danger that mature seeds will drop off and increase the area of infestation.

Pasture management

Grazing management is the most useful method of controlling large-scale parthenium infestations. Maintain pastures in good condition with high levels of ground and grass crown cover. This may require rehabilitation of poor pastures, followed by a sound grazing maintenance program.

Sown pasture establishment—Poor establishment of sown pastures can allow parthenium colonisation.

Pasture agronomy—Aerial seeding prior to scrub pulling is normally beneficial.

Overgrazing—High grazing pressure caused by drought or high stock numbers decreases the vigour and competitiveness of pastures and allows the entry and spread of parthenium. Maintenance of correct stock numbers is most important in controlling parthenium.

Pastures spelling—In situations of serious infestation, pasture spelling is essential for rehabilitation. Total spelling is much more effective than simply reducing the stocking rate. However, overgrazing of the remainder of the property must be avoided.

The most appropriate time for pasture spelling is the spring–summer growing period, with the first 6–8 weeks being particularly important. If the condition of perennial grasses (native or sown) is low, spelling for the entire growing season may be required or introduced grasses may need to be re-sown. Herbicide treatment can hasten the rehabilitation process by removing a generation of parthenium seedlings and allowing grass seedlings to establish without competition. In the presence of parthenium, grass establishment is poor.

Grazing during winter should not increase the parthenium risk. Most tropical grasses are dormant and can tolerate moderate grazing during this period. However, parthenium may germinate and grow at this time.

Fencing—One of the main problems in controlling parthenium is the large paddock size and the variability of country within paddocks. The resulting uneven grazing pressures encourage parthenium to colonise the heavily grazed country. Ideally, similar land types should be fenced as single units. Fencing can be used to great effect to break up large paddocks, allowing more flexible management such as pasture spelling or herbicide application, options not available previously.

Burning—Burning is not promoted as a control strategy for parthenium. However, research suggests that burning for pasture management (e.g. woody weed control) should not result in an increased infestation if the pasture is allowed to recover prior to the resumption of grazing. Stocking of recently burnt areas known or suspected to contain parthenium decreases pasture competition and favours parthenium, ultimately creating a more serious infestation.

Biological control

The combined effects of biological control agents reduced the density and vigour of parthenium and increased grass production.

There are currently a number of insect species and two rust pathogens that have been introduced to control parthenium—a selection of these are outlined below. *Epiblema strenuana* is a moth introduced from Mexico established in all parthenium areas. The moth's larvae feed inside the stem, forming galls that stunt the plant's growth, reduce competitiveness and seed production.

Listronotus setosipennis is a stem-boring weevil from Argentina but is of limited success in reducing parthenium infestations.

Zygogramma bicolorata is a defoliating beetle from Mexico which is highly effective where present. It emerges in late spring and is active until autumn.

Smicronyx lutulentus (Mexico) lays eggs in the flower buds where the larvae feed on the seed heads. *Conotrachelus albocinereus* (stem-galling weevil from Argentina) produces small galls and is still becoming established in Queensland.

Bucculatrix parthenica (leaf mining moth from Mexico) larvae feed on leaves, leaving clear windows in the leaf. *Carmentia ithacae* is a stem boring moth from Mexico which is becoming established at favourable sites in the northern Central Highlands.

Puccinia abrupta is a winter rust from Mexico that infects and damages leaves and stems. It is currently established over a wide area from Clermont south. It requires a night temperature of less than 16 degrees and 5–6 hours of leaf wetness (dew). Sporadic outbreaks occur where weather conditions are suitable.

Puccinia melampodii is a summer rust from Mexico that weakens the plant by damaging the leaves over the summer growing season. It is currently established and spreading at a number of sites from north of Charters Towers to Injune in the south.

Herbicide control

Non-crop areas

Parthenium should be sprayed early before it can set seed. A close watch should be kept on treated areas for at least two years.

Small and/or isolated infestations should be treated immediately. Herbicide control will involve a knockdown herbicide to kill plants that are present and a residual herbicide to control future germinations. Repeated spraying may be required even within the one growing season to prevent further seed production.

Extensive infestations will require herbicide treatment in conjunction with pasture management. Timing of spraying is critical so that parthenium is removed when plants are small and before seeding has occurred. Grasses should be actively growing and seeding so that they can recolonise the infested area.

Table 1. shows the herbicides registered for parthenium control and application rates. All herbicides must be applied strictly in accordance with the directions on the label.

Cropping areas

Controlling parthenium in cropland requires selective herbicide use and/or crop rotations. For further information on parthenium control in crops consult your local biosecurity officer.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

Table 1. Herbicides for the control of parthenium

Situation	Herbicide	Rate	Comments
Pastures, rights-of-way and industrial land	2,4-D as amine 625 g/L (e.g. Ken-Amine 625)	320 mL/100 L water	Spot spray Apply to young actively growing plants, ensuring thorough coverage
	2,4-D as amine 700 g/L (e.g. Amicide Advance 700)	285 mL/100L water	
Non agricultural areas (native pastures), commercial and industrial areas, rights-of-way	Aminopyralid 375 g/kg plus metsulfuron-methyl 300 g/kg (Stinger)	10 g/100 L water plus wetting agent Consult label	Spray to thoroughly wet all foliage but not to cause run-off
Fields and fallow, various crops (see label)	Atrazine 500 g/L (e.g. Kenso Atrazine 500)	3.6–6 L/ha Rate varies with situation Consult label	Boom spray. Pre and post emergent application Restrictions apply. Consult label for details of specific conditions. Max 3 kg a.i./ha/yr
Roadside and rights-of-way		6 L/ha	Boom spray. Pre and post emergent application Restrictions apply. Consult label for details of specific conditions. Max 3 kg a.i./ha/yr
Fields and fallow, various crops (see label)	Atrazine 900 g/kg (e.g. Atradex WG)	2–3.3 kg/ha Rate varies with situation Consult label	Boom spray. Pre and post emergent application Restrictions apply. Consult label for details of specific conditions. Max 3 kg a.i./ha/yr
Roadside and rights-of way		3.3 kg/ha	Boom spray. Pre and post emergent application. Restrictions apply. Consult label for details of specific conditions. Max 3 kg a.i./ha/yr
Non-crop areas, commercial and industrial areas, pastures and rights-of-way	2,4-D 300 g/L + picloram 75 g/L (e.g. Tordon 75-D)	125 mL/100 L	Spot spray during rosette stage Use at least 3000 L/ha in dense infestations Consult label
		3 L/ha	Boom spray during rosette stage Consult label
Native pastures, rights-of-way, commercial and industrial land	metsulfuron methyl 600g/L (e.g. Associate)	5 g/100 L water + wetter	Hand gun. Spray to thoroughly wet all foliage but not to cause runoff
		7 g/ha + wetter	Boom spray. For pastures only. Treat in rosette stage. Consult label for details
Wheat, barley, triticale and cereal rye		5–7 g/h	Boom spray. Lower rate up to 4-leaf stage, higher rate 4-leaf stage to rosette
Native pastures, rights-of-way, commercial and industrial land	Triclopyr 75 g/L + metsulfuron-methyl 28 g/L (e.g. Zelam Brush Weed)	125 mL/100 L water	Spot spray plants from rosette to flowering Consult label for critical comments
Commercial and industrial areas, rights-of-way, around agricultural buildings	Hexazinone 750 g/kg (e.g. Velpar DF)	1 kg/ha 2 g/10 L/20 m^2	Boom spray or spot spray
Around agricultural buildings	Hexazinone 250 g/L (e.g. Velpar L)	3.5 L/ha or 7 L/10 L/20 m^2	
Grass pastures, fallows, various crop and non-crop situations (consult label for details	Dicamba 500 g/L (e.g. Kamba 500) Dicamba 700 g/kg	Rates vary with situation Consult label	Boom spray or spot spray Consult label for details and critical comments

A number of the listed herbicides are available as different formulations, but some may not be registered for parthenium. Check the label for registration, rate and critical comments. Only use products that list parthenium on the label. The registered rates are for non-crop uses. Consult label for in-crop recommendations. For power hand spray or knapsack use, spray plants to the point of runoff.

Read the label carefully before use. Always use the herbicide in accordance with the directions on the label.

This fact sheet is developed with funding support from the Land Protection Fund.

Restricted invasive plant

Parkinsonia

Jerusalem thorn or jelly bean tree

Parkinsonia aculeata

Parkinsonia is native to tropical America but has spread throughout the world as an ornamental and shade tree. It can form dense impenetrable thorny thickets along river courses, bore drains, floodplains and grasslands. This makes land inaccessible for people and animals, restricts stock access to drinking water, decreases the amount of pasture available and excludes native vegetation.

Because of its invasiveness it has been recognised in Australia as a Weed of National Significance.

Legal requirements

Parkinsonia is a restricted invasive plant under the *Biosecurity Act 2014*. It must not be given away, sold, or released into the environment without a permit. The Act requires everyone to take all reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control. This is called a general biosecurity obligation (GBO). This fact sheet gives examples of how you can meet your GBO.

Queensland Government

At a local level, each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

Description

A hairless shrub or small tree that rarely grows any more than 10 m high. Parkinsonia has slender green photosynthetic zigzag branches armed with sharp spines.

Its leaves have a short, spine-tipped stalk, with leaf branches 20–40 cm long, flattened with small, oblong leaflets along each edge.

Flowers are yellow, fragrant, five petals, each on a long, slender drooping stalk. Seeds are oval and hard, about 15 mm long, and borne in pencil-like pods 5–10 cm long, constricted between the seeds.

Life cycle

Parkinsonia is fast growing and may flower in early summer of its second or third year of growth. Once established, flowering can occur opportunistically to exploit variable seasonal conditions. Pods mature in late summer, float on water and hence are readily dispersed by flood waters.

Under favourable warm and wet field conditions, most seeds germinate within two years. However, a small proportion of seed may remain dormant for longer periods if it's under heavy pasture cover, buried deeper in the soil profile, when inundated or when insufficient rain has fallen.

Methods of spread

The pods float easily on water so can be carried long distances in floods. Seeds can spread in mud, sticking to vehicles, machinery and on footwear.

Parkinsonia can be spread by livestock, native and feral animals consuming the seed, though this is more in drought times as the pods have low palatability.

Habitat and distribution

As parkinsonia is adapted to an extremely wide range of soil types, there is little doubt that it will continue to spread through watercourses and adjoining areas throughout the sub-humid and semi-arid environments of Queensland.

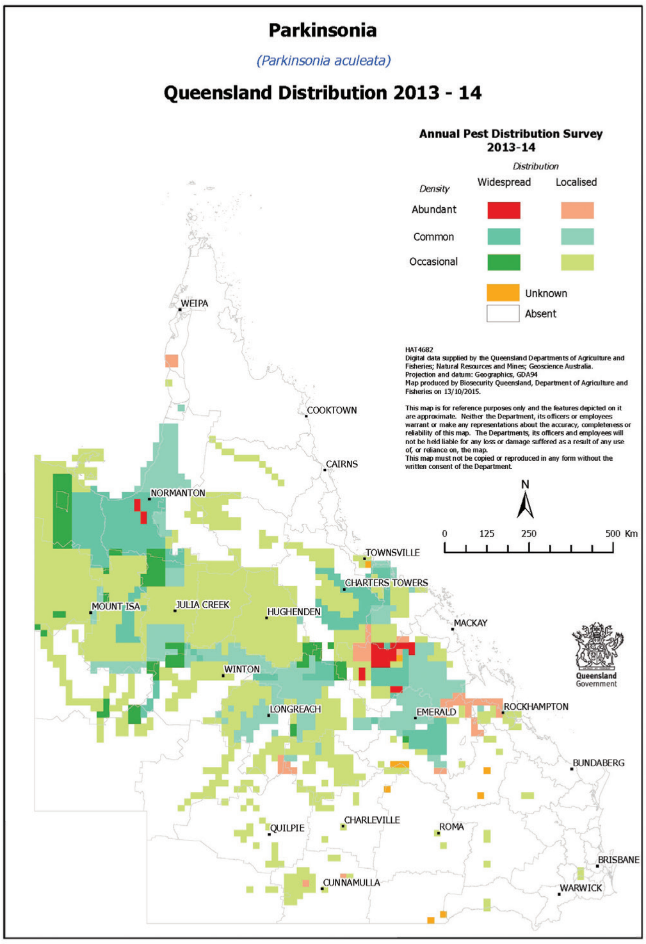
The most vulnerable areas are the lower Gulf of Carpentaria region, Lake Eyre catchment especially the Channel country, Central Queensland including coastal areas and highlands, and Cape York.

Control

Managing parkinsonia

The GBO requires a person to take reasonable and practical steps to minimise the risks posed by parkinsonia. This fact sheet provides information and some options for controlling parkinsonia.

Map 1. Distribution of parkinsonia in Queensland



Mechanical control

Initial clearing by stick raking, blade ploughing or ripping is effective, however:

- it is restricted to reasonably level areas away from watercourses
- clearing will hasten seed germination, necessitating follow-up control either mechanically or chemically.

Establishing improved pasture will aid in managing parkinsonia by competition.

Fire

Fire may be a useful tool for the management of parkinsonia infestations. Kill rates may vary from 30% to 90% with best results obtained from slow moving fires.

Fire will destroy seedlings if sufficient fuel load is present, but mature plants will usually survive.

Biological control

Four species of insects have been introduced into Australia as biological control agents against parkinsonia.

Parkinsonia seed beetles (*Penthobruchus germaini* and *Mimosetses ulkei*)

Both *Penthobruchus germaini* and *Mimosetes ulkei* are seed beetles that attack only parkinsonia and whose larvae destroy mature parkinsonia seeds.

Penthobruchus germaini is a small (5– 6 mm long) brown beetle from Argentina. It was first released in 1995 and has established much more readily than *Mimosestes*.

It has established readily at all release sites and spreads rapidly.

Penthobruchus can exert heavy pressure on parkinsonia seeds in some areas. In the field its presence is indicated by white eggs against a darker background of the pods. Round holes in the pods indicate that beetles have emerged.

Mimosestes ulkei is a small (about 5 mm long) two-tone grey beetle from the USA. While it is established at several sites, it does not establish as readily as *Penthobruchus*. It has potential to contribute to the destruction of parkinsonia seeds. In the field, round emergence holes are the only external indication of its presence.

Parkinsonia leaf bug *(Rhinacloa callicrates)*
Rhinacloa callicrates is a small green bug (about 3 mm long) imported from the USA. It feeds on leaves and shoots of parkinsonia resulting in tiny round white spots where it destroys photosynthetic tissue. It is well established throughout Queensland.

Leaf-feeding looper *(Eueupithecia cisplatensis)*
Eueupithecia cisplatensis (UU) is a leaf-feeding looper caterpillar from Argentina who was imported by CSIRO. DAF releases commenced in 2013 and it is now widely established throughout Queensland. The caterpillar stage eats and damages the leaves, affecting flower and seeding production.

Dieback research

Naturally occurring fungal pathogens have been identified as causing dieback within many infestations of parkinsonia across Northern Australia. Studies are continuing regarding the use of these pathogens as biological control tools.

Herbicide control

Herbicides for the control of parkinsonia are listed in Table 1.

Aerial application

Aerial application is undertaken by purpose-built applicators by helicopter. This is useful for dense, strategic infestations although it may be expensive on a broad scale.

Foliar (overall) spray

This is an effective control method for seedlings up to 2 m tall. Spray leaf and stems to point of runoff. A wetting agent must be used.

Basal bark spray

For stems up to 15 cm diameter, carefully spray around the base of the plant to a height of 30 cm above ground level. Larger trees may be controlled by spraying to a greater height, up to 100 cm above ground level.

Plants should be actively growing and preferably flowering. Field experience has shown that good soil moisture is essential for effective control.

Because parkinsonia infested areas are often subject to flooding, care is needed to ensure mud and flood debris does not prevent spray penetration to the bark. The trunk may need to be cleared before spraying. Addition of petrol or A-1 jet fuel will aid penetration.

Cut stump treatment

Cut stump treatment may be performed at any time of the year. Cut stems off horizontally as close to the ground as possible. Immediately (within 15 seconds) swab or spray the cut surface and associated stem with herbicide mixture.

Soil application

Use one dose of herbicide per metre of tree height. Place doses close to tree trunk, either with spot gun on clear bare ground, or underground with ground injector. Rain or sufficient soil moisture is required before herbicide is taken up by the plant.

Do not use near watercourses or within a distance equal to at least twice the height of desirable trees.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

Table 1. Herbicides for the control of parkinsonia

Situation	Herbicide	Rate	Optimum stage and time	Comments
Agricultural non-crop areas on floodplains	Triclopyr 300 g/L + picloram 100 g/L (e.g. Conqueror) or Triclopyr 300 g/L + Picloram 100 g/L + Aminopyralid 8 g/L (e.g. Grazon Extra)	3 L/ha	Seedlings 1–2 m tall, or 12–24 months old	Aerial application (helicopter only) Use specified wetting agent (consult label)
Grazing land	Tebuthiuron 200 g/kg registered for aerial applicationm (e.g. Clearview)	10–15 kg/ha	Any time, but needs moisture to activate herbicide	Aerial application Use the high rate on dense infestations or heavy clay soils (consult label)
Agricultural non-crop areas, commercial and industrial areas, forests, pastures and rights-of-way	Triclopyr 300 g/L + Picloram 100 g/L (e.g. Conqueror) or Triclopyr 300 g/L + Picloram 100 g/L + Aminopyralid 8 g/L (e.g. Grazon Extra)	350 mL/100 L water	Seedlings less than 2 m tall and actively growing	High volume foliar spray Wet plant thoroughly Use wetting agent (consult label)
Agricultural non-crop areas, commercial and industrial areas, fence lines, forestry, pastures and rights-of-way	Triclopyr 240 g/L + Picloram 120 g/L (e.g. Access)	1 L/60 L diesel	See details above Stems up to 5 cm diameter	Basal bark spray Do not treat wet stems Parkinsonia can be treated using the alternative ThinLine method (consult label)
			See details above Plants up to and in excess of basal bark size	Cut stump Cut close to ground level and treat immediately
Around agricultural buildings and in pasture situations	Hexazinone 250 g/L (e.g. Velpar L, Bobcat SL Herbicide)	4 mL per spot 1 spot for each shrub/tree	Any time, but needs moisture to activate herbicide	Soil application (hand application via spotgun) Shrubs/trees up to 5 m high Avoid damage to off target species (consult label)
Grazing land	Tebuthiuron 200 g/kg (e.g. Clearview 200 GR, Scrubmaster)	1 to 1.5 g/m^2	Any time, but needs moisture to activate herbicide	Avoid damage to off target species (consult label)

Read the label carefully before use. Always use the herbicide in accordance with the directions on the label.

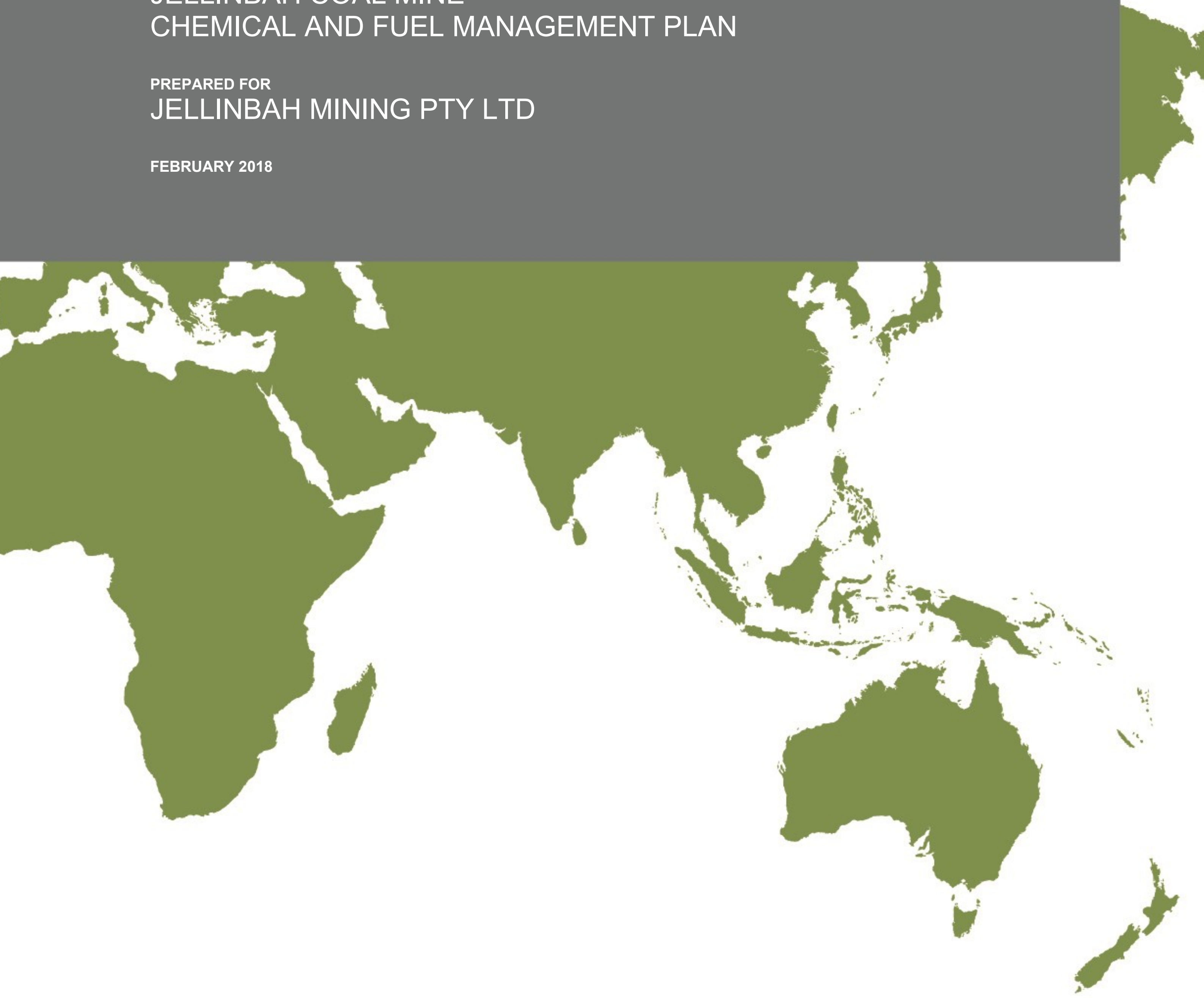
This fact sheet is developed with funding support from the Land Protection Fund.

JELLINBAH COAL MINE
CHEMICAL AND FUEL MANAGEMENT PLAN

PREPARED FOR

JELLINBAH MINING PTY LTD

FEBRUARY 2018



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JELLINBAH COAL MINE
CHEMICAL AND FUEL
MANAGEMENT PLAN

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LIST OF ABBREVIATIONS

AARC	-	AARC Environmental Solutions Pty Ltd
AS	-	Australian Standard
CFMP	-	Chemical and Fuel Management Plan
DES	-	Department of Environment and Science (formerly DEHP)
EA	-	Environmental Authority
EMR	-	Environmental Management Register
EP Act	-	Environmental Protection Act 1994
ERA	-	Environmentally Relevant Activity
km	-	Kilometres
PPE	-	Personal protective equipment
SDS	-	Safety Data Sheet
WHS	-	Work Health and Safety

1.0 INTRODUCTION

AARC Environmental Solutions Pty Ltd (AARC) was commissioned by Jellinbah Mining Pty Ltd (Jellinbah) to prepare a Chemical and Fuel Management Plan for the Jellinbah Coal Mine (the Project). The Project is authorised by current Environmental Authority (EA) EPML00516813. Jellinbah Coal Mine is operated by Jellinbah Mining Pty Ltd on behalf of the Jellinbah East Joint Venture (JEJV). The JEJV participants are: Jellinbah Group Pty Ltd, Marubeni Coal Pty Ltd, and Sojitz Coal Resources Pty Ltd.

Jellinbah Mine is located within the Bowen Basin in Central Queensland, approximately 190 kilometres (km) west of Rockhampton. It is located within the Central Highlands Regional Council area on the southern side of the Mackenzie River, and is approximately 24 km north of the township of Blackwater.

1.1 SCOPE

Much of the Project area is used for cattle grazing by entities not associated with the Project. This plan excludes these areas and is limited to those areas under the direct control of Jellinbah.

This Chemical and Fuel Management Plan has been prepared for Jellinbah Coal Mine on behalf of Jellinbah Resources Ltd and is consistent with current Queensland legislation and Australian standards. The principles of this Plan will be applied to the whole Project and will assist Jellinbah in managing the environmental obligations of the Project.

The storage of chemicals and fuel on the Project site is required for coal processing, transport and equipment use. This storage creates the potential for contamination to occur through spills or other releases including fugitive losses or leaks from the valves, pumps, flanges and seals connected to liquid chemical storage and handling equipment.

This Plan details the management and control strategies required for effective storage and spill contingency in accordance with *Australian Standard 1940-2017 The Storage of Flammable and Combustible liquids* and the applicable EA conditions for EPML00516813.

2.0 LEGISLATION AND STANDARDS

2.1 ENVIRONMENTAL PROTECTION ACT 1994

The Environmental Protection Act 1994 deals with the Storage of fuels and chemicals by listing these activities as both Environmentally Relevant Activities and Notifiable Activities.

Section 19 of the EP Act states that a regulation may prescribe an activity as an Environmentally Relevant Activity (ERA) if the Governor in Council is satisfied that a) a contaminant will or may be released into the environment when the activity is carried out; and b) the release of the contaminant will or may cause environmental harm.

Schedule 3 of the EP Act deals with notifiable activities relevant to the potential contamination of land. Undertaking these activities results in the site being listed on the Environmental Management Register (EMR) which is maintained by DEHP. Chemical and Fuel Storage is listed as notifiable activities number 7 and 29.

2.2 AS 1940-2017: THE STORAGE AND HANDLING OF FLAMMABLE AND COMBUSTIBLE LIQUIDS

This Standard aims to prevent damage to property, persons and the environment where flammable and/or combustible liquids are stored and handled. It deals with flammable liquids of dangerous goods Class 3, as classified in the UN Recommendations for the Transport of Dangerous Goods—Model Regulations. The Standard provides minimum acceptable safety requirements for storage facilities, operating procedures, emergency planning and fire protection. Recommendations provided in the standard are based on current industry best practices.

2.3 WORK HEALTH AND SAFETY REGULATIONS 2011

Chapter 7 in the WHS Regulations (2011) applies to the use, storage and handling of chemicals at a workplace. Safety data sheets must be up to date and provided for all chemicals. Chemicals must be packed, stored and labelled correctly and in accordance with the SDS and WHS Regulations. A register of hazardous chemicals used, handled or stored at the workplace is maintained and up to date.

2.4 PROJECT ENVIRONMENTALLY RELEVANT ACTIVITIES

The following list includes the ERAs authorised by the Project’s EA:

- ERA 8 – Chemical Storage Threshold 3;
- ERA 15 – Fuel Burning;
- ERA 13 – Mining Black Coal
- ERA 16 – Extractive & Screening Industries Threshold 2(c) & 3(c);
- ERA 31 – Mineral processing Threshold 2(b) – processing in a year, more than 100000t of mineral products, other than coke;
- ERA 33 – Crushing, Miling, Grinding or Screening;
- ERA 38 – Surface Coating Threshold 1(a);
- ERA 60 – Waste Disposal Threshold.

3.0 CHEMICALS AND FUEL ON THE PROJECT SITE

3.1 TYPES OF CHEMICALS AND FUELS

The Flammable and Combustible substances used on the Project site for processing, transport and equipment are summarised below in Table 1:

Table 1 Chemicals and Fuel used in the Project

Chemical Name	UN No.	Class	GHS category	Proper Shipping Name	Haz-chem Code	Properties and Observations	Storage Location
Diesel	1202	3	4	DIESEL FUEL	3[Z]		• Fuel Farm, Wash Plant & Downers Yard. • Plains Fuel Farm and Workshop. • Self-bunded tanks at Mackenzie North • Jellinbah South Fuel Farm and Workshop
Petrol	1270	3	2	PETROLEUM FUEL [AUST.]	3[Y]	Entry may only be used for placarding purposed as an identifier of a mixer bulk load in a multi-compartment tank vehicle of refined petroleum products	Petrol is stored in a Flammable liquids storage locker at the Pump crew container beside the Son of Max Dam.
Oil and Lubricants	1268	3	3 and 4 generally	PETROLUEM PRODUCTS	3[Y]		• Fuel Farm and the Main Workshop. • Plains Fuel Farm and Workshop. • Jellinbah South Fuel Farm and Workshop.
MIBC	2053	3	3	METHYL ISOBUTYL CARBINOL	3[Y]	Colourless liquid miscible with water	Not currently used on site, but was stored at the Wash Plant when being used.

4.0 CHEMICAL AND FUEL STORAGE MANAGEMENT STRATEGY

All Chemicals and Fuels to be stored on-site will be handled as per the requirements of AS 1940 - 2017 Storage and Handling of Flammable and Combustible Liquids. This is in accordance with EA Condition A7.

These requirements are summarised in sections 4.1 and 4.2 below.

4.1 GENERAL STORAGE CONSIDERATIONS

Considerations in the design and location of fuel and chemical storage infrastructure include the following:

- Working pressures and structural stresses;
- Heat, corrosion, or attack by the liquid being handled;
- Site conditions such as topography, usage of adjoining areas, or the risk of natural disasters, e.g. flood, earthquake, lightning strike;
- Design of plant, equipment, and operating methods, to minimize fire and accident risks and the possibility of errors or misunderstanding by staff;
- Specific design for emergencies particularly fire-fighting facilities;
- The identification of the function of every valve, switch or control actuator, including any remote switches or actuators;
- Safe access to and egress from all working locations;
- Avoidance of ignition sources;
- Ventilation for vapour dispersal, taking into account the possible effect of nearby structures, excavations, embankments, and the like;
- Separation of potential hazards, including areas where activities cannot be controlled;
- Points of vapour relief; and
- Spill control measures to avoid contamination of soil and water.

4.2 SPILL PREVENTATION MANAGEMENT STRATEGIES

Management Strategies to reduce the risk of spillage of fuels and chemicals stored on-site include:

- Sufficient ventilation, extraction or dispersal provisions where a flammable liquid is being used or transferred in a manner where vapour is released.
- A hazardous area is not to extend beyond a boundary if it could encompass a fixed source of ignition on the adjacent property.

- Storages are to be separated from boundaries, ignition sources, protected places and accumulations of combustible materials by minimum distances outlined in AS 1940:2017 - Storage and Handling of Flammable and Combustible Liquids.

- Access to Safety Data Sheets (SDS) for each hazardous material used on the Project which details storage, transport and disposal information for each material;

- Use of suitable storage facilities, containers and dispensing equipment that are maintained in good working order;

- Implementation of safe work practices for minimising the risk of spillage;

- The use of a spill response procedure which details how spills of hazardous materials will be contained, cleaned up, and the area remediated if necessary (See Section 5 – Spillage Contingency);

- Validation sampling of any remediated contaminated area to establish the site as "clean" as per the Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland; and

- Ensure that all fuel and chemical storage areas are bunded in accordance with Australian Standard AS 1940:2017 - Storage and Handling of Flammable and Combustible Liquids which states the following:

    - All bunds and compounds shall be maintained to retain their designated capacity and in a condition which prevents the escape of liquid from the compound.

    - All bunds and compounds shall be kept free from extraneous combustible material.

    - Provision shall be made to contain any leakage or spillage from the tank storage facility and to prevent it from contaminating the surrounding soil or from entering any watercourse or water drainage system.

- Spill response kits are readily available where flammable or combustible liquids are stored, dispensed or in transit. This kit should consist of absorbent pads, booms, loose absorbent, contaminated waste bags, personal protective equipment, broom and shovel.

5.0 SPILLAGE CONTINGENCY STRATEGY

In the event of a spill the following strategy shall be implemented:

5.1 SPILL CONTAINMENT PROCEDURE

All spills in and about workshops, oil and fuel storage facilities or areas that are environmentally sensitive will be cleaned up as soon as possible and disposed of in a manner recommended by the SDS for the product. Spills occurring within operating pits will be contained and remediated within the pit. All spills greater than 20L will be reported internally, and an environmental specialist should be consulted for large spills which cannot be effectively contained.

Professional advice on spillage management, clean up and disposal will be sought where necessary from emergency services, the Emerald DES (Administering Authority) or environmental specialists. Should the spill pose a fire threat or a threat to human life then the relevant emergency services will be contacted.

Table 2 details the procedure to be followed in the case of a spill.

Table 2 Spillage Management

Type of Spill	Equipment Required	Spill Containment and Clean-up
Leaking packages	PPE, oversized container or clear appropriate packaging. Spill kit may also be required.	• Position package in a manner to minimise the leak. The package should be placed in a suitable container (e.g. oversized drum) or transferred to clean packaging (clearly labelled).
Small Spills (on floor, walls or building structures)	Spill kit, in particular absorbent pads and PPE	• Spill should be collected, absorbed, or diluted, as appropriate.
Diesel, oil, extractant (similar to kerosene), solvent, degreaser or other chemical spill causing or potentially causing environmental harm on or off the Project site.	A sufficient quantity of inert absorbent material (e.g. dirt) or absorbent pads may be located near each fuel or chemical storage area, alternatively; Machinery may be used to bund or absorb large spills with soil/sand from the Project; and Should a large amount of free spilt liquid need to be recovered from a bund then a suction truck or similar may be employed.	• Stop leak or spill at source, contain spilled materials and protect the area (if possible to do without risking contact or exposure to chemical or otherwise risking personal safety); • Should the spill pose a fire threat or a threat to human life initiate site emergency procedures; • Report spill to site management; • If necessary, review SDS for the spilled chemical, and advise of any precautions for safe handling of the spilled material or disposal of the material (e.g. protective clothing); • Absorb spill using absorbent pads, inert absorbent material, or for large spills use soil or sand. Dispose of the contaminated material as per SDS requirements.

		For large spills consult an environmental specialist; • Complete an Environmental Incident Report Form; and • Report spill to DES within 24 hours if necessary.

In accordance with Australian Standards, emergency services should be notified of the spill when:

- The liquids have spread, or have the potential to spread, beyond the boundary of the installation;
- It is beyond the resources of the occupiers to clean up the spill or leak effectively and safely;
- The protective equipment is inadequate for dealing with the situation;
- Staff are not experienced in dealing with the situation; or
- Staff are the public are, or could potentially be, placed at risk.

5.2 NOTIFICATION PROCEDURES

The following provides guidance on reporting spills in accordance with EA conditions A9 to A14:

- All spills of a Hydrocarbon (diesel, lubricating oil, Hydraulic oil, kerosene) or Chemical (solvents-acid or alkali, flammable or non-flammable coolants) nature in excess of 20 litres shall be internally reported to the supervisor and the Jellinbah Environment department (whether on concrete or soil) where these will be placed in the incident register. For any Large spills that occur an environment specialist will be contacted.
- Any spill that impacts the environment outside of the Project will be reported internally and to the administering authority as soon as practicable after becoming aware of the emergency or incident by telephone or fax;
- If a spill on the Project has occurred and it has caused environmental harm or has the potential to cause environmental harm, the spill will be reported internally and to the administering authority as soon as practicable;
- The notification must include the following:
  - The holder of the environmental authority;
  - The location of the emergency or incident;
  - The number of the environmental authority;
  - The name and telephone number of the designated contact person;
  - The time of the release;
  - The time the holder of the environmental authority became aware of the release;
  - The suspected cause of the release;

- The environmental harm caused, threatened, or suspected to be caused by the release; and
- Actions taken to prevent any further release and mitigate any environmental harm caused by the release.

- Not more than **fourteen (14) days** following the initial notification of an incident, written advice must be provided of the information supplied in relation to:
  - proposed actions to prevent a recurrence of the emergency or incident; and
  - outcomes of actions taken at the time to prevent or minimise environmental harm.
- Within six weeks following the conduct of any environmental monitoring performed in relation to the emergency or incident, written advice must be provided to DES of the results of any such monitoring performed.

6.0 REFERENCES

AS 1940:2017 The storage and handling of flammable and combustible liquids

Environmental Protection Act 1994, Queensland Government, Reprinted 3rd February 2012, Reprint No. 10E

https://www.ehp.qld.gov.au/assets/documents/pollution/management/contaminated-land/cm-gl-duty-notify-environmental-harm.pdf *Guideline: The duty to notify of environmental harm (ESR/2016/2271*

https://www.ehp.qld.gov.au/assets/documents/pollution/management/contaminated-land/contam-land-guideline-duty-to-notify.pdf *Guideline: The duty to notify for contaminated land (ESR/2016/2155)*[1]

http://www.ehp.qld.gov.au/management/pdf/enforcement-guidelines.pdf

[1] Guidelines are available at www.qld.gov.au using the publication number as a search term.

Appendix A Duty to Notify of Environmental Harm

Duty to notify of environmental harm

This form is to be used for notifying the administering authority about events or changes in condition of land causing or threatening serious or material environmental harm, in accordance with the duty to notify provisions contained in sections 320 to 320G, Chapter 7 Part 1 of the Environmental Protection Act 1994 (the EP Act).

This Notice should be completed having regard to the guidance in:

- *Guideline: The duty to notify of environmental harm (ESR/2016/2271)*
- *Guideline: The duty to notify for contaminated land (ESR/2016/2155)*[2]

The details provided should address the nature of the event or change in condition as relevant. The notice should be completed as fully as practicable in the circumstances. Indicate any sections of the notice that are not applicable or for which information is not currently available.

If a notice is being given with respect to a notifiable activity, the Template for giving written notice about a notifiable activity *(ESR/2015/1845) should be used. Circumstances could arise in which notice of a related event or change in condition of land also needs to be provided.*

Office use only

Date entered in Ecotrack:		Relevant regional manager:	
Ecotrack reference number:		Date sent to regional manager:	
Relevant regional area:		Officer actioning this item:	

1. Person giving notice

NAME	TELEPHONE (BUSINESS HOURS) TELEPHONE (AFTER HOURS)
COMPANY/ORGANISATION NAME (IF APPLICABLE)	
POSITION IN COMPANY/ORGANISATION (IF APPLICABLE)	
POSTAL ADDRESS	
EMAIL	FACSIMILE

2. Who is giving notice about an event or change of condition

2.1. In what capacity are you giving notice?

[2] Guielines area available at www.qld.gov.au using the publication number as a search term.

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Tick relevant box

- I am the owner of the land ☐
- I am an occupier (e.g. lessor or tenant) of the land ☐
- I am a representative of a local government ☐
- I am an auditor performing an auditor's function under EP Act ☐
- I am an employer ☐
- I am an employer of someone carrying out an activity ☐
- I am an employee carrying out an activity and have not been able to contact my employer ☐
- Other (specify)

2.2. Please provide details of your involvement

For example, what is your involvement as an employer or employer or as a representative of a local government?

3. Details of the affected land where the event or change in condition has occurred

3.1. Please provide details of the lot and plan description at which the event or change in condition has taken place (and full street address if available).

NAME BY WHICH THE PROPERTY IS KNOWN	
FULL STREET ADDRESS OF THE SITE	
ANY OTHER INFORMATION THAT WILL ASSIST IN QUICKLY LOCATING THE LOCATION WHERE AN EVENT OR ACTIVITY HAS OCCURED	
LOT(S)	PLAN(S)
GRID REFERENCES NORTHING EASTING	
LOCAL GOVERNMENT AUTHORITY	

3.2. Is a map or locality plan attached to this notification?

☐ No ☐ Yes

A map or locality plan that shows the affected land may greatly assist the processing of this notification.

3.3. Is the affected land the origin of contamination or area harmed or both?

Is the affected land (as described above) the land on which the contamination originated, caused harm (impacts) or both?

☐ Origin ☐ Harmed ☐ Both

4. Activity that has led to the event or change in condition

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4.1. Nature of activity

- Is the activity a notifiable activity listed under Schedule 3 of the EP Act (if it is then use the template ESR/2015/1845) or another activity that has caused or may cause serious or material environmental harm? ☐ Notifiable ☐ Other
- Is the activity a resource activity? ☐ Yes ☐ No
- Is the activity currently occurring or did it occur previously? ☐ Current ☐ Previous

4.2. Describe the nature of the activity

If you require additional space attach the information on a separate sheet and make reference to that sheet here.

4.3. State whether the primary activity that led to the event was being carried out under:

- an environmental protection policy ☐ Yes
- a transitional environmental program ☐ Yes
- an environmental protection order ☐ Yes
- an environmental authority (use ESR/2015/1845) ☐ Yes
- a development condition of a development approval ☐ Yes
- a prescribed condition for carrying out a small scale mining activity ☐ Yes
- an emergency direction ☐ Yes
- an accredited environmental risk management plan ☐ Yes

4.4. Please provide the identifying details of the relevant approval or authority for carrying out the activity (if known). If possible attach a copy of the relevant document.

5. Special requirement for resource activities (petroleum and gas, geothermal and greenhouse gas storage activities but not a mining activity)

Does this notice relate to notification of an event that has occurred while carrying out a resource activity that has:

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- negatively affected, or is reasonably likely to negatively affect, the water quality of an aquifer; or ☐ No ☐ Yes
- has caused the connection of two or more aquifers ☐ No ☐ Yes

6. Nature and circumstances of how event has occurred

If it is an event involving the release of contaminants that is being notified, the following information should be provided

6.1. Describe the circumstances in which the event has occurred.

Please provide details of the circumstances that led up to the event, any factors that may make the effects of the event worse, any preventive measures or cleanup up action taken and any other matters that may be relevant. If you require additional space attach the information on a separate sheet and make reference to that sheet here.

6.2. Provide any additional information that may be relevant to this notification of an event

If additional space is required attach the information on a separate sheet and make reference to that sheet here.

6.3. Event type:

☐ Spill ☐ Discharge ☐ Leakage ☐ Exposure/uncovering
☐ Fire ☐ Fishkill ☐ Other _______

6.4. Source of release:

☐ Vehicle spill ☐ Vessel spill ☐ Pipeline breach ☐ Dam/pond failure
☐ Drain outlet ☐ Bulk/tank ☐ Vessel sinking ☐ Dumping
☐ Sewage discharge ☐ Industrial activity ☐ Cattle/sheep dip ☐ Horticulture
☐ Excavation ☐ Landfill ☐ Other ______________

6.5. Contaminants (if known):

☐ Solid chemicals ☐ Liquid chemicals ☐ Hydrocarbons ☐ Gas/vapour
☐ Pesticide/herbicide ☐ Nutrients ☐ BOD/COD ☐ Dangerous goods
☐ Other _______

6.6. Details of contaminants (if known):

Substance(s): ________

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Quantity: ______ Litres/Kilograms/Tonnes/<other>
Area/extent affected:____________ m by __________ m

7. Change in condition of land

If it is a change in the condition of land that is being notified, the following information should be provided

7.1. Nature of change in the condition of the land (that has caused or is reasonably likely to cause or involve serious or material environmental harm)

- Dispersal of contaminants in soil ☐ No ☐ Yes
- Dispersal of contaminants in groundwater ☐ No ☐ Yes
- Dispersal of contaminants in surface waters ☐ No ☐ Yes
- Accumulation of gases or vapour in soil or structures ☐ No ☐ Yes
- Change in surface features (e.g. vegetation) ☐ No ☐ Yes

7.2. Details of change in the condition of the land

Describe what the change in condition involves

If additional space is required attach the information on a separate sheet and make reference to that sheet here.

7.3. Cause of change in condition (if known)?

Describe the known factors that have led to the change in condition

If additional space is required attach the information on a separate sheet and make reference to that sheet here.

7.4. Timeframe of change in condition

Outline what is known of the timeframe in which the change in condition has occurred

7.5. Type of environment affected:

What is the type of environment that has been affected by an event or change in condition?

☐ Waterway/drain ☐ Marine ☐ Estuarine ☐ Freshwater
☐ Land contamination ☐ Urban area ☐ Air/fallout ☐ Vegetation
☐ Protected area ☐ Other _______

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8. How and when did you become aware of the event or change of condition

8.1. What was the source of information about the event or change in condition

- own observation ☐ Yes
- information provided by a person with relevant competencies ☐ Yes
- information provided by an employee ☐ Yes

8.2. When did you first became aware of the event or change in condition for which notice is given

TIME	DATE

9. Details of registered owners or occupiers of affected land to which notice has been given

Note: Registered owners or occupiers of affected land do not need to be notified before notifying the administering authority.

9.1. Have any registered owners or occupiers of affected land been notified of this incident?

☐ No

☐ Yes (provide details of the occupiers and registered owners of land affected, or potentially affected, by this incident including details of how notice to those persons was given)

NAME	TELEPHONE
POSTAL ADDRESS	
DESCRIPTION OF HOW NOTICE WAS GIVEN	

If you require additional space you may attach the information on a separate sheet.

10. Declaration

Note: If you have not told the truth in this application you may be liable for prosecution under the relevant Acts or Regulations.

I do solemnly and sincerely declare that the information provided is true and correct to the best of my knowledge. I understand that it is an offence under s. 480 of the *Environmental Protection Act*

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1994 to give to the administering authority or an authorised person a document containing information that I know is false, misleading or incomplete in a material particular.

I understand that all information supplied on or with this application form may be disclosed publicly in accordance with the *Right to Information Act 2009* and the *Evidence Act 1977*.

NOTIFYING PERSON'S SIGNATURE	TIME / DATE

11. Sending the written notice

Please return the completed notice to Permit and Licence Management at the Department of Environment and Heritage Protection by:

Pollution hotline 13000 130 372

AND written notification via email, fax or registered post:

Email:
<pollutionhotline@ehp.qld.gov.au>

Fax: (07) 33330 5875

Note: Include **'Duty to notify of environmental harm'** in the subject line of the fax or email and attach a completed copy of the template.

Registered post:

Permit and Licence Management
Department of Environment and Heritage Protection
GPO Box 2454
Brisbane QLD 4001

12. Phoning the pollution hotline

In addition to providing the written notice if you become aware of a matter which has caused or threatens serious or material environmental harm you should immediately call the pollution hotline on **1300 130 372 and report the matter. Reporting the matter through the pollution hotline allows the administering authority to take necessary measures to prevent further harm and to mitigate the effects of an incident or event.**

In addition to notifying the administering authority, and where that is not the relevant local government, it is good practice to notify the local government for the area where the event has occurred.

13. Further information

The latest version of this publication is available at www.qld.gov.au using the publication number ESR/2015/2230 as a search term or by contacting Permit and Licence Management on 13 QGOV (13 74 68).

Privacy statement

The Department of Environment and Heritage Protection (EHP) will use the personal information collected on this form to investigate an incident that potentially caused or threatened to cause serious or material environmental

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harm, as provided for under ss. 320 -320G of the *Environmental Protection Act 1994*. The information will only be accessed by authorised employees within EHP. The information provided on this form will not be otherwise be used or disclosed unless required or authorised by law. For information about privacy matters email: For queries about privacy matters email: privacy@ehp.qld.gov.au or telephone: (07) 3330 6270.

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JELLINBAH COAL MINE
EROSION AND SEDIMENT CONTROL PLAN

PREPARED FOR

JELLINBAH MINING PTY LTD

MARCH 2019

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Project Manager: Gareth Bramston
Name of Client : Jellinbah Mining Pty Ltd
Name of Project: Jellinbah Coal Mine
Title of Document: Erosion and Sediment Control Plan
Document Version: 3

Opinions and judgments expressed herein, which are based on our understanding and interpretation of current regulatory standards, should not be construed as legal opinions. Information obtained from interviews and contained in the documentation has been assumed to be correct and complete. AARC Environmental Solutions Pty Ltd does not accept any liability for misrepresentation of information or for items not visible, accessible, nor able to be inspected at the sites at the time of the site visits.

JELLINBAH COAL MINE
EROSION AND SEDIMENT
CONTROL PLAN

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LIST OF ABBREVIATIONS

°C	degree(s) Celsius
AARC	AARC Environmental Solutions Pty Ltd
CHRC	Central Highlands Regional Council
CPP	coal processing plant
EA	Environmental Authority
ESCP	Erosion and Sediment Control Plan
ha	hectare(s)
IECA	International Erosion Control Association
IRC	Isaac Regional Council
JEJV	Jellinbah East Joint Venture
Jellinbah	Jellinbah Mining Pty Ltd
km	kilometre(s)
m^3	cubic metre(s)
ML	mining lease(s)
mm	millimetre(s)
Mtpa	million tonnes per annum
PCI	pulverised coal injection
QLD	Queensland
ROM	run-of-mine
SGWRP	Surface and Groundwater Response Plan
the Mine	Jellinbah Coal Mine
WMP	Water Management Plan

1.0 INTRODUCTION

The Jellinbah Coal Mine (the Mine) is an open-cut coal operation, mining shallow, low stripping ratio coal reserves and producing approximately 4.5 – 5.0 million tonnes per annum (Mtpa) of pulverised coal injection (PCI) and a minor amount of thermal coal, primarily for export. The Project is authorised by Environmental Authority (EA) EPML00516813 and operated by Jellinbah Mining Pty Ltd (Jellinbah) on behalf of the Jellinbah East Joint Venture (JEJV). The participants of the JEJV are: Jellinbah Group Pty Ltd, Tremell Pty Ltd, Marubeni Coal Pty Ltd and Sojitz Coal Resources Pty Ltd.

The Mine is located within the Bowen Basin in Central Queensland, approximately 190 kilometres (km) west of Rockhampton. It is located within the Central Highlands Regional Council (CHRC) and Isaac Regional Council (IRC) areas and is approximately 24 km north of the township of Blackwater.

1.1 PURPOSE

This Erosion and Sediment Control Plan (ESCP) describes the erosion and sediment control measures to be implemented during construction and operational phases of the Jellinbah Coal Mine. This ESCP has been developed to meet the requirements of conditions C37 and C38 of the EA:

C37 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.

C38 Stormwater, other than mine affected water, is permitted to be released to waters from:

a) Erosion and sediment control structures that are installed and operated in accordance with the Erosion and Sediment Control Plan required by condition C37; and

b) Water management infrastructure that is installed and operated, in accordance with a Water Management Plan that complies with conditions C29 to C34 inclusive, for the purpose of ensuring water does not become mine affected water.

1.1.1 Aims and Objectives

The purpose of the ESCP is to describe erosion and sediment control measures required to:

- Minimise the potential for erosion and sediment loss from the Jellinbah Mine; and
- Prevent contamination of the receiving environment.

1.2 SCOPE

This ESCP addresses the described management objectives through the following scope:

- Description of the existing environment, as it relates to erosion and sediment control risks;
- Identification of activities and locations at the Mine which are considered at risk of erosion and sediment loss;
- Recommending erosion and sediment control strategies appropriate for each identified source;
- Recommending a routine inspection and maintenance program for existing sediment control infrastructure; and

- Providing a routine monitoring program which targets high risk locations when environmental conditions are conducive to erosion and sediment runoff. The monitoring program aims to provide:
    - Early identification of sediment and erosion control issues; and
    - Confirmation of the effectiveness of the existing strategies in managing erosion and sediment control.

2.0 PROJECT DESCRIPTION

The Mine is located in the Bowen Basin in central Queensland (QLD). Current operations areas are located approximately 24 km north-north-east of Blackwater and 190 km west of Rockhampton, within the CHRC area. The Mackenzie North operational area, located north of the Mackenzie River, is situated within the Isaac Regional Council area. The Project is accessed via the Capricorn Highway and the Boonal Haul Road.

Low intensity cattle grazing, and coal mining operations form predominant land uses throughout the region of the Project site. Any areas within the Mine that are not required for mining activities or associated infrastructure are utilised for low intensity cattle grazing.

The Mine comprises the following approved areas:

- Jellinbah South (not currently operational);
- Jellinbah Central (operational);
- Jellinbah Plains (operational);
- Central North (approved) / Central North Extension (proposed); and
- Mackenzie North (under development).

2.1 PROJECT ACTIVITIES

The principal activities undertaken at the Mine are:

- Mining of a high-grade coal;
- Continuous assessment of the coal resource by exploration;
- Clearing of any remaining vegetation in advance of mining;
- Selective stripping of available topsoil under supervision to be immediately reused or stockpiled for future use in the rehabilitation program;
- Drilling and blasting of overburden to provide access to coal resources;
- Operation of a conventional open-cut truck and excavator mine to maintain production to meet market demands;
- Overburden used to form bunds, haul roads and hardstands or transported to out-of-pit spoil dumps located clear of the coal resource but within the boundary of the MLs or placed in the previous mining strip to backfill mined-out areas;
- Reshaping of spoil dumps, replacement of topsoil and revegetation of the mined out and backfilled area;
- Crushing and screening of run-of-mine (ROM) coal;
- Coal washing (if required) at the coal processing plant (CPP), located on ML 80053;

- Disposal of CPP rejects together with overburden (coarse rejects) and tailings (fine rejects) within existing mining voids;

- Transport of crushed and washed coal by private road to the existing rail loading area for rail transport to Gladstone;

- Operation of water management infrastructure such as regulated dams, sediment ponds, drains and bunds;

- Maintenance of a levee bank at Jellinbah Plains to protect mining operations from flooding of the Mackenzie River;

- Utilisation of existing infrastructure facilities, including offices, power and water; and

- Continued direct and contract employment of operating workers and support personnel with flow-on employment through the provision of associated goods and services.

2.1.1 Jellinbah Central

Jellinbah Central is established as a central hub for the mining operations. Jellinbah Central contains the largest open-cut pit operations as well as the site offices, workshop and wash plant. The open cut pit occupies the central portion while some of the overburden has been placed to the east of the pit. The wash plant, workshop and ROM areas are located to the west of the open cut pit. The main site office is located in the far west of Jellinbah Central. The mine site haul road extends through the west of Jellinbah Central to Plains. The runoff dams and tailings dam are located to the south and west of the ROM areas.

2.1.2 Jellinbah Plains

The Jellinbah Plains operational area is located north of Jellinbah Central, immediately south of the Mackenzie River. The site consists of a centrally-located open-cut pit with active spoil stockpiles to the east and west. ROM ore is located towards the south-west of the site. The pit is currently being extended to the north and backfilling operations are occurring at the southern end of the pit. Spoil dumps are being progressively rehabilitated to minimise the area of active spoil.

2.1.3 Jellinbah South

The Jellinbah South site is not currently in operation. A small open-cut pit is located on the site and is currently used for excess water storage. When required, the water is pumped and returned to Jellinbah Central and Plains for use on-site.

2.1.4 Central North

The future (approved) Central North area is located between Jellinbah Plains and Jellinbah Central. It will involve the development of a new open-cut pit, with the creation of new spoil dumps and topsoil stockpiles in the west and north-east. Numerous sediment traps, drainage lines and two clean water sediment dams will be established. The proposed Central North Extension is a small lateral extension of the Central North area. MLs to the west are for infrastructure and spoil dumps only, whilst the Central North Pit will get extended to the east into the proposed extension. All infrastructure will be shared, and the two areas are intended to function as one following final approvals.

2.1.5 Mackenzie North

The Mackenzie North operational area, currently in initial stages of development, is located immediately north of the Mackenzie River and is planned to supplement production from Jellinbah Plains as it nears the end of its economic life, in order to maintain overall mine production rates. The Mackenzie North operation will involve the establishment of the following infrastructure:

- Haul road and bridge across the Mackenzie River and Mackenzie River Anabranch;
- Flood levee and dams;
- Diversion of an anabranch of the Mackenzie River;
- Crusher, loading and stockpile area;
- Access roads and tracks;
- Administration area and workshops; and
- Water management dams and sediment control traps.

Crushed coal will be hauled to existing processing facilities at Jellinbah Central.

2.2 WATER MANAGEMENT PRINCIPLES

The principal objective of the Jellinbah Mine Water Management Plan (WMP) (Engeny, 2017) is to effectively manage the separation of clean water and mine-affected water. The different types of water on site are summarised below:

- Clean stormwater runoff – Runoff from areas not affected by coal or operational facilities, including undisturbed or rehabilitated areas, or disturbed natural earth areas. Clean runoff is directed to sediment traps and/or dams to minimise sediment loads and subsequent downstream impacts; and
- Mine-affected water – Water that comes into contact with coal areas (e.g. ROM pad) or other potentially contaminated areas. This includes pit water (including groundwater and rainfall runoff), runoff from coal-contaminated areas, and water contained in the Max Pit Tailings Dam. This is consistent with the definition of mine-affected water provided in the EA, which states that water associated with the pit, tailings dam or processing plant is mine-affected, while rainfall runoff from other areas such as spoil, managed by sediment and erosion control structures, is not. The Site Water Management Plan aims to ensure mine-affected water remains separate from other water sources to minimise the potential for offsite release.

The Site Water Management Plan also ensures the quality and quantity of surface water is appropriately managed prior to release into the surrounding natural environment. Clean water management structures include clean water dams, sediment control traps / dams, diversion channels and a water recycling scheme. A drainage system is in place that allows natural (clean) water flows to be diverted around the pit and operational areas into natural watercourses. Mine-affected runoff is diverted to dams in the mine-affected water system to avoid contamination of the receiving environment.

In accordance with EPML00516813 Jellinbah Coal Mine, Condition 30, the Mine is required to prepare a Water Management Plan (WMP). This Erosion and Sediment Control Plan (ESCP) feeds into the WMP, ensuring that water management infrastructure installed and operated onsite maintains separation between clean water and mine-affected-water. Figure 1 shows the components of the WMP. This ESCP should be read in conjunction with the other components of the WMP.

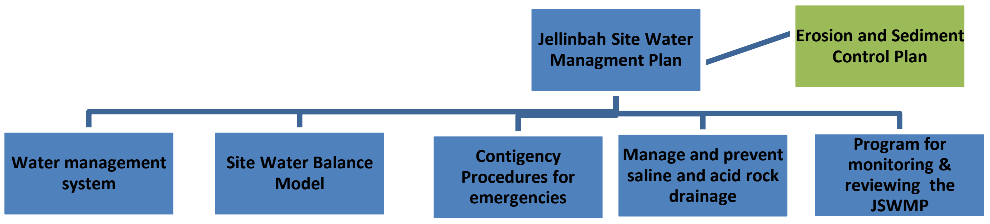

Figure 1 Jellinbah Site Water Management Plan

In accordance with the Mine's continuous improvement and review processes a review of the ESCP has been undertaken to ensure that erosion and sediment impacts from the Mine are managed and minimised where possible.

3.0 EXISTING ENVIRONMENT

3.1 REGIONAL CLIMATE

The Mine is located in sub-tropical central QLD where climatic conditions comprise a wet season period from November to February and a dry season from March to October. Average annual rainfall for the region is approximately 570 millimetres (mm).

Average maximum temperatures range from 23.4 degrees Celsius (°C) to 34.1 °C. The average summer evaporation rate is more than double the average winter evaporation rate. On average the evaporation rate is 5.7 mm per day.

3.2 SURFACE WATER AND DRAINAGE

The Mine is located within the catchment of Blackwater Creek and the Mackenzie River, a major tributary of the Fitzroy River which flows to the Coral Sea at Rockhampton. The Mackenzie River traverses the Mine between the Mackenzie North area and the mining operations at Jellinbah Plains.

The topography on the Mine consists of flat to gently undulating plains. The Mackenzie North area is located on the northern alluvial plain of the Mackenzie River. The Mine naturally drains to either Blackwater Creek or the Mackenzie River directly. Blackwater Creek is predominantly dry with temporary flows during large wet season rainfall events. The Mackenzie River supports surface flows throughout the year, including controlled releases from Fairbairn Dam, along the Nogoa River, upstream of the Mine.

3.3 SOILS

Despite variation across the Project, soil types are primarily derived from three parent materials including (Ison 1998):

- Soils developed over Cainozoic unconsolidated materials of clay, silt and sand which overlie Permian sedimentary rocks;
- Soils developed directly over sedimentary rocks, mainly sandstone and siltstone of Permian and Tertiary age; and
- Soils developed in recent alluvium.

Generally, soils within the project area are structurally competent in their natural setting, such as strongly structured alluvial clays or soils of sandy texture on gentle slopes, and are not considered at high risk of dispersion. A small proportion of the soils display characteristics identified as increasing the susceptibility of the soil to erosion and dispersion (high Exchangeable Sodium Percentage and low calcium to magnesium ratio).

3.4 OVERBURDEN

The bulk of the overburden is typically comprised of clays and sands above siltstones and mudstones. Weathered overburden / interburden materials may be partly sodic and subject to surface crusting and high erosion rates if exposed directly to rainfall. Fresh overburden and interburden is typically sodic but non-dispersive. However, this fresh material has potential to become dispersive when under certain weathering conditions after mining. It should be noted that the overburden material is not considered acid forming or containing known contaminants.

4.0 SOURCES OF EROSION AND SEDIMENT LOSS

Activities and locations considered to be a potential source of erosion and sediment loss have been identified for each of the five working areas at the Mine.

Table 1 describes these sources along with the nature of the hazard and the potential risk associated. It is intended that Table 1 is updated with additional sources which may become apparent with progressing mine life and changing environmental conditions.

Table 1 Potential Sources of Erosion and Sediment Loss

Activity / Location	Description	Nature of Risk (No Mitigation)
Jellinbah Plains		
Rehabilitated spoil	Rehabilitated spoil consisting of unconsolidated overburden / interburden with varying levels of saline and sediment pre-disposition. Exposed areas above the natural ground level without vegetation cover are susceptible to water erosion.	**Low – moderate risk** of sheet, rill and gully erosion on slopes and tunnel erosion on flats. Risk is greatest where areas of exposed topsoil remain with poor vegetation cover.
Active spoil	Stockpiles of overburden / interburden containing unconsolidated material with varying levels of saline and sediment pre-disposition. Exposed areas susceptible to storms and weathering.	**High risk** of sheet, rill and gully erosion form active dumping areas.
Mine infrastructure areas: • Pre-strip areas • Topsoil stockpiles • Infrastructure areas • Exploration • Access tracks / haul road	Exposed soil surfaces on disturbed land leads to increased runoff velocities with greater potential for erosion and sediment loss.	**Low – moderate risk** of sheet and rill erosion. Risk is greatest on uncompacted and exposed land such as pre-strip areas.
Coal stockpiles	Stockpiles of coal are susceptible to wind and water erosion.	**High risk** of sheet, rill and gully erosion on slopes and wind erosion from elevated stockpiles.
Flood levee	Water erosion can result from concentrated runoff on the slopes of the levee and flood erosion.	**Moderate risk** of sheet, rill and gully erosion on slopes of the levee. Gully and tunnel erosion can occur when flooding results in water movement along the levee. Risk is greatest during significant flood events.

Activity / Location	Description	Nature of Risk (No Mitigation)
Drains and embankments	Water erosion can result from concentrated runoff on the slopes of constructed embankments and in drainage channels (natural and constructed).	**Low – moderate risk** of sheet, rill and gully erosion on slopes of embankments and stream bank erosion in channels. Risk is elevated where vegetation cover is poorest and/or where runoff is most concentrated, including the constructed clean water diversion channel.
Jellinbah Central		
Rehabilitated spoil	Rehabilitated spoil consisting of unconsolidated overburden / interburden with varying levels of saline and sediment pre-disposition. Exposed areas above the natural ground level without vegetation cover are susceptible to water erosion.	**Low – moderate risk** of sheet, rill and gully erosion on slopes and tunnel erosion on flats. Risk is greatest where areas of exposed topsoil remain with poor vegetation cover.
Mine infrastructure areas: • Pre-strip areas • Topsoil stockpiles • Infrastructure areas • Exploration • Access tracks / haul road	Exposed soil surfaces on disturbed land leads to increased runoff velocities with greater potential for erosion and sediment loss.	**Low – moderate risk** of sheet and rill erosion. Risk is greatest on uncompacted and exposed land such as pre-strip areas.
Active spoil	Stockpiles of overburden / interburden containing unconsolidated material with varying levels of saline and sediment pre-disposition. Exposed areas susceptible to storms and weathering.	**High risk** of sheet, rill and gully erosion form active dumping areas.
Coal stockpiles	Stockpiles of coal are susceptible to wind and water erosion.	**High risk** of sheet, rill and gully erosion on slopes and wind erosion from elevated stockpiles.

Activity / Location	Description	Nature of Risk (No Mitigation)
Drains and embankments	Water erosion can result from concentrated runoff on the slopes of constructed embankments and in drainage channels (natural and constructed).	**Low – moderate risk** of sheet, rill and gully erosion on slopes of embankments and stream bank erosion in channels. Risk is elevated where vegetation cover is poorest and/or where runoff is most concentrated, including the constructed clean water diversion channel.
Jellinbah South		
Rehabilitated spoil	Rehabilitated spoil consisting of unconsolidated overburden / interburden with varying levels of saline and sediment pre-disposition. Exposed areas above the natural ground level without vegetation cover are susceptible to water erosion.	**Low – moderate risk** of sheet, rill and gully erosion on slopes and tunnel erosion on flats. Risk is greatest where areas of exposed topsoil remain with poor vegetation cover.
Mine infrastructure areas: • Hardstand • ROM pad	Exposed soil surfaces on disturbed land leads to increased runoff velocities with greater potential for erosion and sediment loss.	**Low – moderate risk** of sheet and rill erosion.
Central North / Central North Extension (when developed)		
Mine infrastructure areas: • Pre-strip areas • Topsoil stockpiles • Access tracks / haul road	Exposed soil surfaces on disturbed land leads to increased runoff velocities with greater potential for erosion and sediment loss.	**Low – moderate risk** of sheet and rill erosion. Risk is greatest on uncompacted and exposed land such as pre-strip areas.
Active spoil	Stockpiles of overburden / interburden containing unconsolidated material with varying levels of saline and sediment pre-disposition. Exposed areas susceptible to storms and weathering.	**High risk** of sheet, rill and gully erosion form active dumping areas.

Activity / Location	Description	Nature of Risk (No Mitigation)
Rehabilitated spoil	Rehabilitated spoil consisting of unconsolidated overburden / interburden with varying levels of saline and sediment pre-disposition. Exposed areas above the natural ground level without vegetation cover are susceptible to water erosion.	**Low – moderate risk** of sheet, rill and gully erosion on slopes and tunnel erosion on flats. Risk is greatest where areas of exposed topsoil remain with poor vegetation cover.
Drains and embankments	Water erosion can result from concentrated runoff on the slopes of constructed embankments and in drainage channels (natural and constructed).	**Low – moderate risk** of sheet, rill and gully erosion on slopes of embankments and stream bank erosion in channels. Risk is elevated where vegetation cover is poorest and/or where runoff is most concentrated, including the constructed clean water diversion channel.
Mackenzie North (when developed)		
Mine infrastructure areas: • Pre-strip areas • Topsoil stockpiles • Infrastructure areas • Exploration • Access tracks / haul road • ROM pad • Hardstand	Exposed soil surfaces on disturbed land leads to increased runoff velocities with greater potential for erosion and sediment loss.	**Low – moderate risk** of sheet and rill erosion. Risk is greatest on uncompacted and exposed land such as pre-strip areas.
Active spoil	Stockpiles of overburden / interburden containing unconsolidated material with varying levels of saline and sediment pre-disposition. Exposed areas susceptible to storms and weathering.	**High risk** of sheet, rill and gully erosion form active dumping areas.

Activity / Location	Description	Nature of Risk (No Mitigation)
Rehabilitated spoil	Rehabilitated spoil consisting of unconsolidated overburden / interburden with varying levels of saline and sediment pre-disposition. Exposed areas above the natural ground level without vegetation cover are susceptible to water erosion.	**Low – moderate risk** of sheet, rill and gully erosion on slopes and tunnel erosion on flats. Risk is greatest where areas of exposed topsoil remain with poor vegetation cover.
Coal stockpiles	Stockpiles of coal are susceptible to wind and water erosion.	**High risk** of sheet, rill and gully erosion on slopes and wind erosion from elevated stockpiles.
Drains and embankments	Water erosion can result from concentrated runoff on the slopes of constructed embankments and in drainage channels (natural and constructed).	**Low – moderate risk** of sheet, rill and gully erosion on slopes of embankments and stream bank erosion in channels. Risk is elevated where vegetation cover is poorest and/or where runoff is most concentrated, including the constructed clean water diversion channel.
Flood levee	Water erosion can result from concentrated runoff on the slopes of the levee and flood erosion	**Moderate risk** of sheet, rill and gully erosion on slopes of the levee. Gully and tunnel erosion can occur when flooding results in water movement along the levee. Risk is greatest during significant flood events.

5.0 EROSION AND SEDIMENT CONTROL MEASURES

The erosion and sediment management strategy for the Mine is designed to:

- Minimise the potential for erosion and sediment loss from the Mine; and
- Prevent contamination of the receiving environment.

These objectives are achieved through implementation of the following erosion and sediment control measures:

- Diversion drains and banks – designed to divert clean runoff into sediment detention basins before release to natural watercourses in the receiving environment;
- Catch drains – designed to capture mine affected water which is then conveyed to settlement detention ponds for recycling;
- Rock-lined drains – installed on rehabilitated landforms to manage runoff and prevent sediment loss particularly on spoil dumps above the natural ground surface;
- Final landform design – spoil areas above the natural ground surface will be design to <17% slope with batters. Levee banks will be designed to <33% slope.
- Sediment fences – designed to slow the flow of water and catch sediments in erosion susceptible locations;
- Sediment control dams – designed to intercept runoff and allow sediments in runoff to settle out before release to the receiving environment or recycling;
- Progressive rehabilitation of disturbed lands such that a stable, vegetated landform is achieved, minimising the area of exposed surface to erosion; and
- Regular inspections of sediment control structures and monitoring of locations known to be at risk of erosion, particularly during the wet season and following rainfall events. An erosion hazard inspection checklist is provided in Appendix A.

Table 2 below describe the erosion and sediment management strategies, which have been prepared for identified at risk areas at each of the operational areas (refer to Appendix B for general diagrams of the erosion and sediment control measures). Monitoring and maintenance programs have also been described. Locations of sediment control dams are displayed in Figure 2 through to Figure 6.

Table 2 Mitigation Measures

Activity / Location	Mitigation Measures	Inspection and Maintenance Program
Jellinbah Plains		
Rehabilitated spoil	• Landform design <17% slope with batters. • Runoff collected in diversion drains and sediment dams (KW32). • Rock-lined drains installed in locations susceptible to erosion.	• Sediment dams and open drains are inspected prior to the wet season to assess condition, water retention and transport capacity. Where design capacity is reduced to less than 70%, sediment deposits are to be removed prior to the wet season. • Drains, sediment dams and other control devices should be inspected during the wet season, in particular following heavy rainfall events to monitor for failures. • Spoil areas are inspected to assess erosion impacts (e.g. rills, gullies or tunnels). • Exposed areas to be stabilised through revegetation. • Eroded areas (e.g. rills, gullies or tunnels) to be re-instated / repaired with non-dispersive materials; and • As required sediment fences, straw bale filters or upslope diversion drains should be installed in locations of observed erosion.
Active spoil	• Runoff collected in diversion drains and sediment dams (KW41, KW40 and unnamed sediment dams). • Progressive rehabilitation as areas become available	• Sediment dams and open drains are inspected prior to the wet season to assess condition, water retention and transport capacity. Where design capacity is reduced to less than 70%, sediment deposits are to be removed prior to the wet season. • Drains, sediment dams and other control devices should be inspected during the wet season, in particular following heavy rainfall events to monitor for failures. • Spoil areas are inspected to assess erosion impacts (e.g. rills, gullies or tunnels). • Exposed areas to be stabilised; and • As required sediment fences, straw bale filters or bunds should be installed in locations of observed erosion.

Activity / Location	Mitigation Measures	Inspection and Maintenance Program
Mine infrastructure areas: • Pre-strip areas • Topsoil stockpiles • Infrastructure areas • Exploration • Access tracks / haul road	• Runoff collected in diversion drains and sediment dams (KW41 and unnamed sediment dams)	• Sediment dams and open drains are inspected prior to the wet season to assess condition, water retention and transport capacity. Where design capacity is reduced to less than 70%, sediment deposits are to be removed prior to the wet season. • Drains, sediment dams and other control devices should be inspected during the wet season, in particular following heavy rainfall events to monitor for failures. • Existing roads and infrastructure should be inspected for erosion damage. • Exposed surfaces to be stabilised with non-dispersive materials. • Eroded kerbside areas should be regraded or re-shaped to facilitate runoff. • As required, roadside turf filter strips should be planted to stabilise topsoil and filter sediments from runoff.
Coal stockpiles	• Runoff collected in dirty water diversion drains and sediment retentions dams (KW31)	• Sediment dams and open drains are inspected prior to the wet season to assess condition, water retention and transport capacity. Where design capacity is reduced to less than 70%, sediment deposits are to be removed prior to the wet season. • Drains, sediment dams and other control devices should be inspected for coal deposits during the wet season, in particular following heavy rainfall events to monitor for failures. • Existing roads and infrastructure should be inspected for erosion damage. • Exposed surfaces to be stabilised with non-dispersive materials. • Eroded kerbside areas should be regraded or re-shaped to facilitate runoff. • As required, roadside turf filter strips should be planted to stabilise topsoil and filter sediments from runoff.
Flood levee	• Landform design <33% slope • Progressive revegetation	• Pre wet season monitoring of levee condition by Registered Professional Engineer of Queensland. • Monitoring of levee following flood events and routinely during the wet season for early identification of erosion. • Major modifications should be inspected by a qualified engineer.

Activity / Location	Mitigation Measures	Inspection and Maintenance Program
Drains and embankments	• Drain design minimises water velocity	• The diversion drain and embankments should be inspected for bank erosion and sediment accumulation prior to and following heavy rainfall events during the wet season.
Jellinbah Central		
Rehabilitated spoil	• Landform design <17% slope with batters. • Runoff collected in diversion drains and sediment dams (KW08, KW12, KW13, KW09 and unnamed dams) prior to release or reuse. • Rock-lined drains installed in locations susceptible to erosion.	• Sediment dams and open drains are inspected prior to the wet season to assess condition, water retention and transport capacity. Where design capacity is reduced to less than 70%, sediment deposits are to be removed prior to the wet season. • Drains, sediment dams and other control devices should be inspected during the wet season, in particular following heavy rainfall events to monitor for failures. • Spoil areas should be inspected to assess erosion impacts (e.g. rills, gullies or tunnels). • Exposed areas to be stabilised through revegetation. • Eroded areas (e.g. rills, gullies or tunnels) to be re-instated / repaired with non-dispersive materials. • As required sediment fences, straw bale filters or upslope diversion drains should be installed in locations of observed erosion.

Activity / Location	Mitigation Measures	Inspection and Maintenance Program
• Active spoil	• Runoff from active spoil areas at Central west is intercepted by unnamed sediment retention dams prior to reuse or release. • Runoff from active spoil at Central east passes through vegetated catchment buffers and into Sediment dams. Runoff is then diverted around mine infrastructure via open drains prior to release. • Progressive rehabilitation as areas become available.	• Sediment dams and open drains are inspected prior to the wet season to assess condition, water retention and transport capacity. Where design capacity is reduced to less than 70%, sediment deposits are to be removed prior to the wet season. • Drains, sediment dams and other control devices should be inspected during the wet season, in particular following heavy rainfall events to monitor for failures. • Spoil areas are inspected to assess erosion impacts (e.g. rills, gullies or tunnels). • Exposed areas to be stabilised • As required sediment fences, straw bale filters or bunds should be installed in locations of observed erosion.
Mine infrastructure areas: • Pre-strip areas • Topsoil stockpiles • Infrastructure areas • Exploration • Access tracks / haul road	• Runoff from infrastructure areas on the western side of Central is treated via a series of collection dams (KW05, KW11, KW21, KW15, KW14) that capture runoff, allow coal sediment to settle out and enable water recycling.	• Sediment dams and open drains are inspected prior to the wet season to assess condition, water retention and transport capacity. Where design capacity is reduced to less than 70%, sediment deposits are to be removed prior to the wet season. • Drains, sediment dams and other control devices should be inspected during the wet season, in particular following heavy rainfall events to monitor for failures. • Existing roads and infrastructure should be inspected for erosion damage. • Exposed surfaces to be stabilised with non-dispersive materials. • Eroded kerbside areas should be regraded or re-shaped to facilitate runoff. • As required, roadside turf filter strips should be planted to stabilise topsoil and filter sediments from runoff.

Activity / Location	Mitigation Measures	Inspection and Maintenance Program
Coal stockpiles / ROM pad	• Runoff collected in dirty water diversion drains and sediment retentions dams (KW21, KW15, KW14).	• Sediment dams and open drains are inspected prior to the wet season to assess condition, water retention and transport capacity. Where design capacity is reduced to less than 70%, sediment deposits are to be removed prior to the wet season. • Drains, sediment dams and other control devices should be inspected for coal deposits during the wet season, in particular following heavy rainfall events to monitor for failures. • Existing roads and infrastructure should be inspected for erosion damage. • Exposed surfaces to be stabilised with non-dispersive materials. • Eroded kerbside areas should be regraded or re-shaped to facilitate runoff. • As required, roadside turf filter strips should be planted to stabilise topsoil and filter sediments from runoff.
Drains and embankments	• Drain design minimises water velocity.	• The diversion drain and embankments should be inspected for bank erosion and sediment accumulation prior to and following heavy rainfall events during the wet season.

Activity / Location	Mitigation Measures	Inspection and Maintenance Program
Jellinbah South		
Rehabilitated spoil	• Landform design <17% slope with batters. • Runoff drains to unnamed sediment dams. • Rock-lined drains installed in locations susceptible to erosion.	• Sediment dams and open drains are inspected prior to the wet season to assess condition, water retention and transport capacity. Where design capacity is reduced to less than 70%, sediment deposits are to be removed prior to the wet season. • Drains, sediment dams and other control devices should be inspected during the wet season, in particular following heavy rainfall events to monitor for failures. • Spoil areas should be inspected to assess erosion impacts (e.g. rills, gullies or tunnels). • Exposed areas to be stabilised through revegetation. • Eroded areas (e.g. rills, gullies or tunnels) to be re-instated / repaired with non-dispersive materials. • As required sediment fences, straw bale filters or upslope diversion drains should be installed in locations of observed erosion.
Mine infrastructure areas: • Hardstand • ROM pad	• Runoff drains to Jellinbah South Dam (KW23), Jellinbah South Void (KW25), or an unnamed sediment dam.	• Sediment dams and open drains are inspected prior to the wet season to assess condition, water retention and transport capacity. Where design capacity is reduced to less than 70%, sediment deposits are to be removed prior to the wet season. • Drains, sediment dams and other control devices should be inspected during the wet season, in particular following heavy rainfall events to monitor for failures. • Existing roads and infrastructure should be inspected for erosion damage. • Exposed surfaces to be stabilised with non-dispersive materials. • Eroded kerbside areas should be regraded or re-shaped to facilitate runoff. • As required, roadside turf filter strips should be planted to stabilise topsoil and filter sediments from runoff.

Activity / Location	Mitigation Measures	Inspection and Maintenance Program
Central North / Central North Extension (when developed)		
Rehabilitated spoil	• Landform design <17% slope with batters. • Runoff drains to sediment traps and dams at Central North / Central North Extension. • Rock-lined drains installed in locations susceptible to erosion.	• Sediment dams and open drains are inspected prior to the wet season to assess condition, water retention and transport capacity. Where design capacity is reduced to less than 70%, sediment deposits are to be removed prior to the wet season. • Drains, sediment dams and other control devices should be inspected during the wet season, in particular following heavy rainfall events to monitor for failures. • Spoil areas should be inspected to assess erosion impacts (e.g. rills, gullies or tunnels). • Exposed areas to be stabilised through revegetation. • Eroded areas (e.g. rills, gullies or tunnels) to be re-instated / repaired with non-dispersive materials. • As required sediment fences, straw bale filters or upslope diversion drains should be installed in locations of observed erosion.
Active spoil	• Runoff collected in diversion drains and sediment traps and dams at Central North. • Progressive rehabilitation as areas become available.	• Sediment dams and open drains are inspected prior to the wet season to assess condition, water retention and transport capacity. Where design capacity is reduced to less than 70%, sediment deposits are to be removed prior to the wet season. • Drains, sediment dams and other control devices should be inspected during the wet season, in particular following heavy rainfall events to monitor for failures. • Spoil areas are inspected to assess erosion impacts (e.g. rills, gullies or tunnels). • Exposed areas to be stabilised. • As required sediment fences, straw bale filters or bunds should be installed in locations of observed erosion.

Activity / Location	Mitigation Measures	Inspection and Maintenance Program
Mine infrastructure areas: • Pre-strip areas • Topsoil stockpiles • Access tracks / haul road	• Runoff from infrastructure areas is treated via a series of sediment traps and clean water dams that capture runoff, allow coal sediment to settle out and enable water recycling.	• Sediment dams and open drains are inspected prior to the wet season to assess condition, water retention and transport capacity. Where design capacity is reduced to less than 70%, sediment deposits are to be removed prior to the wet season. • Drains, sediment dams and other control devices should be inspected during the wet season, in particular following heavy rainfall events to monitor for failures. • Existing roads and infrastructure should be inspected for erosion damage. • Exposed surfaces to be stabilised with non-dispersive materials. • Eroded kerbside areas should be regraded or re-shaped to facilitate runoff. • As required, roadside turf filter strips should be planted to stabilise topsoil and filter sediments from runoff.
Drains and embankments	• Drain design minimises water velocity	• The diversion drain and embankments should be inspected for bank erosion and sediment accumulation prior to and following heavy rainfall events during the wet season.

Activity / Location	Mitigation Measures	Inspection and Maintenance Program
Mackenzie North		
Rehabilitated spoil	• Landform design <17% slope with batters.	• Sediment dams and open drains are inspected prior to the wet season to assess condition, water retention and transport capacity. Where design capacity is reduced to less than 70%, sediment deposits are to be removed prior to the wet season. • Drains, sediment dams and other control devices should be inspected during the wet season, in particular following heavy rainfall events to monitor for failures. • Spoil areas should be inspected to assess erosion impacts (e.g. rills, gullies or tunnels). • Exposed areas to be stabilised through revegetation. • Eroded areas (e.g. rills, gullies or tunnels) to be re-instated / repaired with non-dispersive materials. • As required sediment fences, straw bale filters or upslope diversion drains should be installed in locations of observed erosion.
Active spoil	• Runoff collected in diversion drains and sediment dams (NE Sediment Dam, Central North Sediment Dam, Central South Sediment Dam). • Progressive rehabilitation as areas become available.	• Sediment dams and open drains are inspected prior to the wet season to assess condition, water retention and transport capacity. Where design capacity is reduced to less than 70%, sediment deposits are to be removed prior to the wet season. • Drains, sediment dams and other control devices should be inspected during the wet season, in particular following heavy rainfall events to monitor for failures. • Spoil areas are inspected to assess erosion impacts (e.g. rills, gullies or tunnels). • Exposed areas to be stabilised. • As required sediment fences, straw bale filters or bunds should be installed in locations of observed erosion.

Activity / Location	Mitigation Measures	Inspection and Maintenance Program
Mine infrastructure areas: • Pre-strip areas • Topsoil stockpiles • Infrastructure areas • Exploration • Access tracks / haul road • ROM pad • Hardstand	• Runoff from infrastructure areas is treated via the Southern Contaminated Water Dam, which captures runoff, allow coal sediment to settle out and enable water recycling.	• Sediment dams and open drains are inspected prior to the wet season to assess condition, water retention and transport capacity. Where design capacity is reduced to less than 70%, sediment deposits are to be removed prior to the wet season. • Drains, sediment dams and other control devices should be inspected during the wet season, in particular following heavy rainfall events to monitor for failures. • Existing roads and infrastructure should be inspected for erosion damage. • Exposed surfaces to be stabilised with non-dispersive materials. • Eroded kerbside areas should be regraded or re-shaped to facilitate runoff. • As required, roadside turf filter strips should be planted to stabilise topsoil and filter sediments from runoff.
Coal stockpiles	• Runoff collected in mine-affected water diversion drains and sediment retentions dam.	• Sediment dams and open drains are inspected prior to the wet season to assess condition, water retention and transport capacity. Where design capacity is reduced to less than 70%, sediment deposits are to be removed prior to the wet season. • Drains, sediment dams and other control devices should be inspected for coal deposits during the wet season, in particular following heavy rainfall events to monitor for failures. • Existing roads and infrastructure should be inspected for erosion damage. • Exposed surfaces to be stabilised with non-dispersive materials. • Eroded kerbside areas should be regraded or re-shaped to facilitate runoff. • As required, roadside turf filter strips should be planted to stabilise topsoil and filter sediments from runoff.
Flood levee	• Landform design <33% slope • Progressive revegetation	• Pre wet season monitoring of levee condition by Registered Professional Engineer of Queensland. • Monitoring of levee following flood events and routinely during the wet season for early identification of erosion. • Major modifications should be inspected by a qualified engineer.

Activity / Location	Mitigation Measures	Inspection and Maintenance Program
Drains and embankments	• Drain design minimises water velocity	• The diversion drain and embankments should be inspected for bank erosion and sediment accumulation prior to and following heavy rainfall events during the wet season.

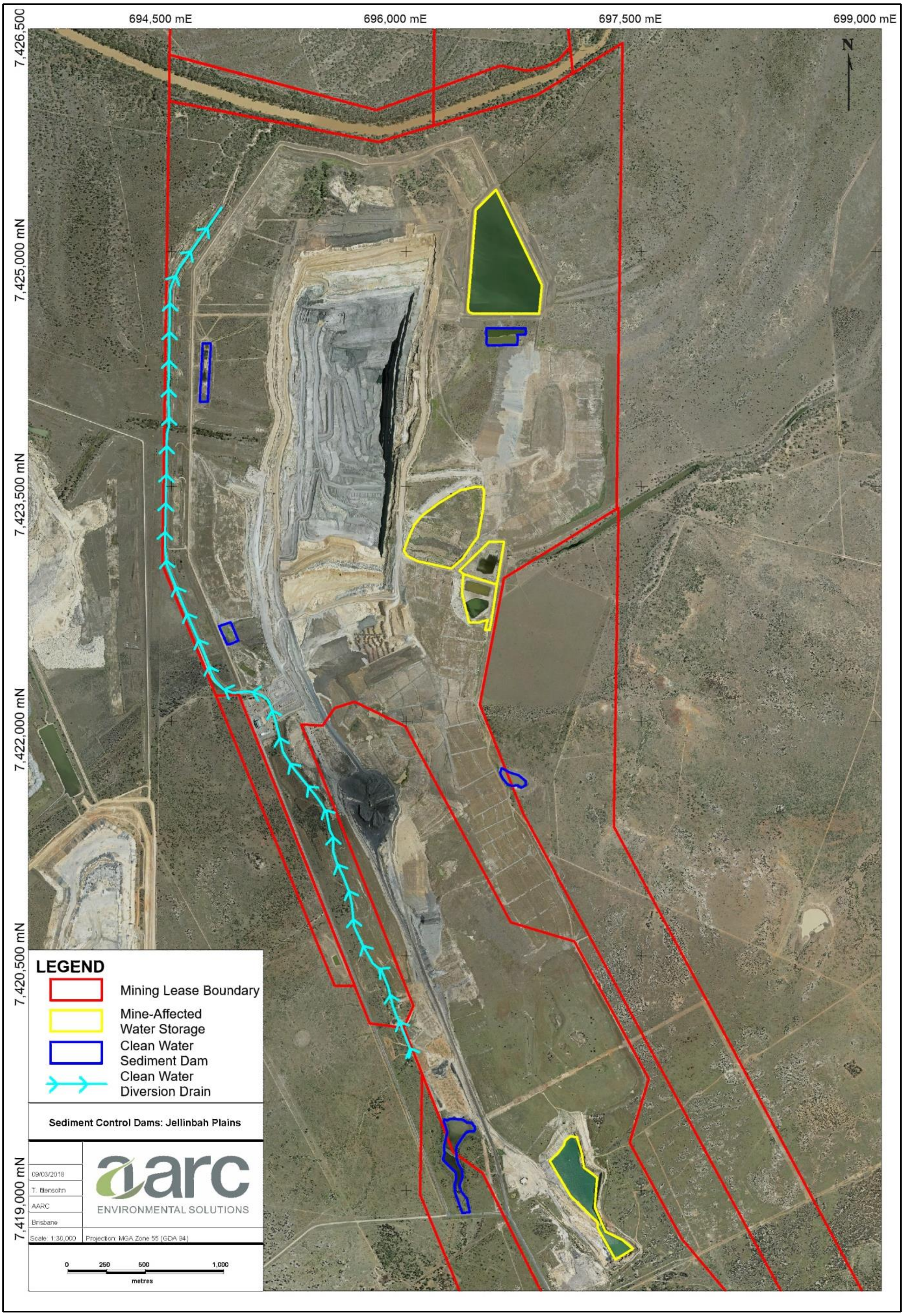

Figure 2 Sediment Control Dams – Jellinbah Plains

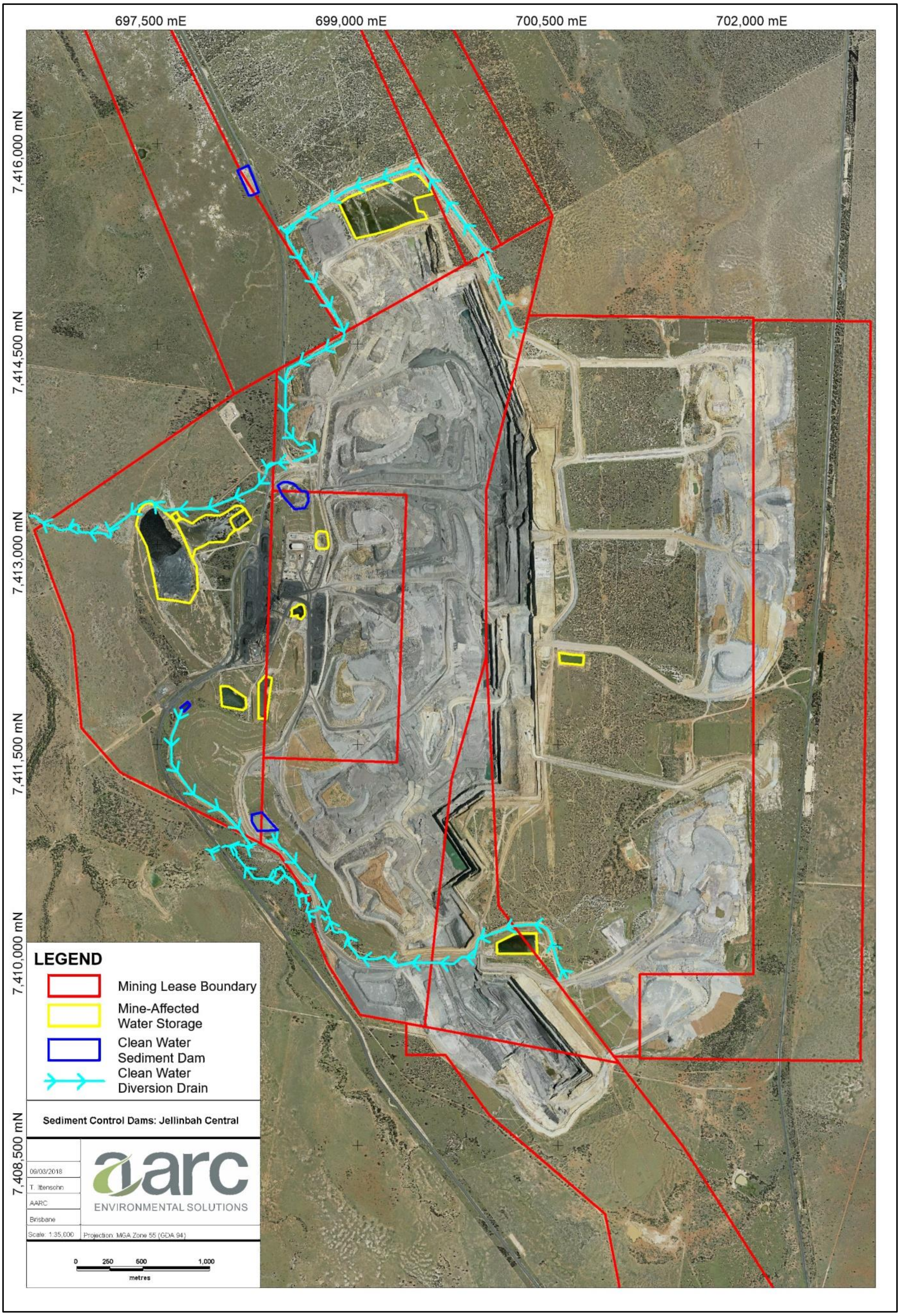

Figure 3 Sediment Control Dams – Jellinbah Central

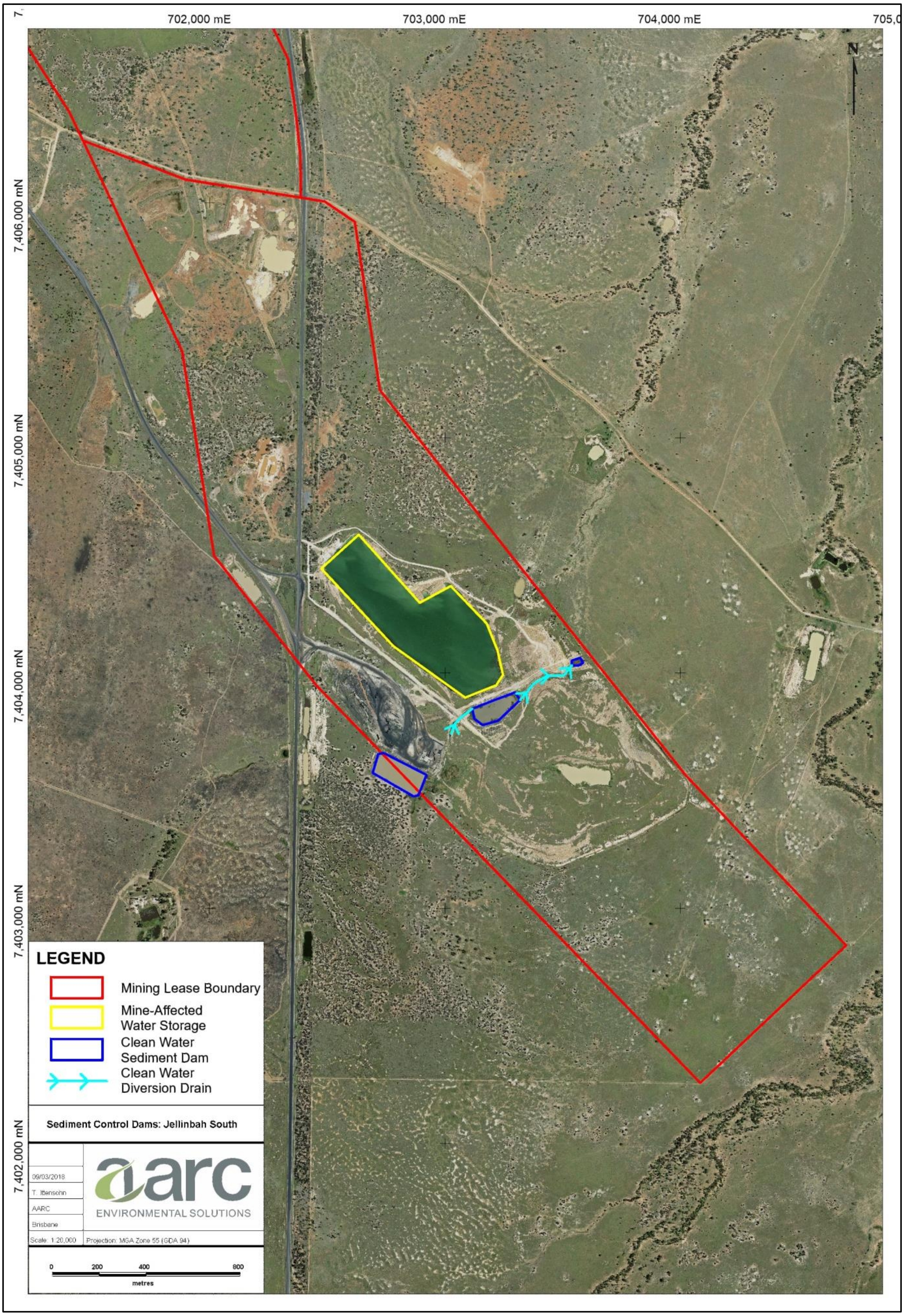

Figure 4 Sediment Control Dams – Jellinbah South

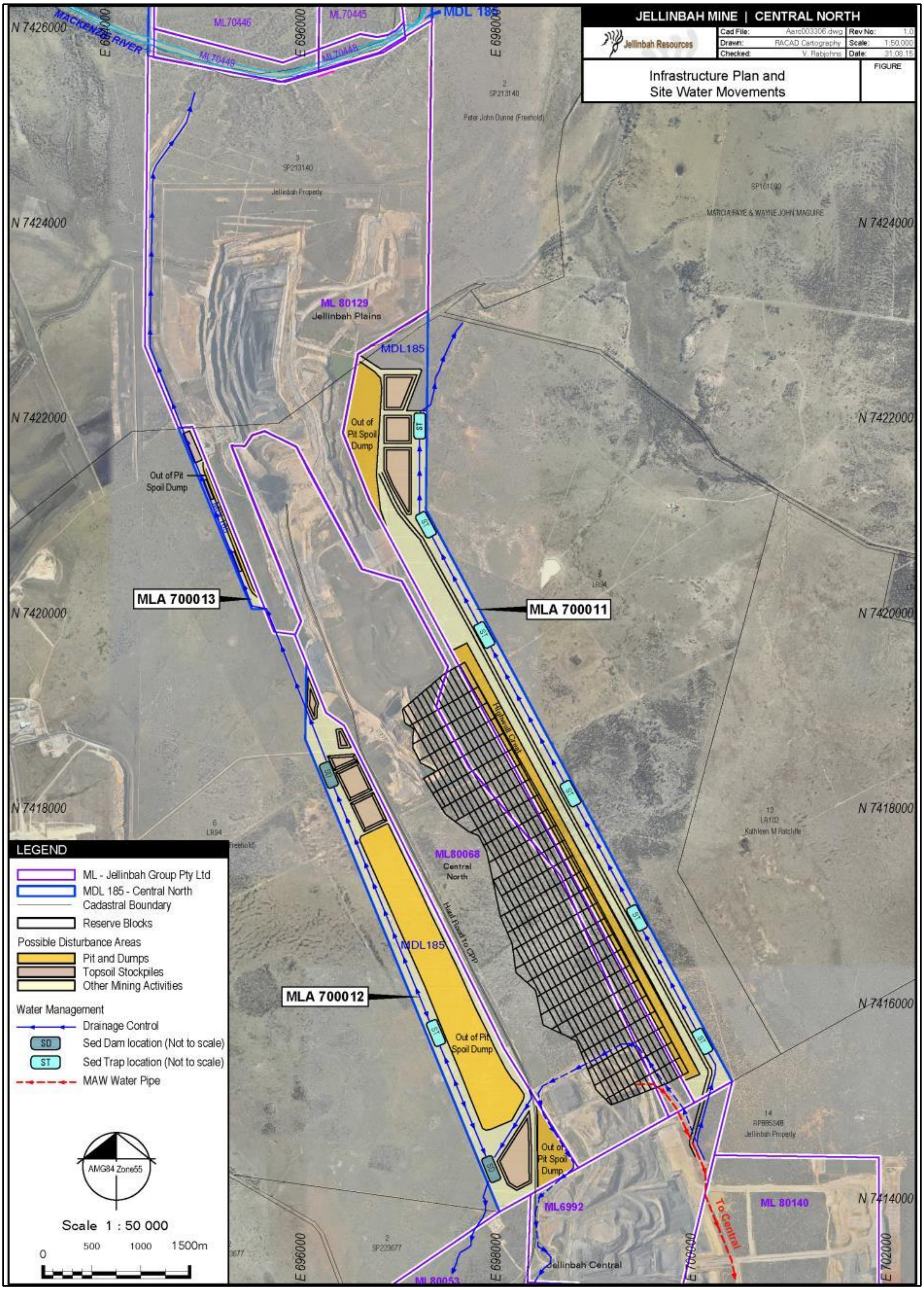

Figure 5 Sediment Control Dams – Central North / Central North Extension

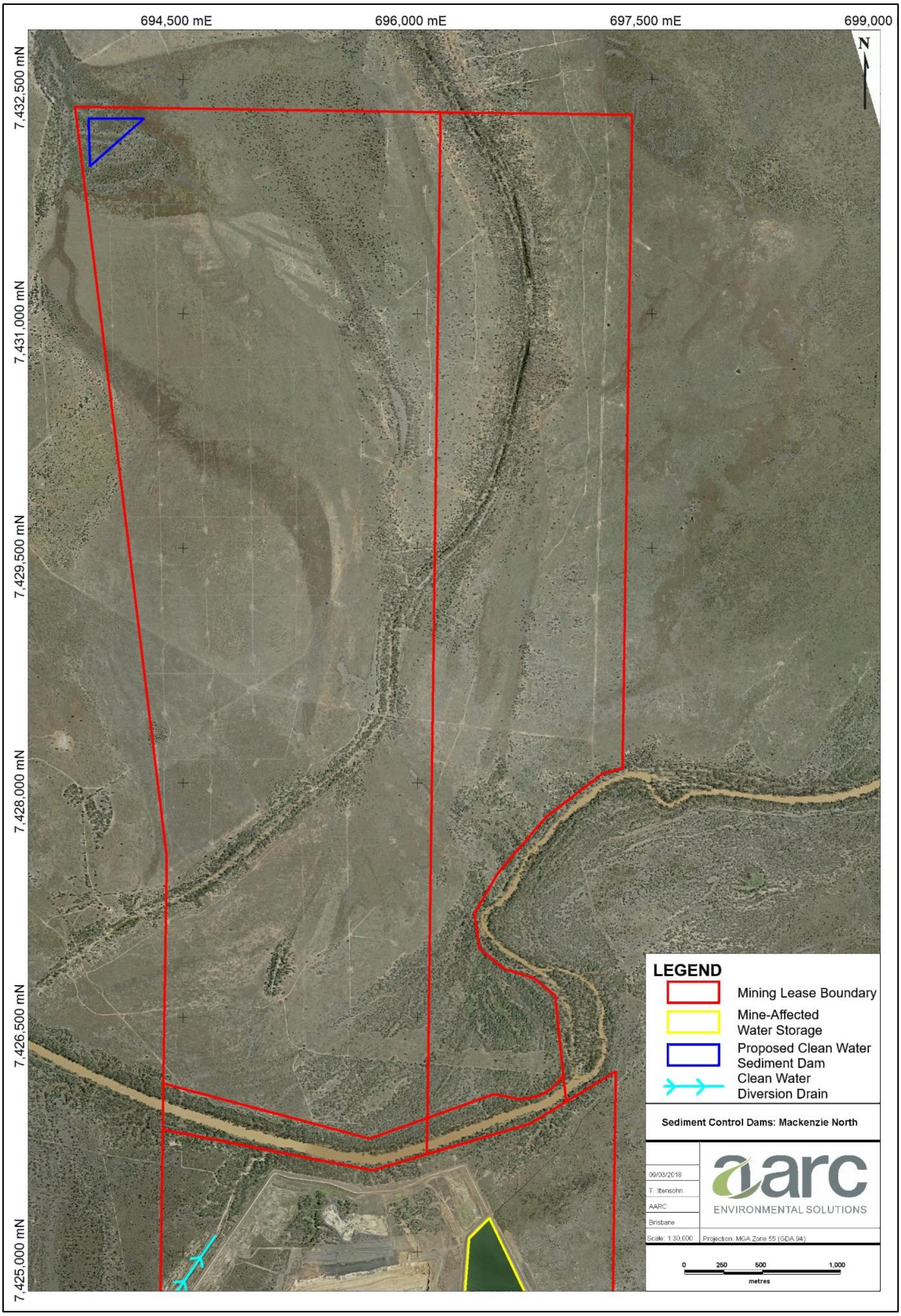

Figure 6 Sediment Control Dams – Mackenzie North

5.1 SEDIMENT CONTROL DAM DESIGN

Sediment dams / traps at the Mine have been designed as Type D basins in accordance with the International Erosion Control Association (IECA) Best Practice Erosion and Sediment Control guidelines. Type D basins are the most appropriate for dispersive soils.

The minimum volume of the upper settling zone is defined by the following equation, defined in IECA (2008):

$$V_S = 10.R_{(Y\%,5-day)}.C_v.A$$

Where:

V_s	-is the volume of the settling zone in cubic metres (m^3)
$R_{(Y\%,5-day)}$	-is the Y%, 5-day rainfall depth in mm
C_v	-is the volumetric runoff coefficient
A	-is the effective catchment surface area connected to the basin in hectares (ha)

For the design of Type D sediment control basins, the following constants were used:

$R_{(Y\%,5-day)}$	59 mm (based on a 1:1 year, 12 hour storm event)
C_v	0.5

6.0 REFERENCES

Engeny (2017) Jellinbah Mine Water Management Plan, Engeny Water Management, Brisbane

Environmental Geochemistry International Pty Ltd (EGI) (2013) *Geochemical Assessment of the Mackenzie North Coal Project*. Environmental Geochemistry International Pty Ltd, Balmain.

Environment ACT, Erosion and Sediment Control During Land Development, Canberra, 1998.

Environment Protection Authority, ACT Government, Environment Protection Guidelines for Construction and Land Development in the ACT, Canberra, 2011.

IECA (2008) Best Practice Erosion and Sediment Control

Ison Environmental Planners (Ison) (1998), *Soil and Land Capability Assessment: Jellinbah Plains Extension*. Ison Environmental Planners, Brisbane.

Appendix A Routine Erosion Hazard Inspection List

Routine Erosion Hazard Inspection Check Sheet

Erosion management, maintenance and repair is most effective on the mine site if hazards are identified early before the problem worsens. Generally, areas of sheet and rill erosion should be identified before the wet season and re-seeded to establish root growth before erosion becomes more severe.

<table>
<tr><th>Activity</th><th>Erosion Hazard Trigger</th><th>Maintenance Required</th></tr>
<tr><td>Rehabilitated Spoil</td><td>Gullies > 0.5m deep
Sinkholes > 1m deep</td><td rowspan="6">Earthworks required to repair the landform.
Preventative measure to avoid pooling water or to slow or redirect runoff should be installed (fences, hay bales, bunds & drains).
Clean sediment out of channels.</td></tr>
<tr><td>Mine infrastructure areas
(Hardstand and ROM pad; Pre-strip areas, topsoil stockpiles, infrastructure areas, exploration and access tracks)</td><td>Gullies > 0.3m deep
Evidence of coal fines in uncontained runoff</td></tr>
<tr><td>Active Spoil</td><td>Gullies > 0.7m deep
Evidence of bulk earth movement or sediment flow from dump</td></tr>
<tr><td>Coal stockpiles</td><td>Gullies > 0.3m deep
Evidence of coal fines in uncontained runoff.</td></tr>
<tr><td>Drains and embankments</td><td>Gullies > 0.3m deep on embankments
Evidence of shearing or wall failure in channels
Build-up of coal fines or sediment in channel > 25% capacity</td></tr>
<tr><td>Flood Levees</td><td>Gullies > 0.3m deep on embankments
Any observed tunnel erosion or gouging</td></tr>
</table>

Appendix B Use and Design of Sediment Control Structures

Diversion Banks and Drains

The purpose of diversion structures is to intercept water runoff (either clean or mine water) and to divert it at low velocities either around disturbed land or into sediment control\ structures for treatment. To minimise the level of erosion, the velocity of runoff water can be reduced by implementing controls such as hay bales and rock structures which are described below.

Design and dimensions of diversion banks and drains in relation to slope are shown below.

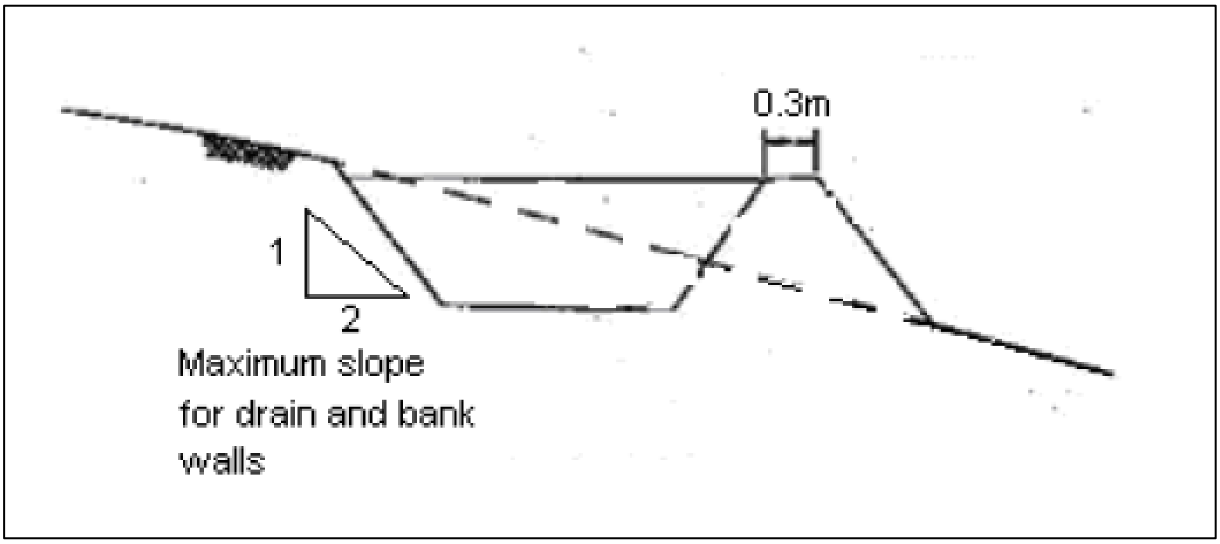

Figure B-1 Diversion Bank and Drain Design Dimensions

Sediment Dams

There are two types of sediment dams, those that are for temporary use (less than 6 months), and those that are larger and expected to be used for a longer period of time.

Small, temporary sediment dams are used to capture water and sediment runoff from disturbed areas to allow the sediment to settle and the clean water to evaporate or released from the system. These temporary dams are constructed to treat runoff water from rehabilitation or disturbed land for sediment until vegetation establishes.

Typical design is shown below.

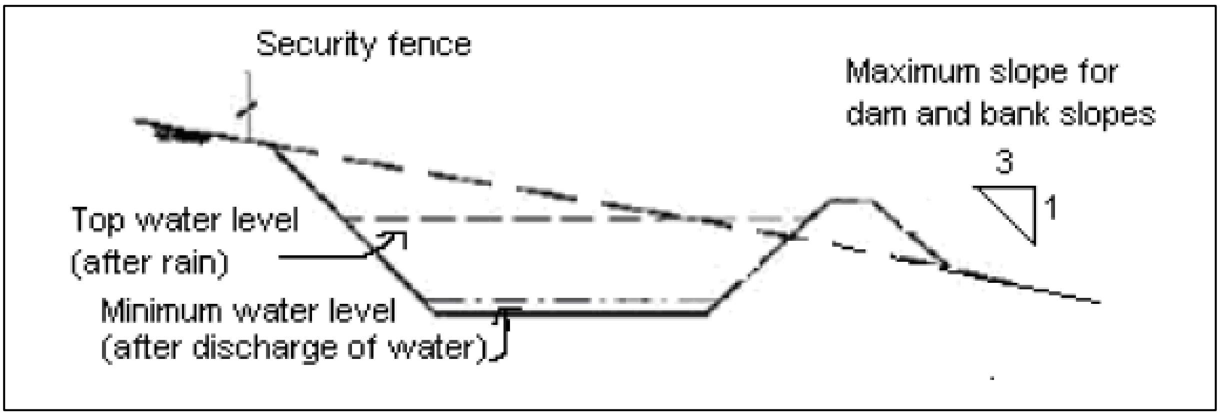

Figure B-2 Temporary Sediment Dam Design

Larger, long term sediment dams are used to intercept sediment laden runoff. The sediment is retained in the dam while the water is allowed to be released from a pipe outlet wrapped in the same geotextile fabric used for sediment fencing.

The typical design is shown below.

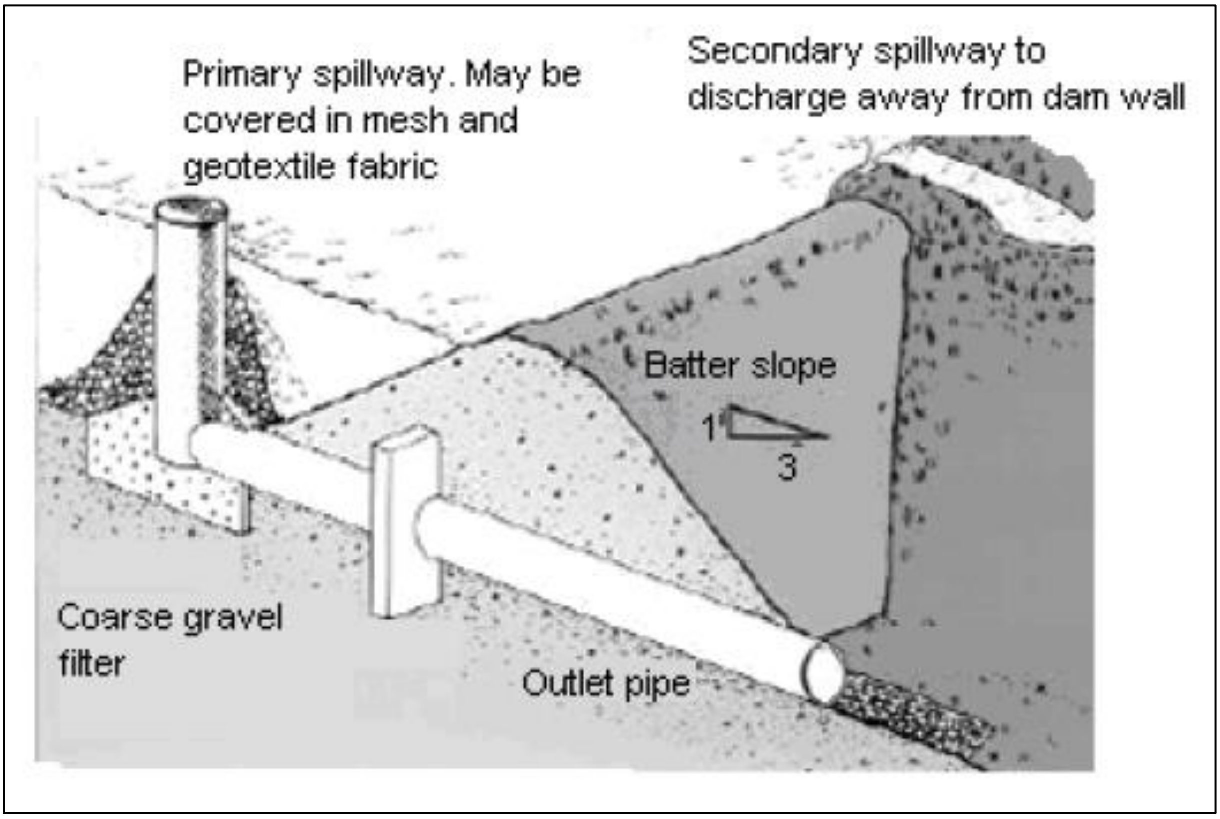

Figure B-3 Large, Long Term Sediment Dam Design

Sediment Fences

Sediment fences are used to intercept sheet flow runoff from disturbed areas containing sediment. Sheet flow is flow which is parallel to the sediment fence, not hitting the fence directly. Green geotextile fabric made specifically for sediment fencing is pegged at least every 3 m and the bottom of the cloth is buried 150 mm into the ground. Black geotextile fabric is a weed mat, and is not an effective sediment control. Green textile fabric is designed to capture the sediment in runoff but allow the clean water through the fabric at a rate which will not destroy the sediment structure.

Design is shown below.

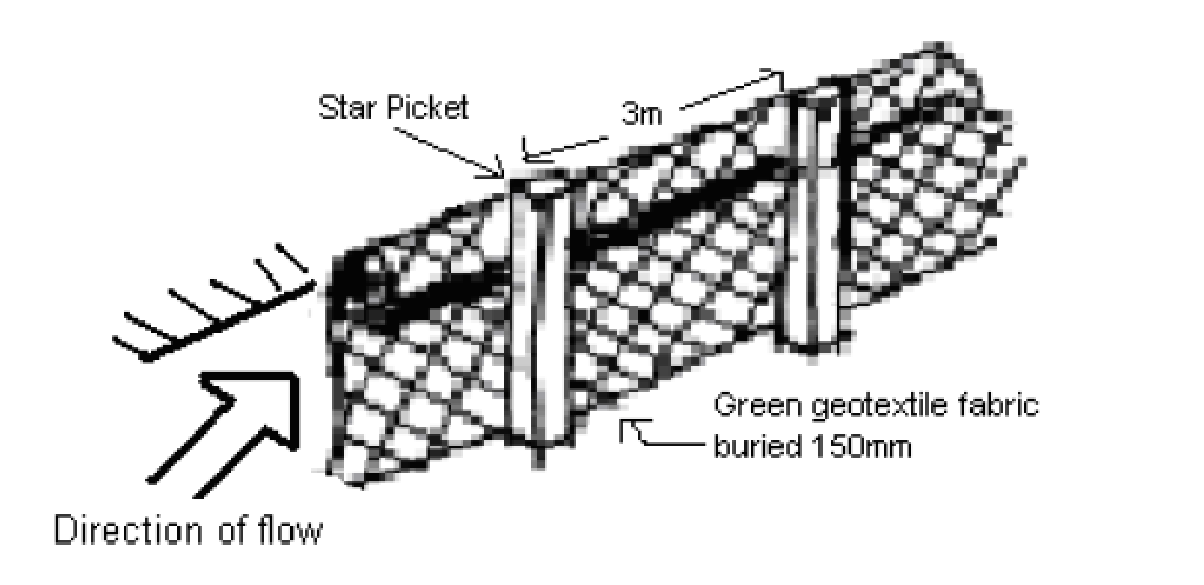

Figure B-4 Sediment Fence Design Hay Bales and Rock Structures

Hay bales and rock structures are used on drainage lines or upstream of other controls (such as sediment dams), and often in conjunction with sediment fences to minimise erosion. Hay bales are used in areas where a temporary form of control is required until vegetation establishes to provide natural erosion and sediment control.

The typical design is shown below.

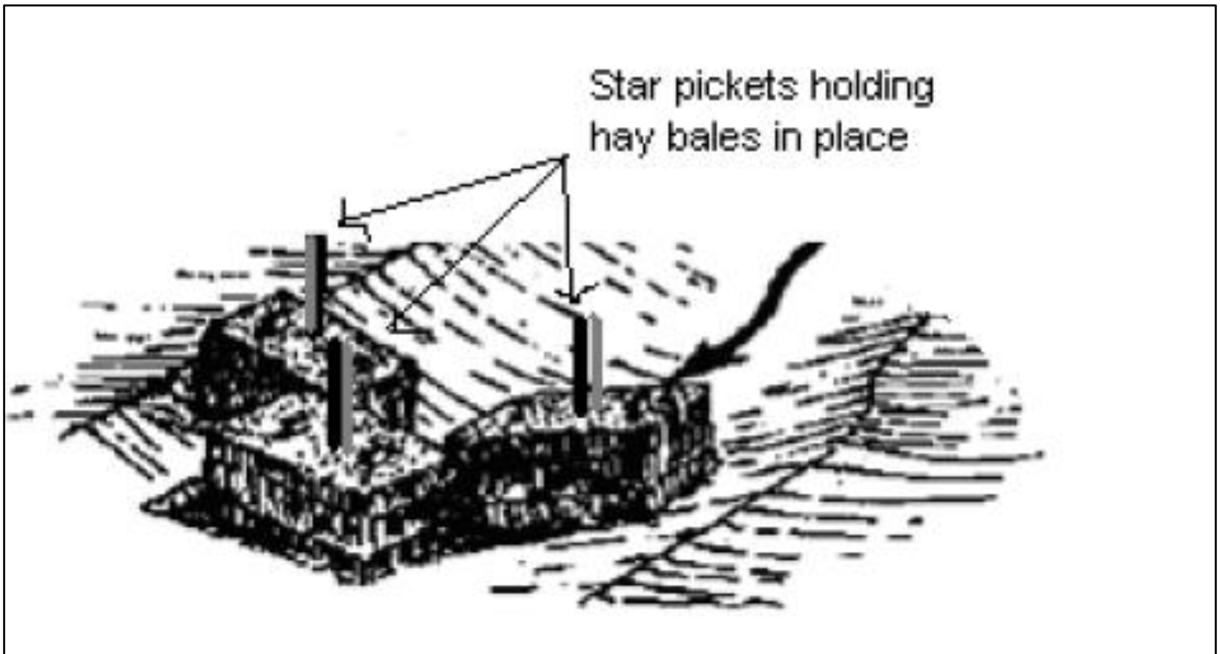

Figure B-5 Use of Hay Bales in Diversion Drain

Rock structures can also be used in areas where temporary control is required but can also be used as a permanent erosion and sediment control. The rocks receive the initial force of the flow and disperse it, slowing down the flow and therefore minimising the erosion potential, similar to the hay bales. Rock structures can be used in two ways, one is at the outlet of pipes or culverts where the rocks are simply placed under and around the outlet, and the other is in a kind of embankment wrapped in geotextile fabric at intervals to slow the flow further.

Designs are shown below.

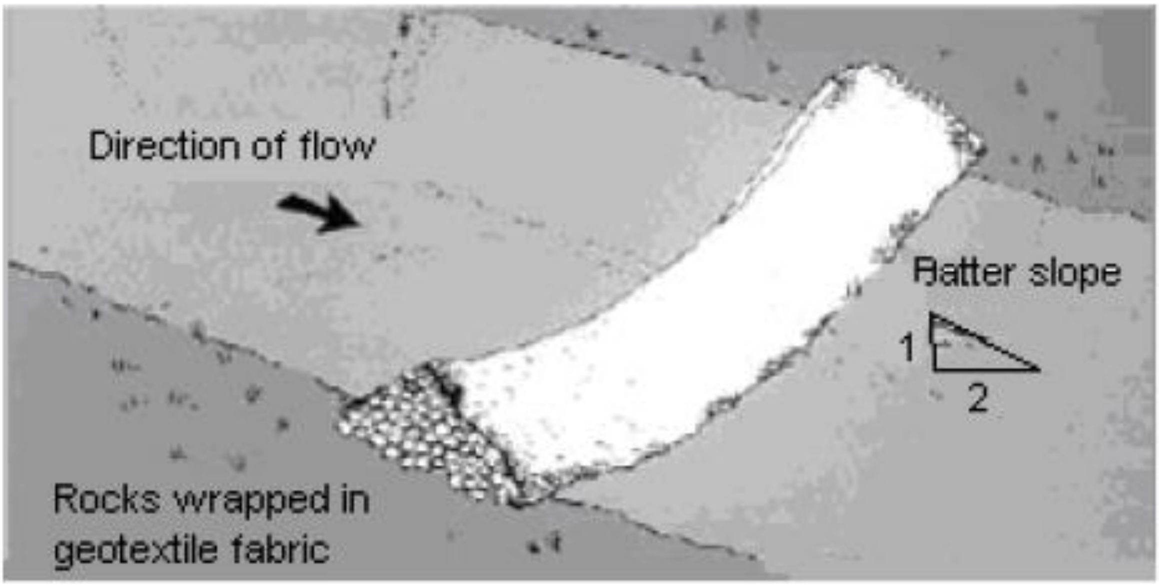

Figure B-6 Rock Structure as an Embankment

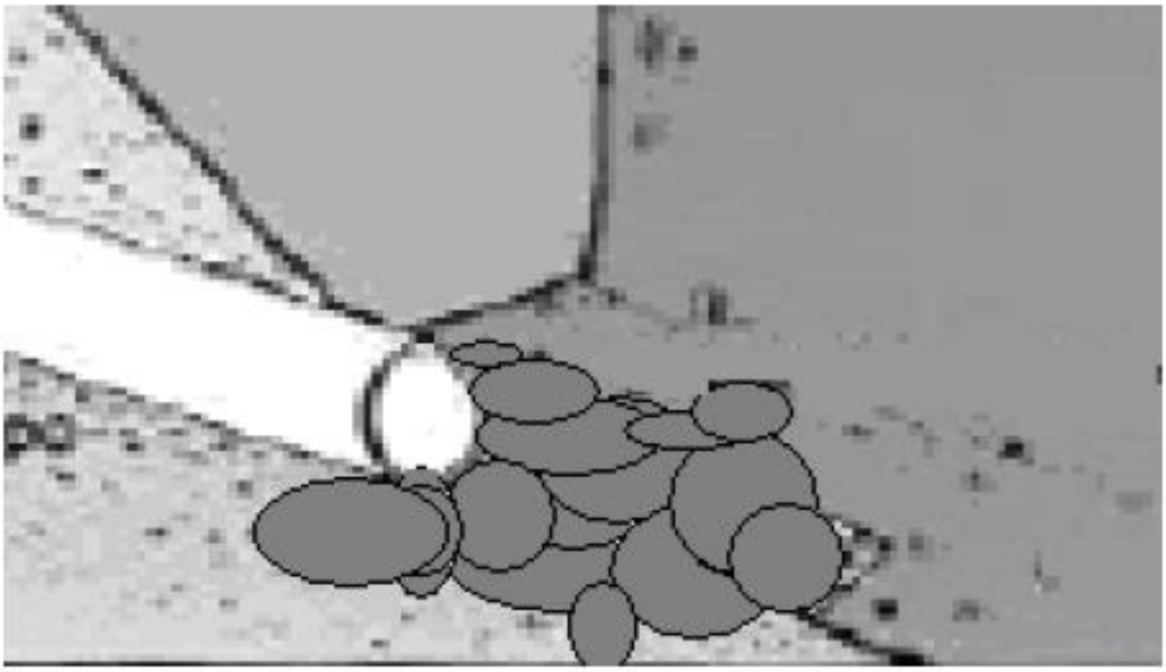

Figure B-7 Rock Structure at the Outlet of Pipe

Referenced from Environment ACT, Erosion and Sediment Control During Land Development, Canberra, 1998 and EPA 2011.

JELLINBAH RESOURCES

Jellinbah Mine Central North Extension Surface Water Assessment

November 2019

M61000_022-REP-002

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REV	**DESCRIPTION**	**AUTHOR**	**REVIEWER**	**APPROVED BY**	**DATE**
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Signatures					

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1. INTRODUCTION

Jellinbah Mine (the Site) is an open-cut coal operation in the Bowen basin with approval to produce up to 7.5 million tonnes per annum (Mtpa) of run-of-mine (ROM) pulverised coal injection (PCI) and thermal coal. Mining activities at Jellinbah Coal Mine are approved under Environmental Authority EPML00516813 (DEHP, 2019).

The Jellinbah Central North Extension (CNE) is a proposed extension of the existing Jellinbah Central North (CN) open-cut operations, which includes three (3) additional mining leases. The proposed extension will extend the operational life of the mine by 20 years and contribute 1 Mt per annum (Mtpa) run-of-mine (ROM) coal.

The Australian Government Department of the Environment and Energy has requested the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) to provide advice on the Jellinbah Coal Mine CNE.

Engeny Water Management (Engeny) was commissioned to assist Jellinbah Resources respond to queries raised by IESC associated with surface water.

1.1 IESC Review Comments and Responses

The key objective of the current assessment is to provide responses to the IESC information request (IESC, 2019). The IESC's relevant questions regarding surface water management, summary of responses and reference to further discussion in the report are provided in Table 1.1.

Table 1.1 IESC Advices and Responses

Advice No.	IESC Advice	Response & Reference
23	The IESC recommends that the proponent undertakes flood modelling (as outlined in the response to Question 2) and determines the risks of uncontrolled releases from water dams, sediment traps, storage ponds and other associated infrastructure during extreme weather events, such as cyclones and extended wet seasons to assist in developing monitoring and mitigation plans. Images from WOfS may add value in calibrating this modelling (e.g. Mueller et al. 2016). The information gathered from the flood modelling can be used to inform the SWMP as well as the REMP (e.g. risk of overtopping hypersaline final voids).	No additional mine-affected water dams have been proposed as part of the CNE project. The risk of uncontrolled release from structures associated with Jellinbah Mine was assessed. The water balance modelling, including extreme weather events (e.g. 2011 flood event), indicates that the proposed CNE does not increase the likelihood or volume of mine water releases (Refer Section 5.4).
7	Surface waters within the project area and nearby include the perennial Mackenzie River, ephemeral creeks including Blackwater Creek and Twelve Mile Creek, floodplain wetlands such as Three Mile Lagoon and Five Mile Lagoon, and	Catchment boundaries for CNE have been developed and are shown in Figure 5.2. Run-off from non-mine affected catchments within the CNE

Advice No.	IESC Advice	Response & Reference
	palustrine wetlands associated with gilgai (much of which lies in the Brigalow TEC which is to be cleared). Although many of these surface waters are ephemeral, they play crucial ecological roles when inundated because they provide habitat, water and food resources for diverse biota and are the sites of ecological processes such as organic matter breakdown and nutrient cycling (Boulton et al. 2014). Changes to their water regimes are likely to be caused by alteration of catchment areas and topography, vegetation clearance and altered surface runoff due to open-cut mining and sediment dams. In turn, these altered water regimes will affect water depth and pool persistence in many surface waters. The proponent has not presented any information on the biota of these flowing and standing surface waters or their fringing vegetation at different stages of inundation which makes it difficult to judge likely impacts of altered water regimes (and altered water quality, see Paragraphs 20 and 24). Without such baseline data against which to assess changes after mining commences, it is impossible for the proponent to demonstrate the success of management and mitigation plans designed to minimise impacts on the flora, fauna and ecological processes in surface waters. The IESC recommends that the proponent survey water quality, riparian vegetation and aquatic biota of Blackwater Creek and Twelve Mile Creek at several times (e.g. during flow and when disconnected pools form) to obtain baseline water quality and biological data to guide predictions of potential impacts and against which to assess the effectiveness of mitigation strategies.	area report to unnamed tributaries immediately downstream via sediment control devices. These unnamed tributaries flow to the Mackenzie River and do not interact with 12 Mile Creek.
17	The IESC notes that Twelve Mile Creek runs through additional mine sites downstream, and impacts arising from those sites may limit the value of any mitigation undertaken for the Jellinbah CNE (see response to Question 3). Baseline data on water quality and biota (see Paragraph 7) should be collected to guide the prediction of these cumulative impacts and provide reference data for assessing the effectiveness of mitigation strategies.	Catchment boundaries for CNE have been shown in Figure 5.2.The CNE catchments flow to unnamed tributaries immediately downstream via sediment control devices. These unnamed tributaries flow to the Mackenzie River and do not interact with 12 Mile Creek.
8	Although the proponent provided a water balance, it has not accounted for the quantity of mine-affected water discharge and 'clean' water discharge in the calculations. Quantification of the amounts of water discharged by the proponent into Blackwater Creek and the Mackenzie River for both 'clean' and mine-affected water is required. The water balance does not consider cyclones or high rainfall events which could	Water balance modelling results indicate no additional accumulation of mine-affected water as a result of the proposed CNE. (Refer Section 5.4.1). There are no mine affected water release points proposed for the Central North Extension mining area.

Advice No.	IESC Advice	Response & Reference
	produce high quantities of runoff and erosion (relevant for transport of sediment-bound contaminants, see Paragraph 4). The proponent has also not provided evidence of how the drainage, designed runoff and sediment traps will withstand extreme rainfall and weather events. The proponent should provide an updated water balance considering the above matters. The IESC suggests using the Minerals Council of Australia Water Accounting Framework (Minerals Council of Australia 2014) to do this.	While the IESC recommends using the Water Accounting Framework (WAF) to quantify the volumes of mine affected water and clean water releases discharge, we consider the proposed daily water balance using GoldSIM is a more accurate methodology than the WAF due to its ability to simulate the containment performance of individual storages, including daily fluctuations storage levels, water transfers, controlled and uncontrolled release. The WAF was developed by MCA as a mechanism by which industry can report water consumption in standardised units to comply with industry reporting requirements and was not developed with the intention of use to assess and/or quantify the performance of mine water management systems in terms of managing the impacts to the environmental values.
9	The IESC recommends the proponent undertakes a sensitivity analysis on the water balance model to investigate and report on the uncertainties in model parameterisation and future hydro-meteorological assumptions. The current analysis is based on a “looping” of the past 100 years of climate (Paragraph 3(d)), and no consideration, even in the form of a sensitivity analysis, has been given to the likely impacts of magnitude (and hence variability) of rainfalls over the next 100 years. This could be informed through the use of the Climate Futures Framework and Tools (Whetton et al. 2012) (https://www.climatechangeinaustralia.gov.au/en/climate-projections/climate-futures-tool/projections/) which allows for various climate regimes to be simulated.	Climate change scenarios for the CNE have been considered, as described in Section 5.5. The sensitivity analysis indicates no significant change to the mine water inventory or increased risk of mine affected water releases for CNE.
19	According to the proponent, the Surface Water Management System will ensure the project maintains compliance with Environmental Authority conditions pertaining to release and receiving water quality, which will ensure regional Water Quality Objectives (WQOs) are achieved. However, the IESC recommends that the proponent should demonstrate how the	Water balance modelling results indicate no change in the release of mine affected water and non-mine water for the CNE, as discussed in Section 5.4

Advice No.	IESC Advice	Response & Reference
	existing water management system will ensure that these WQOs continue to be achieved. An adaptive monitoring and management framework need to be appropriately targeted for future stages in the proposed extension, including: c. regular and event-based (e.g. during spates) water quality testing of the discharge water, upstream water and water immediately downstream of the licenced discharge points to determine when individual contaminants consistently exceed water quality guidelines; and, d. commitments for surface water and groundwater monitoring should be presented as part of the relevant water monitoring plans and should be consistent with the Water Quality Objectives for the Fitzroy River (State of Queensland 2013).	Recommendations on adaptive monitoring and management framework are provided in Section 6
11	The proponent proposes to use multiple sediment dams to intercept runoff, and it is anticipated that there will be overflow from the sediment dams to the off-site receiving environment. It is also stated that geochemical characterisation of the overburden material indicates that runoff from spoil dumps draining to sediment dams would have concentrations of dissolved salts and metals below guideline values. However, no geochemical assessment was provided for the project area to support this conclusion, which is important if design changes for the spoil dumps and associated infrastructure can be made to preserve the Brigalow TEC in ML 700012.	A waste characterisation assessment was undertaken for Jellinbah Mine (EGI, 2013) and reported low levels of salt and dissolved metals. CNE has the same geological sequence as the CN and as such, it is expected these results are representative of waste material associated with CNE (Refer Section 3.2).
12	The IESC notes that there are no water treatment systems in place, but rather the proponent states that they 'recycle' as much water as possible. The quality of the water once it has been 'recycled' and used for site activities has not been provided by the proponent. The tailings dams' water is used at the wash plant and is pumped into water trucks at the Jellinbah Plains site. It is not clear if this water is used for dust suppression. Given that the water quality data provided by the proponent for the Tailings Dam (KW14) from 2016 show elevated levels of sulfate, arsenic and nickel, further information is needed on the exact use of this water and its potential impacts on and risks to the receiving environment.	The tailings decant water is re-cycled through the wash plant circuit and used for dust suppression within the mining void catchment areas. This strategy eliminates the risk of tailings decant water being released to the receiving waterway. CNE will not result in changes to the existing operational activities associated with using tailings water for dust suppression.
4	The proponent has not provided information on the project's potential impacts to the ephemeral surface water systems of Twelve Mile Creek, Five Mile Lagoon and Three Mile Lagoon. The IESC notes that there is a potential release point located at Five Mile Lagoon and water released here may have high concentrations of aluminium, arsenic, cobalt, copper, lead and	There are no mine affected water release points proposed for the Central North Extension mining area. Catchment boundaries for CNE have been shown in Figure 5.2. The CNE

Advice No.	IESC Advice	Response & Reference
	zinc compared to 80th percentile (for highly disturbed aquatic ecosystems) ANZG (2018) guideline values. Further consideration of potential impacts should be provided, including those from sediment-bound contaminants deposited downstream or on the floodplain.	catchments flow to unnamed tributaries immediately downstream via sediment control devices. These unnamed tributaries flow to the Mackenzie River and do not interact with 12 Mile Creek. The waste characterisation assessment (EGI, 2013) indicates that overburden/interburden materials represented by the samples tested are NAF (Non-Acid Forming) and unlikely to release significant concentrations of salt or metals/metalloids. Any mine affected water generated as a result of the CNE operations will be contained within and managed by the existing Jellinbah mine water management system. Sediment and erosion control structures are proposed to capture runoff from disturbed areas not classified as mine affected water. Ongoing surface water monitoring and adaptive management strategies will identify whether surface water runoff characteristics change and/or do not align with current assessments. Modifications to the surface water management controls will be made accordingly to ensure water quality guideline values are achieved.

2. RECEIVING ENVIRONMENT

2.1 Receiving Waterways

2.1.1 Blackwater Creek

Blackwater Creek is located to the west of the mine lease area and flows in a north-westerly direction before discharging into the Mackenzie River 10 km north-west of Jellinbah Central (upstream of the Bingegang Weir). Non-mine affected water from Jellinbah Central area will report to Blackwater Creek via unnamed tributaries.

Blackwater Creek is an ephemeral waterway and stock may have access to this waterway downstream of the mining lease.

2.1.2 Mackenzie River

The Mackenzie River is the receiving waterway for Blackwater Creek and Twelve Mile Creek and as such any surface water runoff from the Jellinbah Coal Mine site will ultimately flow into the Mackenzie River.

The Mackenzie River has a significant number of water extraction points located both upstream and downstream of the confluences with the Blackwater Creek and Twelve Mile Creek. Water extracted from the Mackenzie River is primarily used for agricultural purposes, however, also includes riparian, stock and domestic entitlements.

The Nogoa-Mackenzie Water Supply Scheme releases water from Fairbairn Dam into the Mackenzie River via the Nogoa River for agricultural, urban and industrial use. There are major industrial and urban water supply off-takes downstream of the confluence of Blackwater Creek and Mackenzie River.

The Bingegang Weir is located 60 km downstream of the confluence with Blackwater Creek and 30 km downstream from the Plains mining precinct. The Bingegang Weir supplies water to the towns of Middlemount and Dysart along with a number of mines in the region.

2.1.3 Twelve Mile Creek

Twelve Mile Creek is located to the east of the mine lease area and flows in a northerly direction before discharging into the Mackenzie River downstream of the Bingegang Weir. Surface water runoff from the Jellinbah South area reports to an unnamed tributary of Twelve Mile Creek.

Twelve Mile Creek is an ephemeral waterway and stock may have access to this waterway downstream of the mine lease. Twelve Mile Creek flows through the centre of the neighbouring Yarrabee Coal Mine approximately 20 km downstream of Jellinbah South.

2.2 Climate

Jellinbah Mine has a sub-tropical climate, dominated by a wet humid summer and dry winter. Long-term climate for Jellinbah Mine was obtained from the SILO climate database facility hosted by the Department of Science, Information Technology, and Innovation (DSITI). A SILO Patched Point Data climate series was obtained for the New Caledonia Station (35132), which is located about 5 km from Jellinbah Mine. This site is considered to be representative of Jellinbah Mine site rainfall and the data set ranges back to January 1889. Table 2.1 presents a summary of this data.

Average annual rainfall is 572 mm. Average evaporation from ponded water bodies at Jellinbah Mine is 171 mm/month, varying from 96 mm/month in June to 236 mm/month in December.

The long-term climate data used in this assessment include several historical extreme events such as 2011 flooding event.

Table 2.1 Average Climate Data Statistics for New Caledonia Station (BoM, 2019)

Month	Mean Rainfall (mm)	Mean Minimum Temperature (°C)	Mean Maximum Temperature (°C)	Mean Pan Evaporation (mm)
Jan	95.3	33.7	21.6	229
Feb	82.7	32.9	21.4	186
Mar	59.3	31.9	20.1	194
Apr	29.5	29.4	16.5	153
May	29.8	26.1	12.3	118
June	30.0	23.3	9.4	96
July	24.7	23.0	7.8	104
Aug	17.6	25.0	9.4	131
Sept	21.8	28.2	12.8	171
Oct	39.9	30.8	16.5	209
Nov	54.6	32.4	18.9	222
Dec	86.7	33.7	20.7	236
Annual	**571.9**	**-**	**-**	**2049**

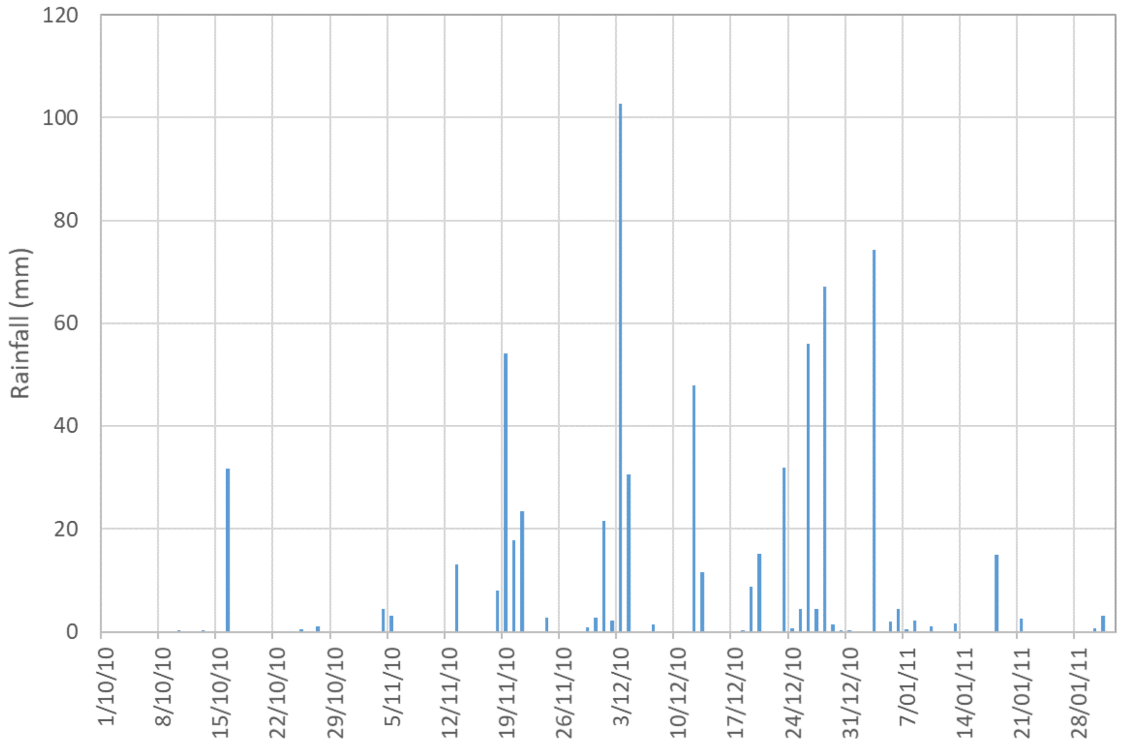


Figure 2.1 Recorded Rainfall Depths for the 2011 Flood Event

2.3 Geology

Jellinbah Mine falls on the eastern flank of the Comet Ridge of the Bowen Basin, at the north-western end of the Jellinbah Zone. The coal seams at Jellinbah Mine dip to the east. The coal is at least 10 m deep at its shallowest location and increases as the seam dips by between 2 degrees and 20 degrees.

The initial overburden layers are made up of clays and sands before reaching siltstones and mudstones that are above the coal layers. Removal of most material is by blasting then loading and hauling with truck and excavator equipment. The overburden material has been classified as non-acid forming.

2.4 Groundwater

The Quaternary alluvium and Permian coal measures are the main regional groundwater bearing units across the Jellinbah Mine.

Groundwater interactions vary across the site with minimal groundwater being encountered at the Central and Central North mining areas and recent inflows from the Quaternary alluvium into Plains Pit have been estimated as high as 4.6 ML/day.

Groundwater inflows to the proposed Mackenzie North Pit are estimated to range from 0.2 ML/day to a peak of 1 ML/day (AGE 2013).

There is no quaternary alluvium in the Central North operations area and the tertiary sediments have been assessed to be dry (JBT 2006). As such, the only inflows are from the Permian coal measures and will occur mainly via the Pollux seam. Groundwater inflows into the Central North mining void are estimated by JBT consulting as 0.3 ML/day and is considered to be a conservative estimate as it does not account for evaporation. With evaporation applied JBT reports the net inflow would be closer to zero.

No information is available regarding groundwater interactions at Jellinbah South.

3. EXISTING OPERATIONS

3.1 Overview

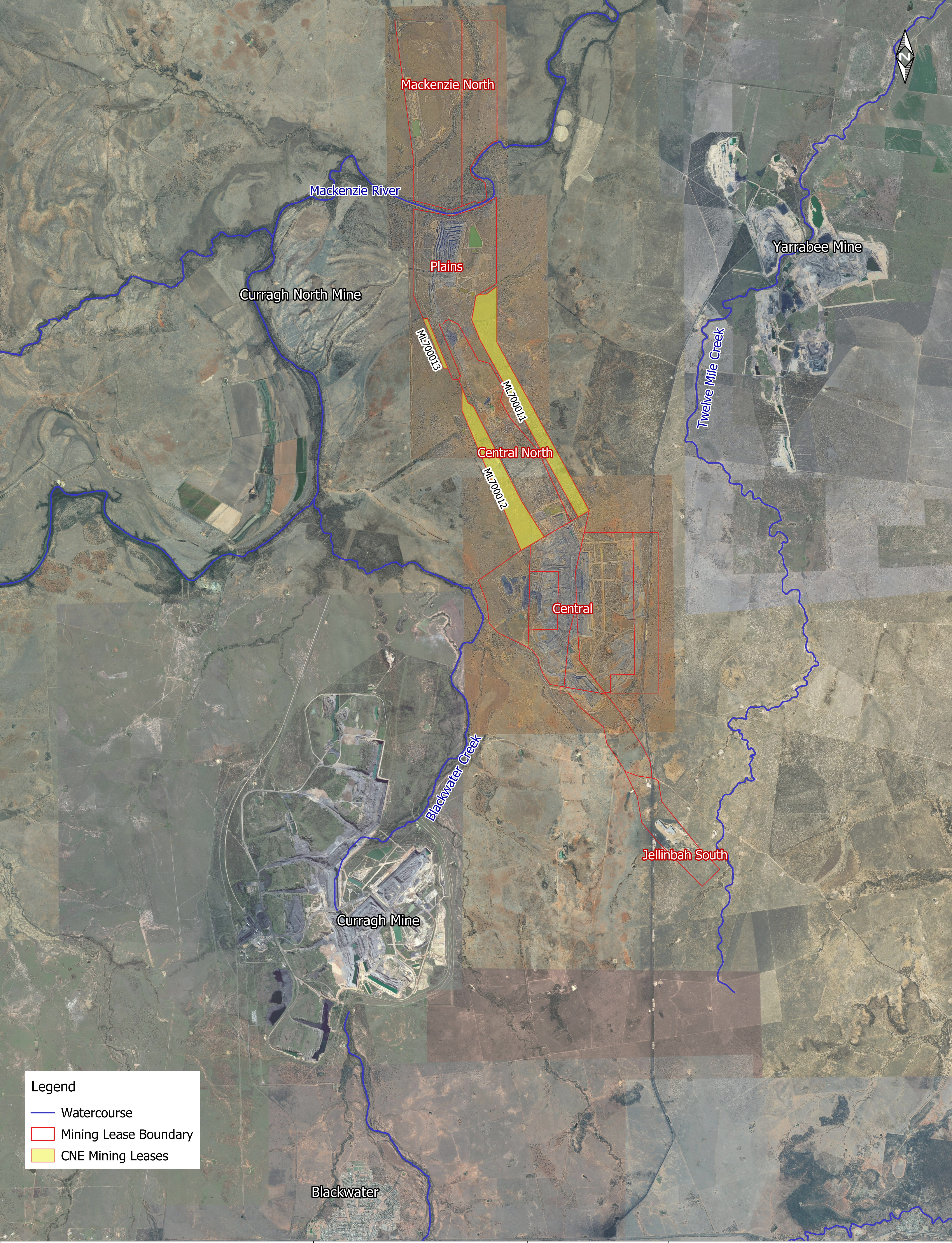
Jellinbah Coal Mine is located approximately 25 km north of the township of Blackwater in central Queensland (Refer Figure 3.1). The Jellinbah Coal Mine consists of five (5) distinct operating areas, referred to as the Jellinbah South, Central, Central North, Plains and Mackenzie North sites. Current operations involve open cut coal mining in the Central and Plains areas with Mackenzie North early works having started in 2019. Jellinbah South was mined up until 2003 and has since been used for the storage of excess mine affected water. The Central North mining void has been used for the storage of mine affected water in recent years, however, has recently been dewatered to facilitate the recommencement of mining.

Current coal production is approximately 5.0 Mtpa. Coal is hauled from mining areas along a dedicated haul road to the Boonal Loadout Facility on the Capricorn Highway, east of Blackwater.

The main operations occur in the Central mining precinct which includes workshops, offices and the coal wash plant. Runoff containment dams and a tailings dam are located at Central.

Progressive backfilling of the Plains mining void has occurred in recent years with coal production planned to cease in 2020. The Plains area has a ROM area, including a crusher, from which coal transported directly to the Boonal Loadout Facility.

Mining operations in Mackenzie North will include an open cut pit that will progress to the south towards Mackenzie River and include a crusher, from which coal will be transported either to Central CPP for washing or directly to Boonal Loadout Facility. The Mackenzie North Pit commenced pre-stripping in late 2019 and is expected to commence coal haulage in 2020. Mine affected water dams and sediment dams are located in the Mackenzie North precinct.



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Map Projection: Tranverse Mercator	DRAWN	AJ	Site Overview Plan
Horizontal Datum: Geocentric Datum of Australia Vertical Datum: Australia Height Datum Grid: Map Grid of Australia, Zone 56	JOB NO.	M61000_022	
			A3	Figure 3.1	0

3.2 Contaminant Sources

Surface water runoff from mine landforms and disturbed areas can potentially contain a variety of contaminants, including sediment, heavy metals, hydrocarbons and soluble salts. Potential contaminant sources identified across Jellinbah Mine include:

- Coal Handling and Processing Plant (CHPP).
- Tailings and rejects storage facilities.
- Overburden dumps.
- ROM and stockpile areas.
- Haul roads and access roads.
- Pit voids.
- Water containment and sediment dams.
- Pre-strip areas.

A summary of the potential contaminant sources, flow paths and destinations are summarised in Table 3.1.

The overarching surface water management strategy for Jellinbah Mine focuses on managing water in distinct categories including:

- Mine Affected Water – Water that contains contaminants which have been generated as a result of the extraction and processing of coal, such as soluble salts, dissolved metals and hydrocarbons. This includes water that has come into contact with coal, tailings and groundwater intercepted by mining voids.
- Sediment Water – Rainfall runoff in which the only contaminants are dissolved or suspended sediments.
- Clean Water - Rainfall runoff generated from areas not impacted by activities associated with the approved mining.

The waste characterisation assessment for the Mackenzie North Coal Project was undertake by EGI (2013). Results indicate that overburden/interburden materials represented by the samples tested are NAF (Non-Acid Forming) and unlikely to release significant salinity or metals/metalloids. The pH values were circum neutral to slightly alkaline, ranging from 7.1 to 9.8. The EC values ranged from 100 to 1080 µS/cm.

There is no evidence of acid mine drainage at Jellinbah Mine.

Table 3.1 Contaminant Source Summary

Source	Transport Mechanisms	Site Containment	Receiving Waterway	Potential Contaminants
CHPP	Surface runoff	Water containment dams	Blackwater Creek	Sediment, heavy metals, coal fines, soluble salts, processing reagents (i.e. flocculent / magnetite), fuels, oils and grease
Overburden Dumps	Surface runoff	Pit voids Sediment dams	Blackwater Creek, Mackenzie River	Low concentrations of elevated metals/metalloids, Slight alkalinity, Sediment (EGI, 2013)
ROM and Stockpile Areas	Surface runoff	Pit voids Water containment dams	Blackwater Creek, Mackenzie River	Sediment, coal fines, soluble salts and acid forming material
Haul roads and access roads	Surface runoff	Sediment dams	Blackwater Creek, Mackenzie River, Twelve Mile Creek	Sediment, soluble salts, fuels, oils, grease (total petroleum hydrocarbons) and coal (coarse or fines)
Pit Void	Pumping of pit runoff to water containment dams	Pit voids Water containment dams	Groundwater	Alkaline or sodic soils and heavy metals, coal fines and pH altering materials
Water Containment Dams	Seepage through floor of dams Pumping within mine water system Overflows during heavy rainfall Loss of containment (failure)	Pit voids, if containment dam capacity is limited	Blackwater Creek, Mackenzie River, Twelve Mile Creek	Elevated pH, sediment, dissolved metals, coal fines, soluble salts and hydrocarbons

3.3 Water Management

Table 3.2 summarises the types of water on site and the management strategy employed for each type.

Table 3.2 Overall Water Management Strategies

Type of Water	Definition	Management Strategy
Clean Runoff	Runoff from all areas that are not affected by coal or operational facilities.	Drains and dams are used to keep clean water separate and ultimately divert clean catchment runoff to receiving waterways.
Sediment Runoff	Runoff in which the only contaminants are dissolved or suspended sediments.	Runoff with a sediment load is directed through sediment dams to minimise solid content prior to exiting the site.
Mine Affected Water	Includes any water that encounters coal stockpiles, coal pads, plant areas, pit areas and coal seam groundwater. Typically, elevated salinity.	Objective is to keep this water separate from the other water types, recycle and evaporate as much as possible and discharge if required only in accordance with release condition.
Raw Water	The site has a license to supplement water supply by pumping from Mackenzie River. This water is untreated and mainly used for vehicle wash down and coal processing.	Minimise consumption where possible – constrained by 300 ML/yr extraction license.
Potable Water	Water for drinking and sanitation purposes.	Water is trucked to site as required.

3.3.1 Water Storage Infrastructure

The water management system at Jellinbah Mine comprises of storages which serve the following purposes:

- Pit dewatering.
- Containment of tailings.
- Storage of mine affected water.
- Collection of runoff from un-rehabilitated and rehabilitated overburden.
- Controlled release of mine affected water.
- Water truck filling points.
- Active and inactive mine pits.

The majority of mine affected water at the Jellinbah Mine is stored in Plains South mining void and dedicated mine water containment dams such as Plains Environmental Dam, Max

Pit Tailings Dam and Mackenzie North Mine Water Dam. Table 3.3 lists the water storages at Jellinbah Mine and associated details.

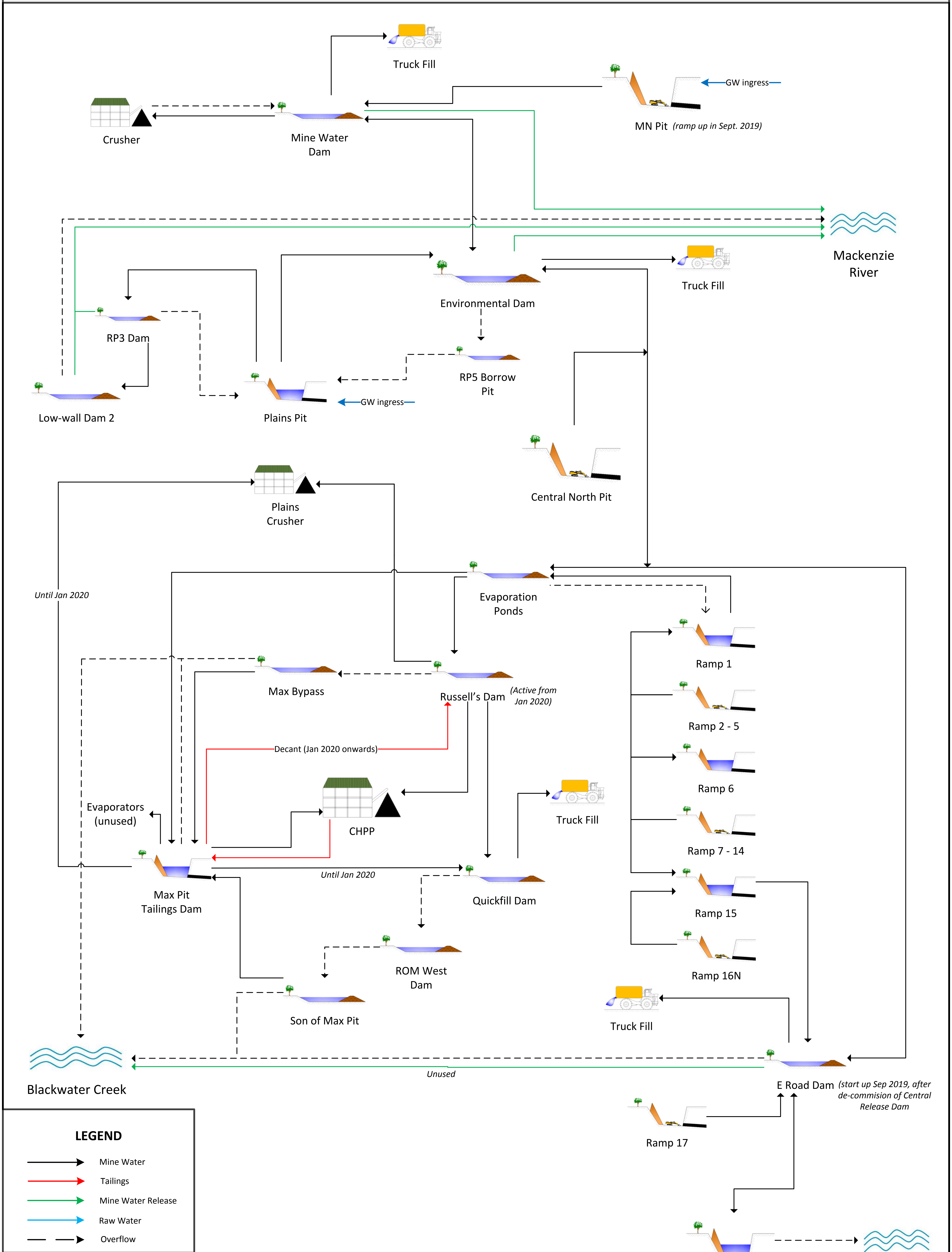
The water management system also includes an interconnecting pipe network with associated pumps which allow mine affected water to be transferred between water storage structures across the site.

Under the current mining operations coal tailings from the CPP are contained in the Max Pit Tailings Dam. The tailings decant will be recycled to Russell's Dam for site water consumption at CPP. It is proposed that Russell's Dam will replace the water supply to Central CPP and Plains crusher from Max Pit, whilst Max Pit will continue to be used for tailings storage.

A water management system schematic was developed for Jellinbah Mine and is presented as Figure 3.2.

Sediment and erosion control infrastructure is documented in the Jellinbah Mine Sediment and Erosion Control Plan (AARC, 2018).

Figure 3.2 - Jellinbah Mine Water Management System Schematic



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Revision:1
Drawn: AJ
Date: 11 Nov 2019

Table 3.3 Site Water Storages

Site	Storage/Pit	Capacity (ML)	18 Sept 2019 Inventory (ML)	Catchment Area (ha)	Water Management Details
PLAINS	Plains Pit	100 (in-pit sump capacity)	3	328.3	Receives runoff from spoil and groundwater ingress at the base of the pit and up the northern wall. Dewatered to Environmental Dam and RP3 Dam.
	Environmental Dam	1,602	978	27.6	Turkey's nest dam that receives pit water and provides water to truck fill for dust suppression. Authorised EA release point to Mackenzie River.
	Lowwall Dam 2	18	14	9.1	Receives alluvial water from RP3 as storage expansion to RP3. Storage overflows to Mackenzie River.
	RP5 Borrow Pit	55[2]	0[2]	86.1	Receives overflows from Environmental Dam.
	RP3 Dam	32[2]	0[2]	38.7	Receives alluvial water from Plains pit advanced dewatering trenches. Potential to release via authorised EA point through levee to Mackenzie North.
CENTRAL NORTH	Central North Pit	0	NA	72.9	Receives mine affected water runoff and minor groundwater ingress. CN can pump to dedicated mine water storages in Central and Plains.
CENTRAL	Central Pits	1,711[1]	98	698	All central pits are ultimately dewatered to E Road Dam or the Evaporation Ponds. Ramp 1, 6 and 15 are used for intermediate water storage.
	Ramp 17	100	0	94.3	Ramp 17 is pumped to E Road Dam.
	Evaporation Ponds	116	28	24.3	Pit water stored in ponds with large surface area to maximise evaporative loss. Sends water to Max Pit Tailings Dam or north to Environmental Dam. Can also dewater to E Road Dam if needed.

Site	Storage/Pit	Capacity (ML)	18 Sept 2019 Inventory (ML)	Catchment Area (ha)	Water Management Details
	E Road Dam	112	50	4.1	Replacement of Central Release Dam in September 2019. Receives pumping from Jellinbah South Void, Evaporation Ponds and Ramp 17. Supplies truck fill demand for dust suppression on site.
	Russell's Dam	200[3]	0[3]	4.2	Replacement for Marks Dam and currently under construction. In future will supply demands to Central CPP and Plains crusher with Max pit solely receiving Tailings and pumping decant water to Russell's Dam.
	Max Bypass	88	0	76.1	Receives overflows from Russell's Dam and local runoff. Transfers mine affected water to Max Pit Tailings Dam via valve operated pipes.
	Max Pit Tailings Dam	889	236	30.8	Tailings from wash plant, pit water from Evaporation Ponds and runoff from Son of Max Pit Dam. Receives water from Max's bypass. Main source of recycled water until Russell's Dam is operational.
	Quickfill Dam	10	10	2.3	Mine affected waste from workshop and nearby ROM areas. Main fill point for water trucks. Filled by pumping from tailings dam/Russell's Dam.
	ROM West Dam	53[2]	0[2]	93.0	Mine affected runoff from coal ROM areas.
	Son of Max Dam	129	94	40.5	Collects overflows from ROM West Dam, wash plant drains, pump station and some rehabilitated spoil. Pumped to Max Pit. Overflows to a sediment dam and Blackwater Creek.

Site	Storage/Pit	Capacity (ML)	18 Sept 2019 Inventory (ML)	Catchment Area (ha)	Water Management Details
JELLINBAH SOUTH	Jellinbah South Void	3,510	2,304	37.7	Old mining void used to store excess water from Central. Linked via pipeline to E Road Dam.
MACKENZIE NORTH	Mine Water Dam	683	322	16.9	Turkey's Nest Dam receiving water from Environmental Dam and Mackenzie North Pit. Overflows to smaller dam located in the north of Mackenzie North Crusher and is main fill point for water trucks.
Total		**9,408**	**4,137**	**1,684**	-

[1] *Storage capacity of Ramp 1, 2, 6, 9 and 15 combined as per Monthly Dam Volumes sheet.*

[2] *Estimated using LiDAR.*

[3] *Based on site information.*

3.3.2 Mine Water Release Infrastructure

Jellinbah Mine has nominated mine water release points (RPs) specified within the site Environmental Authority (EPML00516813) from which mine water can be discharged to either Blackwater Creek or Mackenzie River. The EA specifies monitoring points (MPs) where water quality must be monitored, and mine water can only be released during natural flow events in accordance with receiving waterway flow triggers. Receiving waterway flows are measured at the gauging stations at MP1 and MP3.

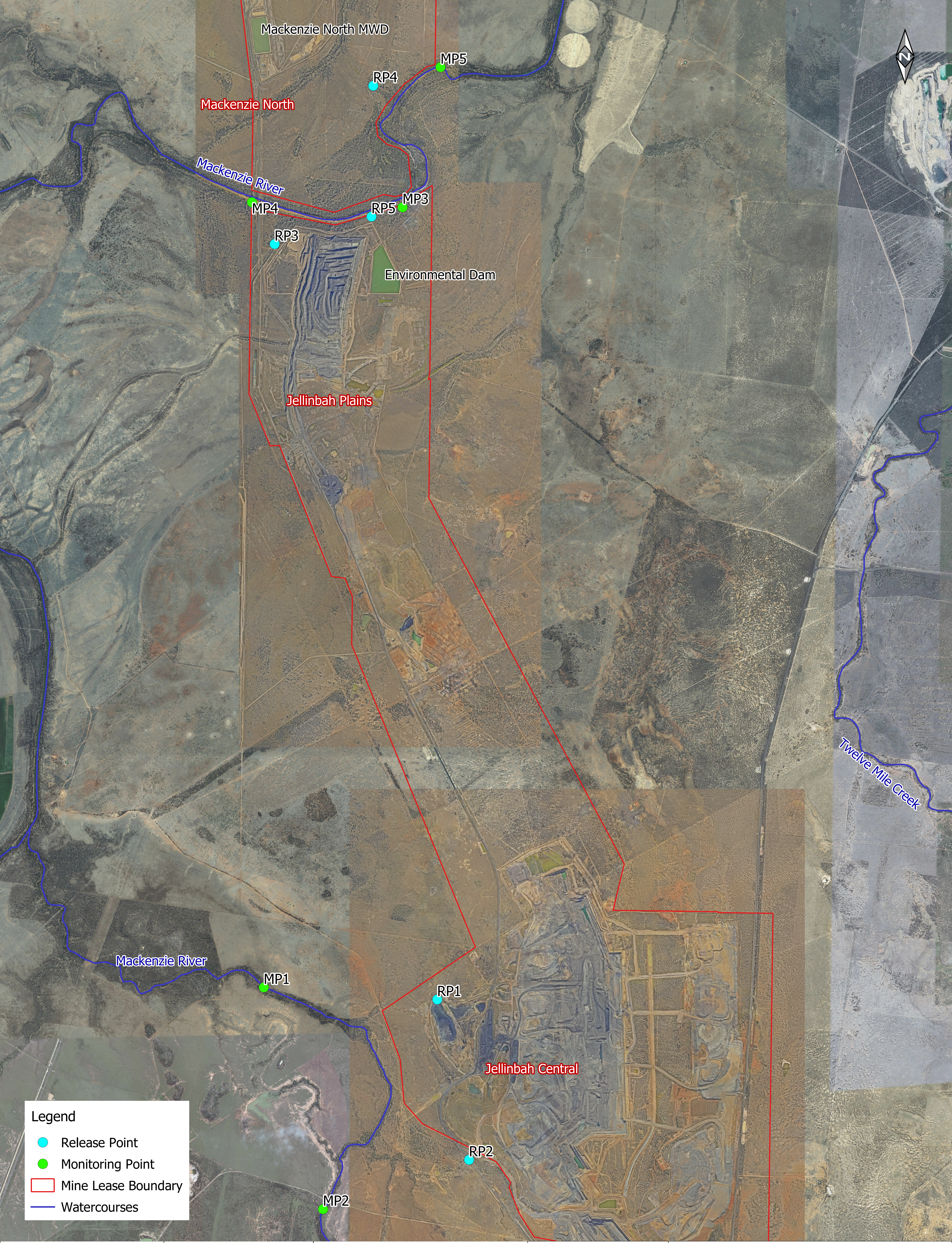
Jellinbah Mine is authorised to release mine affected water as per Table C9 of the environmental authority. Fixed active water release infrastructure has been constructed at Jellinbah Mine and is summarised in Table 3.4.

Table 3.4 Controlled Mine Water Release Infrastructure

Storage	Release Point	Receiving Waterway	Storage Capacity (ML)	Release Infrastructure	Release Capacity (L/s)
Environmental Dam	RP5	Mackenzie River	1,602	3 x DN450 HDPE pipes with manual valves at upstream IL of 124.22 mAHD	1,800[1]
Mackenzie North MWD	RP4	Mackenzie River	683	Release Valve in Pipeline to Environmental Dam	200

Note 1: The outlet structure elevation restricts the release of stored water below 725 ML. Mine water release rates vary dependant on the stored water level. The rate of 1,800 L/s is reached at the spillway level of 127.6 m AHD.

The controlled release during flow events is strictly controlled by continuous real time water monitoring in-stream. If required releases are controlled to ensure downstream water quality is maintained within site specific objectives defined in the EA.



Jellinbah

ENGENY WATER MANAGEMENT

0 1100 2200

Scale in metres (1:53000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

DATE	25/09/2019
DRAWN	JS
JOB NO.	M61000_021

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Jellinbah Mine CNE Surface Water Management

EA Release and Monitoring Points

A3	Figure 3.3	A

4. SITE WATER BALANCE

The site water balance model allows the performance of the water management system to be simulated for a range of potential future climate scenarios.

The details of site water balance model are outlined in the following sections, while the performance of the Jellinbah Mine water management system is discussed in Section 5.

4.1 Water Balance Model Development

A water balance model for Jellinbah Mine was developed using the GoldSim software. GoldSim is an industry standard computer program for carrying out dynamic, probabilistic simulations of systems and processes (e.g. hydrological assessments of mine site water balances).

The water balance model operates on a daily time step and simulates the quantity and quality of water within water storages and operational pits, as well as waterways that have the potential to receive discharges of mine-impacted surface water during large rainfall events.

Key aspects of the model include:

- The model can be used to simulate 118 years of historical data (i.e. SILO climate data and IQQM stream flow data).
- The water balance model includes a coupled salt balance to estimate TDS within each storage and receiving waterway.
- TDS is converted to EC within the model based on an assumed conversion factor of 1 mg/L TDS = 1.49 µS/cm EC in accordance with the *Australian Drinking Water Guidelines* (NHMRC, 2013).
- The various mine water inflows and outflows.
- The model simulates the existing mine water infrastructure including storages, pumps and pipelines and water releases.
- Water storage characteristics are simulated using the latest storage curves representing volume-area and volume-level relationships.
- The mine water release is estimated based upon the simulated flow of receiving waterways at the nominated gauging stations in accordance with current EA conditions. Limits and capacity of the water release infrastructure are incorporated into this release logic.

4.2 Water Inflows

4.2.1 Rainfall

Long-term climate for Jellinbah Mine was obtained from the SILO climate database facility hosted by the Department of Science, Information Technology, and Innovation (DSITI). A SILO Patched Point Data climate series was obtained for the New Caledonia Station (35132), which is located about 5 km from Jellinbah Mine. This site is considered to be representative of Jellinbah Mine site rainfall and the data set ranges back to January 1889.The variation in annual rainfall totals is presented in Figure 4.1 and indicates a median site rainfall of 560 mm.

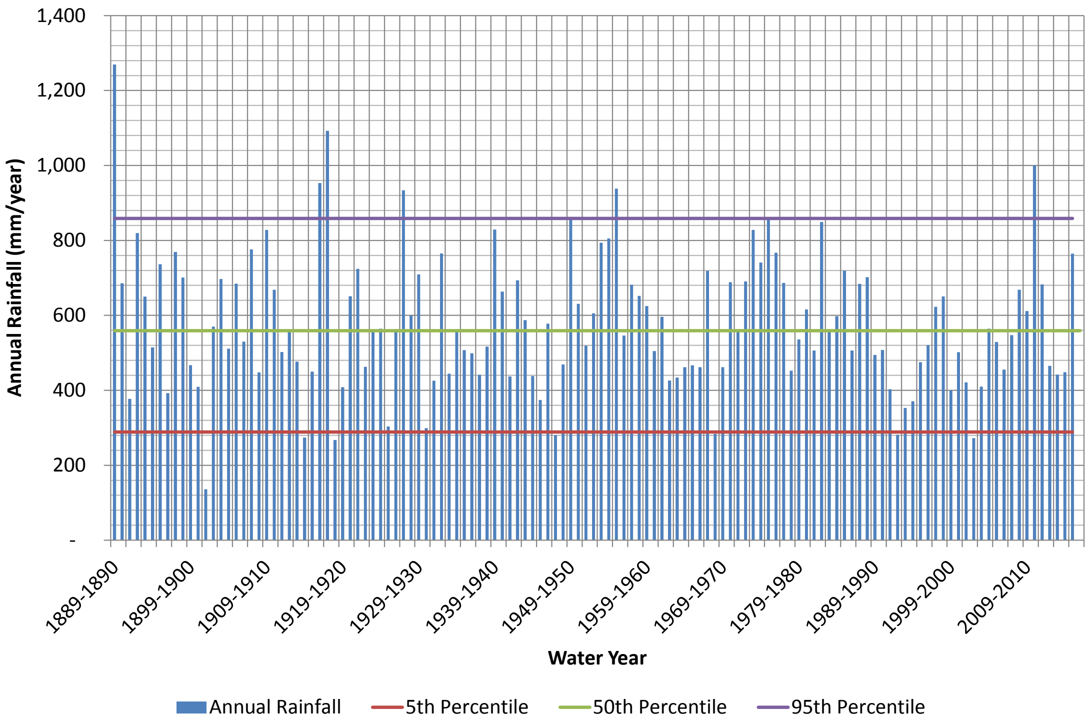


Figure 4.1 Annual Rainfall Totals

4.2.2 Catchment Runoff

Catchment runoff has been simulated using the Australian Water Balance Model (AWBM). A schematic representation of the AWBM model is provided in Figure 4.2. The model represents the catchment using three surface stores to simulate partial areas of runoff. The water balance of each surface store is calculated independently of the others. The model calculates the water balance of each partial area at daily time steps. At each time step, rainfall is added to each of the three surface stores and evapotranspiration is subtracted from each store. If the value of water in the store exceeds the capacity of the store, the excess water becomes runoff. Part of this runoff becomes recharge of the baseflow store if there is a baseflow component to the stream flow.

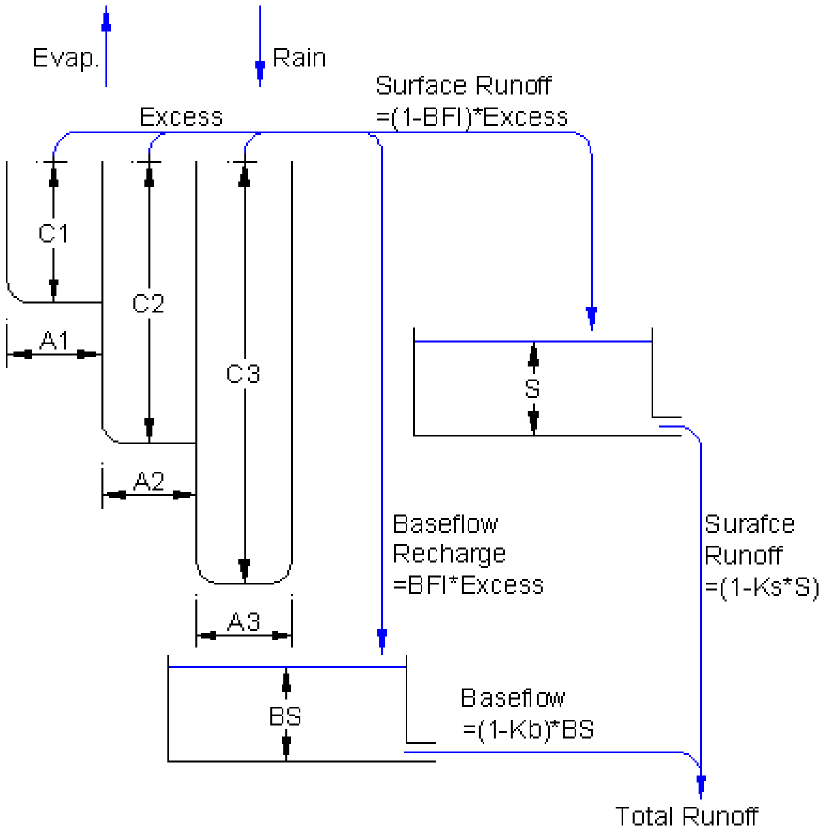


Figure 4.2 AWBM Schematic

AWBM natural land use catchment runoff parameters have been adopted from parameters calibrated to the Blackwater Streamflow Gauging Station owned by DNRM at Curragh (Station Number 130108). The gauging station commenced in August 1972 and closed in May 2009.

Daily rainfall data for the Blackwater Creek AWBM calibration was determined as a catchment average of rainfall data (SILO Patched Point Data) from the BoM rainfall stations at Blackwater Water Treatment Plant (035290), Blackwater Post Office (035009), Ardurad (035003) and Tannyfoil (035111). Morton potential evapotranspiration data was extracted from the Blackwater Post Office (035009) SILO Patched Point Data.

The calibration of the AWBM model involved the prediction of stream flows in Blackwater Creek for the period of adopted stream flow gauging data. The predicted stream flows were compared against the stream gauging data and the AWBM model parameters were adjusted to provide a reasonable comparison between the gauged and modelled stream flow characteristics. The final calibrated AWBM model parameters are summarised in Table 4.1.

Table 4.1 Calibrated AWBM Model Parameters for Blackwater Creek Catchment

Parameters	Inputs		
Partial Area Fractions	A1 = 0.134	A2 = 0.433	A3 = 0.433
Surface Store Capacities	C1 = 25 mm	C2 = 95 mm	C3 = 230 mm
Baseflow Parameters	BFI = 0.03	Kb = 0.98	Ks = 0.50

The gauged and modelled flow duration curves for Blackwater Creek at Curragh are shown in Figure 4.3. The figure shows that Blackwater Creek has a significant baseflow component with flows exceeding 0.1 ML/d approximately 75% of the time. The calibrated parameters produce a curve that matches the gauged curve well for flows above 0.1 ML/d. The discrepancy at the tail end of the curve was unable to be corrected and is considered insignificant due to the very small volume of flow that this represents (modelled flows below 0.1 ML/day represent approximately 0.02% of the total volume over the twenty-year period of simulation).

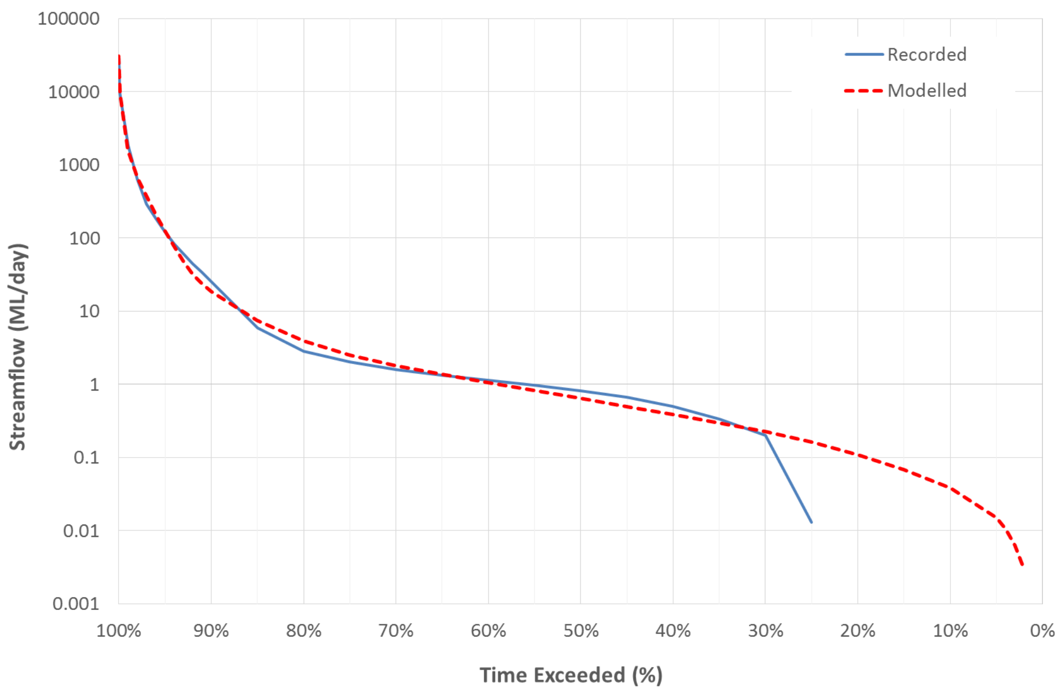


Figure 4.3 Modelled Flow Duration Curve for Blackwater Creek at Curragh

The modelled cumulative stream flow volume during the period 1st June 1972 to 30th September 2008 is displayed in Figure 4.4. The modelled and gauged stream flows appear to show similar runoff volumes for single events as well as total stream flow volume during over the calibration period.

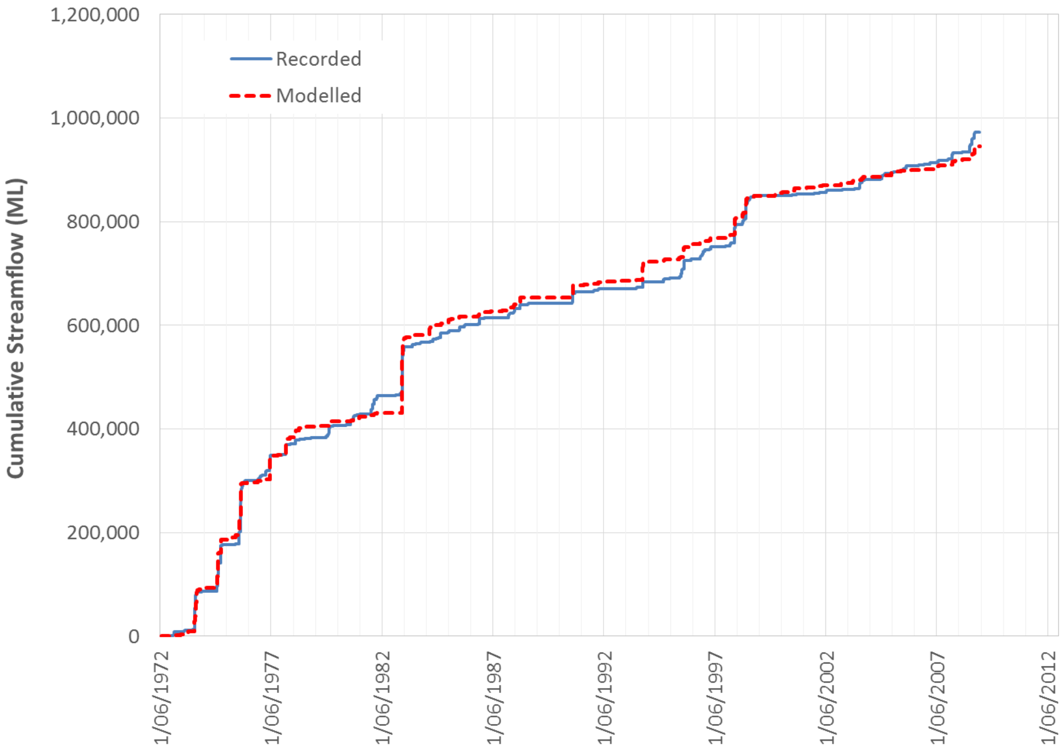


Figure 4.4 Modelled Cumulative Stream Flows for Blackwater Creek at Curragh

The AWBM calibration parameters for the Blackwater Creek catchment are considered to produce similar stream flow characteristics to the gauged stream flow data. These parameters were adopted for the simulation of flows in Blackwater Creek, and runoff from natural land use areas on site.

All other AWBM land use catchment runoff parameters were adopted from parameters developed for nearby mine sites. The adopted AWBM parameters are shown in Table 4.2 along with the resulting average annual runoff coefficient. Table 4.3 presents a summary of the amount of each land use throughout the site catchments. The site has an overall average annual runoff coefficient of 14.3%.

Table 4.2 Adopted AWBM Runoff Parameters

Parameter	Natural	Spoil	Hardstand & Pits	Rehabilitated Spoil	Coal Stockpile
C1 (mm)	25.0	20.0	10.0	11.0	1.0
C2 (mm)	95.0	80.0	25.0	60.0	5.5
C3 (mm)	230.0	160.0	50.0	130.0	0.0
A1	0.134	0.134	0.134	0.134	0.134
A2	0.433	0.433	0.433	0.433	0.433
A3	0.433	0.433	0.433	0.433	0.433
BFI	0.03	0.70	0.10	0.00	0.35
Kb	0.98	0.80	0.60	0.60	0.60
Ks	0.50	0.10	0.10	0.00	0.10
Average Soil Store (mm)	144	107	34	84	5
Average Annual Runoff Coefficient	5.0%	6.5%	19.5%	9.5%	46.4%

Table 4.3 Site Land Type Breakdown

	Natural	Spoil	Hardstand & Pits	Rehabilitated Spoil	Coal Stockpile
Total Area (ha)	302.3	392	992.7	191.3	26.7
Proportion (%)	15.8%	20.6%	52.1%	10%	1.5%

4.2.3 Groundwater Inflows

Groundwater inflows into mining voids have been adopted based on groundwater modelling predictions, anecdotal observations and/or detailed groundwater inflow assessments:

- Mackenzie North – Ranging from 0.2 ML/day to 1 ML/day.
- Plain Pit – 4.6 ML/day

- Central and Central North – 0.3 ML/day
- Jellinbah South – 0 ML/day

4.2.4 Raw Water Supply

Jellinbah Mine has an annual permit for water extraction from the Mackenzie River. This water is used at both the Central and the Plains workshops, primarily for machine and vehicle wash down. The total water extraction of 180 ML over the last four quarters FY18/19 was primarily allocated to vehicle washdown and no additional raw water was taken into the mine water system (discontinued Mackenzie River offtake to Max Pit Tailings Dam).

4.3 Water Demands and Losses

4.3.1 Evaporation

Lake evaporation rates for Jellinbah Mine have been extracted from the SILO Patched Point Data described above and are summarised in Figure 4.5. Mean annual evaporation from ponded water bodies at Jellinbah Mine is 2,043 mm/yr while daily rates vary from 2.6 mm/day in June to 6.8 mm/day in December.

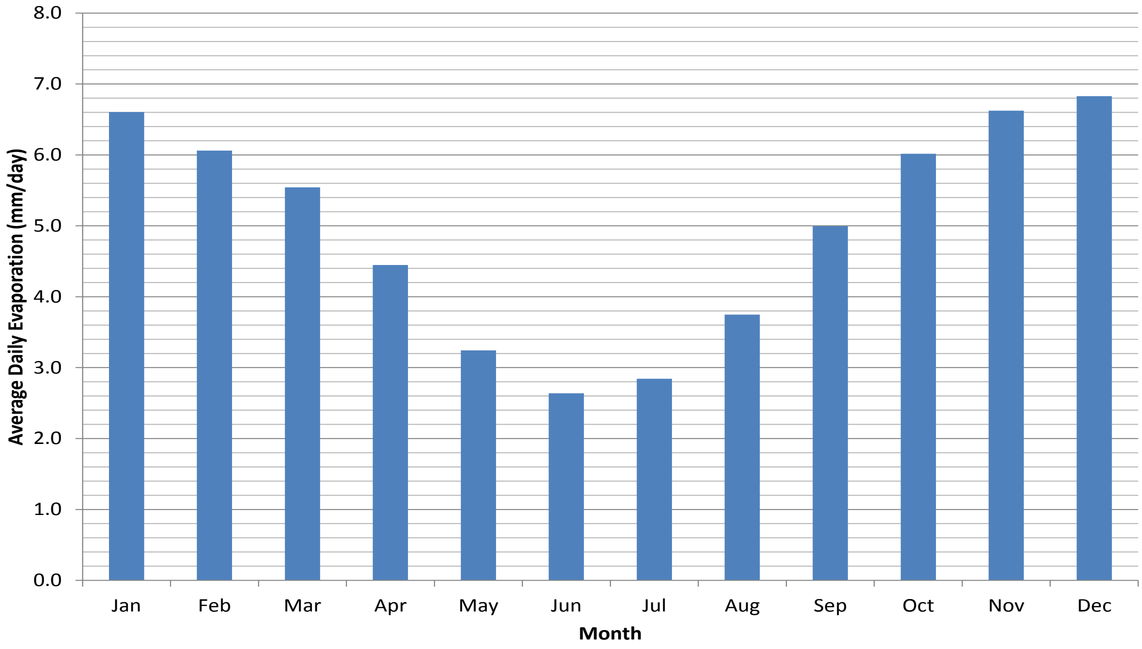


Figure 4.5 Annual Daily Evaporation

4.3.2 Operational Water Consumption

Water consumption rates for mine operation (i.e. dust suppression, plant use, etc.) are summarised in Table 4.4. As indicated by the table, operational water consumption currently accounts for a net outflow from the system of approximately 2 GL/year.

All values are based on site pumping records and estimates. Evaporators are still functional however currently not in use due to ongoing dry weather conditions.

Water is consumed primarily through dust suppression, at a total rate of 248 L/t of coal production. Dust suppression rates reported at other mine sites in the Bowen Basin range from 75L/t to 275L/t, with an average of 150 L/t.

Table 4.4 Jellinbah Mine Water Consumption Summary (FY19/20)

Consumption	Water Source	Net Consumption (ML/yr)
CHPP	Max Pit Tailings Dam	552
Plains Crusher	Max Pit Tailings Dam	95
Dust Suppression	Quickfill Dam E Road Dam Environmental Dam Mackenzie North MWD	1,240
Washdown & other losses	Mackenzie River	180

4.3.3 Controlled Release

The release conditions outlined in the Environmental Authority and the site water release infrastructure are detailed in Section 3.3.2. The water balance model incorporates enhanced release conditions as per EA (2019) Table C9 from Environmental Dam.

5. CENTRAL NORTH EXTENSION

5.1 Overview

The Jellinbah Central North Extension proposes the addition of three mining leases (MLs) to the existing Jellinbah Coal Mine. The purpose of the Central North Extension is to extend approved mining activities further to the east and expand the area available for spoil dumping and topsoil placement. No changes to the currently approved mining methods or production rates are proposed.

Jellinbah Central mining area will be progressed north into the authorised Central North (CN) mining area over the next few years and ultimately under this proposal known as the CNE, will extend the CN mining area downdip to the east by approximately 450 metres (m) relative to the CN mining area limit.

The purpose of the Project is to extend mining activities for current resource areas and expand the area available for dumping of spoil into three new MLs: ML 700011, ML 700012, and ML 700013.

5.2 CNE Water Management

The CNE is located immediately to the north of the Central site and incorporates a lateral extension to the CN mining area. Due to the proximity of the CN and CNE mining areas to the Jellinbah Central site facilities, CNE will utilise much of the same infrastructure.

Water from the pit is the only source of mine affected water (MAW) associated with the CNE that has been in contact with coal / groundwater. Pit water will be pumped to the existing mine water storages located at Central and Plains mining areas.

No new mine affected water storages are proposed as part of the CNE development. The mine affected water generated from CNE is contained within the mining void (from which it originates) prior to being pumped to dedicated mine affected water storages located at Plains and Central mining precincts. As such, there is no possible mechanism by which mine affected water can be released from the CNE mining leases to the receiving surface waters.

Sediment and erosion control infrastructure is proposed to manage runoff from the out-of-pit overburden emplacement on the western side of the CNE and the in-pit overburden emplacement. Surface water runoff from the out-of-pit emplacement will drain towards the western CNE mine lease boundary while the runoff from the in-pit emplacement will drain towards the eastern CNE mine lease boundary. Sediment dams and sediment traps are proposed to collect and treat sediment runoff prior to discharging into receiving waterways. (Refer Figure 5.1). The proposed sediment dams and traps will be constructed as part of the CNE project and designed in accordance with the Jellinbah Mine ESCP (AARC, 2018). It is proposed that that two sediment dams and approximately four to six sediment traps on the drainage paths to capture silt from the runoff of overburden stockpiles or other areas of the site. No coal contamination will be present in these areas. Additional sediment traps in the west of the CNE will be established as required. These drainage systems, sediment traps and dams will be developed as the site expands to its full size.

A clean water diversion drain will be constructed along the eastern alignment of CNE to convey runoff generated from small undisturbed catchment away from the CNE mining void and towards an unnamed tributary of the Mackenzie River located immediately downstream.

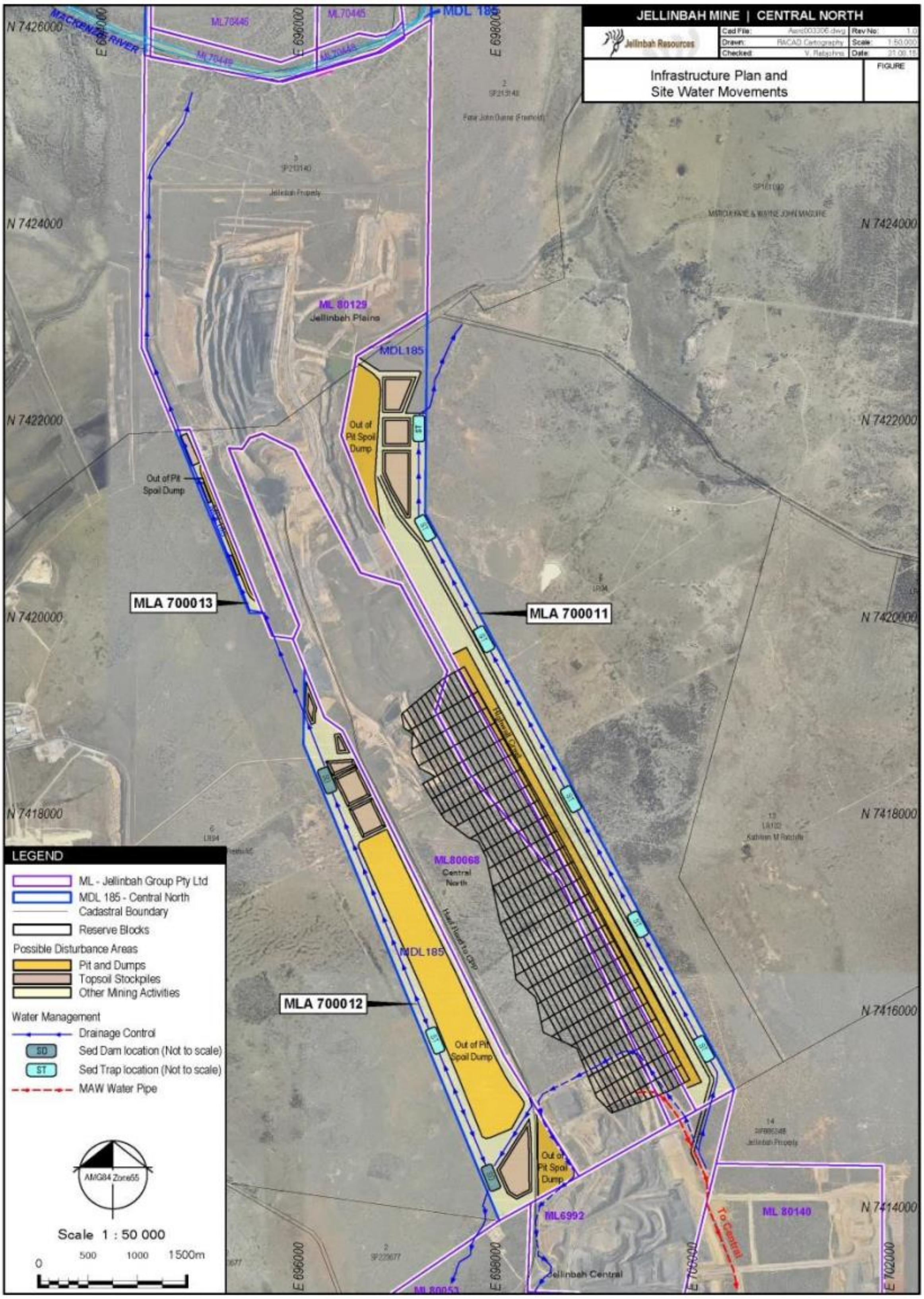


Figure 5.1 Central North Extension Surface Water Management (Source: AARC 2018)

5.3 CNE Catchment Analysis

The catchments associated with CNE are located within unnamed tributaries which flow to the Mackenzie River and Blackwater Creek.

The total catchment area will increase by 797.8 ha as result of the additional 3 mining leases associated with CNE. The total area includes catchments generating mine affected runoff, runoff requiring treatment through sediment and erosion control devices and runoff from undisturbed areas (clean water).

5.3.1 Mine Affected Water Catchments

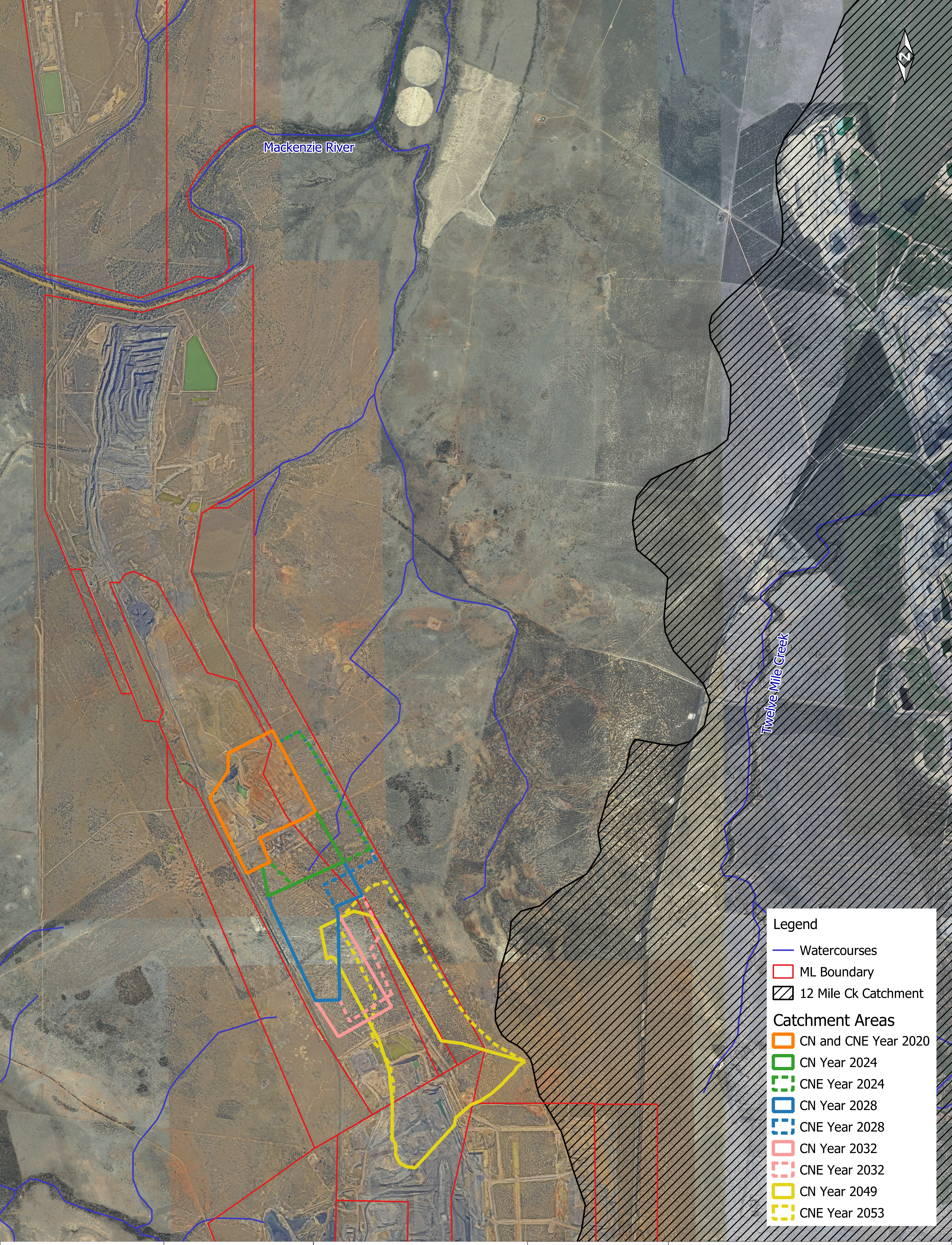
Mine affected water catchment areas associated with the CNE mine plan have been analysed and are shown in Figure 5.2 and Figure 5.3.

The CNE results in an increase to the CN operational mining void of up to 30% (Table 5.1), however these catchments will be reinstated to the receiving waterways through progressive backfilling and rehabilitation of the CNE mining void.

The increase in mine affected water catchment areas associated with CNE has been assessed as part of the mine water balance modelling (Refer Section 5.4)

Table 5.1 Mine Affected Water Catchment Analysis

Date	CN (ha)	CNE (ha)	Increase in mining void catchment area (ha)
2020	151.8	151.8	0.0
2024	229.0	290.7	61.7 (+27%)
2028	357.7	422.1	64.4 (+18%)
2032	428.1	520.4	92.3 (+21%)
2049	337.4	440.0	102.6 (+30%)
2053	337.4	421.1	83.7 (+25%)



Jellinbah

ENGENY WATER MANAGEMENT

Map Projection: Tranverse Mercator
Horizontal Datum: GDA 1994
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

DATE	11/11/2019
DRAWN	AJ
JOB NO.	M61000_022

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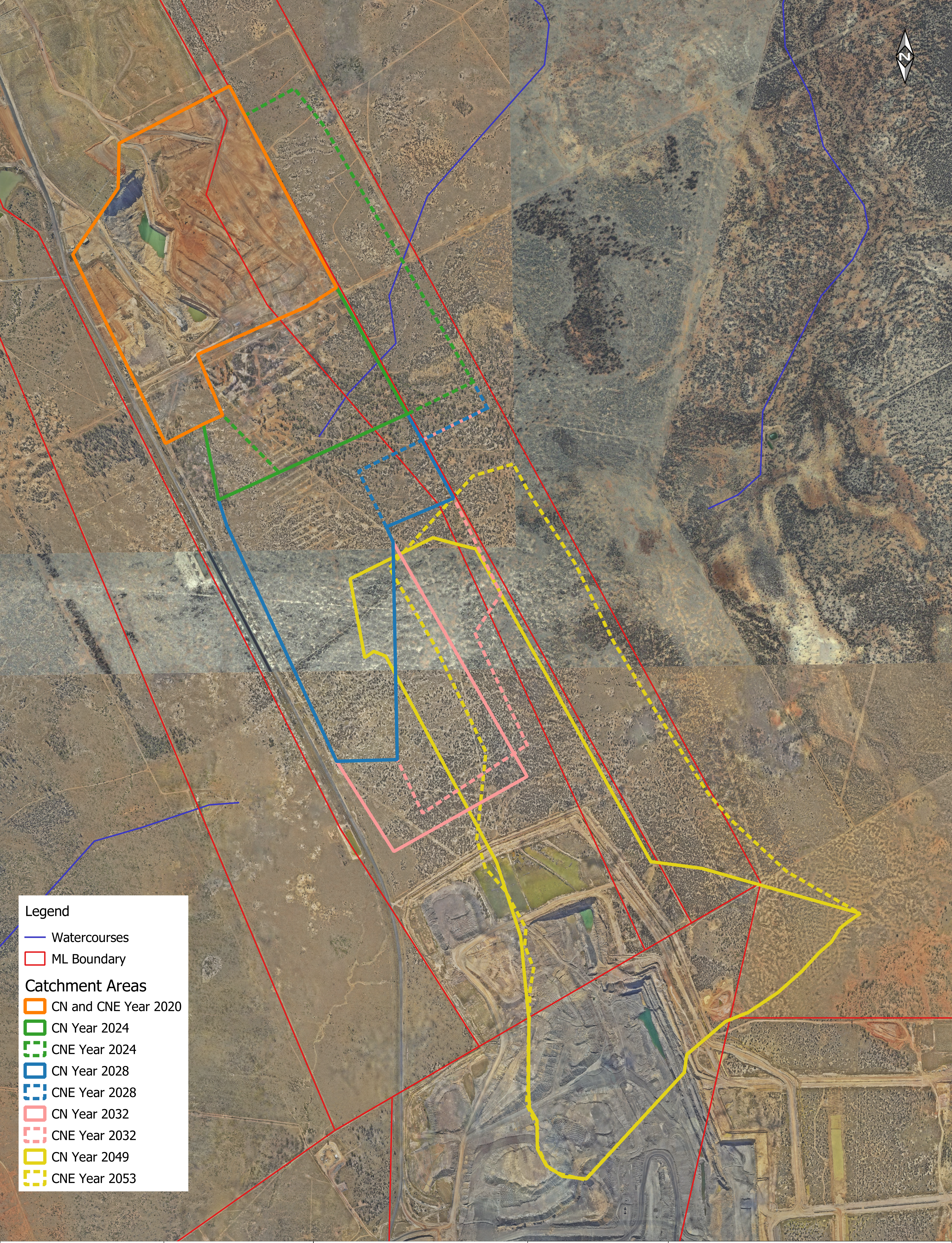
Jellinbah Mine CNE Surface Water Assessment

Catchment Areas

A3	Figure 5.2	0



Jellinbah

ENGENY WATER MANAGEMENT

0 450 900

Scale in metres (1:20000 @ A3)

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Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

DATE	31/09/2019	
DRAWN	AJ	
JOB NO.	M61000_022	

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Jellinbah Mine CNE Surface Water Assessment

CN and CNE Catchment Areas

A3 | Figure 5.3 | B

5.4 CNE Water Balance Assessment

The Jellinbah Mine site water balance model (Refer Section 4) has been used to assess and compare the performance of the water management system for the following scenarios:

- Current mine plan (i.e. without CNE)
- Proposed mine plan (i.e. with CNE)

The site water balance model was updated to represent the CNE by amending the mining void catchment areas and land use, mining production schedule and associated water consumption.

Water balance modelling results indicate a minor increase to net accumulation at a number of mine planning horizons under the proposed CNE scenario, however there is no increase in uncontrolled releases and controlled releases are reduced under the proposed CNE scenario for the median climate scenario. Tables 5.2 and 5.3 provide a detailed breakdown of the inflows and outflows for the overall site water balance for the CN and CNE scenarios.

Table 5.2 Jellinbah Mine CN Overall Water Balance Summary – Median Climate Scenario

Year	2020	2024	2028	2032	2049
Inflows (ML)					
Rainfall Runoff	1608	1929	2266	2338	2368
Groundwater Inflows	2835	2879	3074	3001	2847
Total Inflows	4443	4808	5340	5339	5215
Outflows (ML)					
Evaporation	1571	1825	2059	2154	3198
Uncontrolled Release	0	12	13	14	13
Controlled Release	998	0	0	0	106
CHPP Processing / Co Disposal Losses	763	1237	1091	1185	136
Haul Road Dust Suppression	821	1143	1101	1137	144

Year	2020	2024	2028	2032	2049
Total Outflows	4153	4217	4264	4490	3596
Change in Stored Inventory (ML)	290	591	1076	849	1619

Table 5.3 Jellinbah Mine CNE Overall Water Balance Summary – Median Climate Scenario

Year	2020	2024	2028	2032	2049
Inflows					
Rainfall Runoff	1608	1952	2287	2420	2384
Groundwater Inflows	2835	2879	3074	3001	2847
Total Inflows	4443	4831	5361	5421	5231
Outflows					
Evaporation	1571	1827	2053	2160	2990
Uncontrolled Release	0	12	13	14	13
Controlled Release	998	0	0	0	0
CHPP Processing / Co Disposal Losses	763	1237	1130	1201	370
Haul Road Dust Suppression	821	1143	1107	1140	370
Total Outflows	4154	4219	4303	4515	3742
Change in Stored Inventory	290	612	1058	906	1489

5.4.1 Mine Water Inventory

Figure 5.4 to Figure 5.6 show the total mine water inventory (excluding Plains Pit) forecast for a range of climate scenarios from 1 July 2019 to 31 June 2049.

The modelling results indicate there is generally no significant change to the total mine water inventory as a result of CNE. The results for the 5th percentile climate scenario (dry) show a deviation after 2040 when site water inventories are lower under the "with CNE" scenario. It should be noted that the addition of CNE allows Jellinbah Mine to maintain existing production levels for the remainder of the mine life and without CNE the coal production rate will decline after 2040. The change in overall production levels between the "with CNE" and "without CNE" scenarios has a direct impact on the water consumption requirements which is reflected in the mine water inventory forecasts.

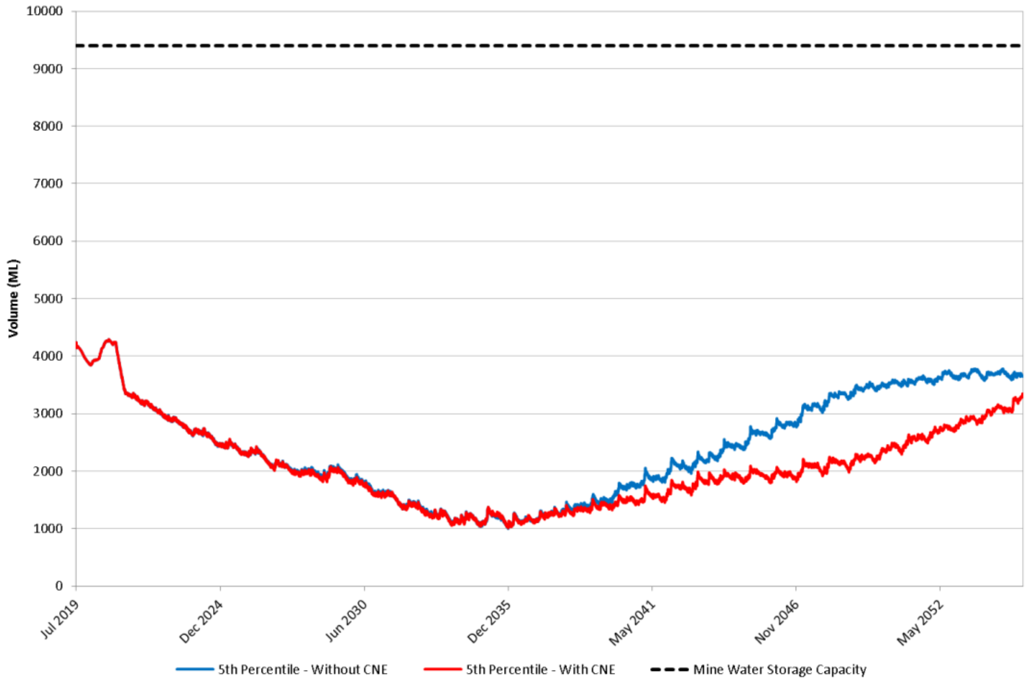

Figure 5.4 Mine Water Inventory Forecast - 5th Percentile

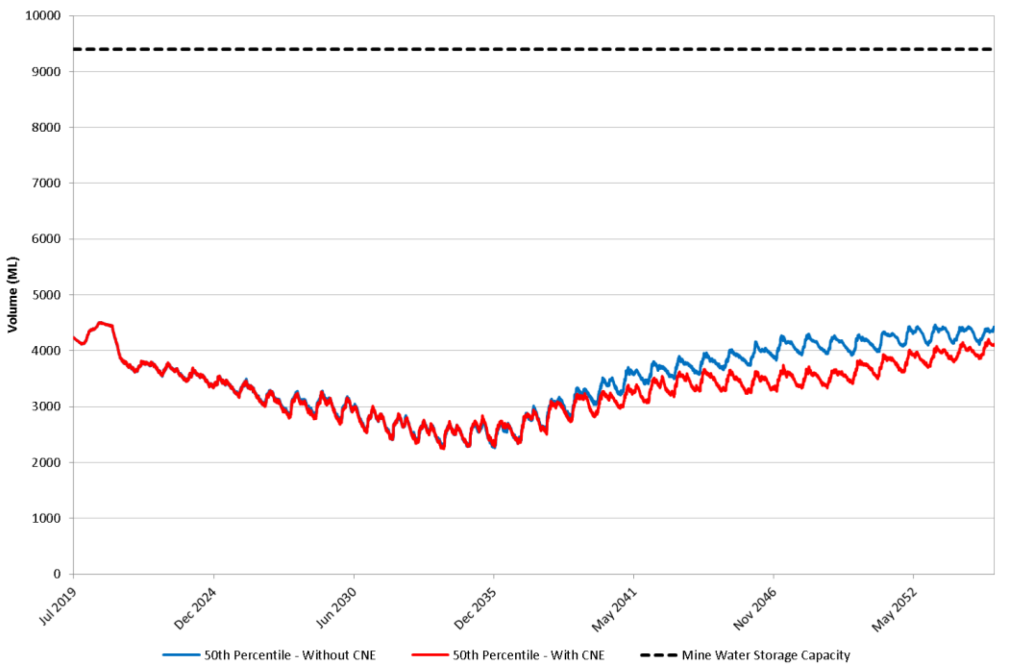

Figure 5.5 Mine Water Inventory Forecast - 50th Percentile

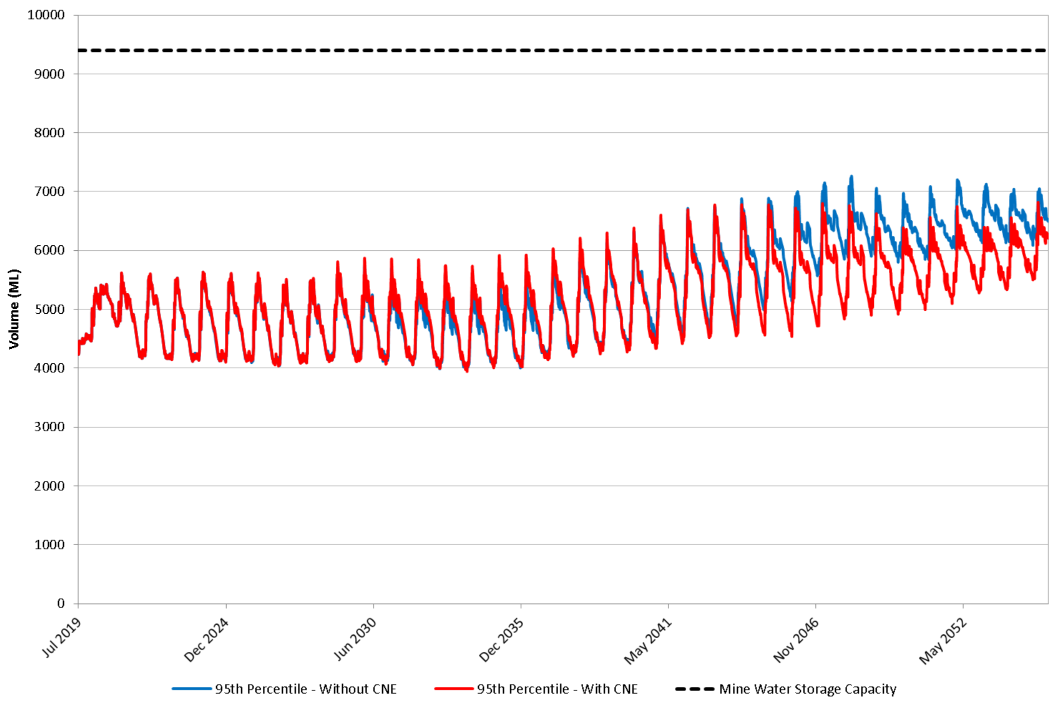

Figure 5.6 Mine Water Inventory Forecast - 95th Percentile

5.4.2 Mine Water Releases

The occurrence and volume of uncontrolled releases from mine water storages was assessed by simulating the site water balance model using the available historical climate data (118 years). The water balance model includes several historical extreme events such as 2011.

Modelling results indicate that uncontrolled releases from mine affected water storages occur in years equivalent to the 95th percentile and higher. These releases occur from designated mine water release points at Jellinbah Mine and are compliant with the release conditions and surface water quality thresholds in the site environmental authority.

The occurrence and volume of uncontrolled mine water releases are lower as a result of the CNE due to slightly lower stored mine water inventory volumes.

Table 5.4 Annual Uncontrolled Mine Water Releases (ML)

Scenario	75th Percentile	95th Percentile	99th Percentile	Max
Without CNE	0	36	113	364
With CNE	0	23	109	342

Table 5.5 presents the results for the annual volume of controlled releases via the approved mine water release points at Jellinbah Mine.

The modelling results demonstrate that there is no difference in the release potential for the two scenarios. This is due to the stored water inventories being very similar in the 50th (median) and 95th (wet) percentile climate scenarios and as such, initiating the same operational water management responses under the site water management trigger action response plan.

Table 5.5 Annual Controlled Mine Water Releases (ML)

Storage	5th Percentile	25th Percentile	50th Percentile	95th Percentile
Without CNE	0	423	998	3579
With CNE	0	423	998	3579

5.4.3 Clean Water

The runoff generated from catchments associated with the CNE mining void will be redirected to the receiving waterways through progressive backfilling and rehabilitation of overburden during the life of the mine. For this reason, there will only be a temporary reduction in the catchment area of the receiving waterways during the course CNE mine life.

A permanent reduction in the catchment area of the receiving waterways results from the proposed final void. The CNE final void catchment area is 421 ha compared to the 337 ha.

The additional 84 ha will result in a reduction in annual median runoff of 0.025 ML (Refer Table 4.2). Based on a median annual streamflow in the Mackenzie River of 1.57 million ML, the reduction in catchment area and associated runoff as a result of CNE is considered to be insignificant.

5.5 Climate Change Sensitivity Analysis

A climate change sensitivity was undertaken using the site water balance model to understand the impact of climate change on the performance of the mine water management system.

The sensitivity analysis was undertaking by adjusting model climate data inputs using the methodologies outlined in “Climate Change in Australia Technical Report” (CSIRO, 2015). The CSIRO report provides projections of future climate variables as a result of climate response to several greenhouses gas and aerosol emission scenarios (Representative Concentration Pathways).

Climate projections for Jellinbah Mine were obtained using the projection builder tool (Whetton et. al, 2012) provided on the Climate Change Australia website which was developed using the climate model evaluations detailed in the CSIRO report. Projections were obtained for the “Best and “worst” case scenarios which are based on the following:

- Worst Case – higher rainfall and lower evaporation, and
- Best Case – lower rainfall and higher evaporation.

Projections are also provided for the “Maximum Consensus” which is the climate future projected by at least 33% of the climate models and which comprises at least 10% more models than any other. The “Maximum Consensus” is considered the most representative forecast of all the climate models which is considered in the current assessment.

Projected changes to annual rainfall and evapotranspiration were obtained for the following most conservative climate change scenario:

- 2090 projection year – furthest available estimated data
- Representative Concentration Pathway 8.5 (RCP8.5) – represents no intervention to reducing greenhouse gas and aerosol emissions.

The climate change sensitivity parameters are provided in Table 5.6. The predicted change in evapotranspiration has increased for all climate change scenarios.

Table 5.6 Climate Change Sensitivity Parameters

Scenario	Change in Annual Rainfall	Change in Annual Evapotranspiration	Model and Consensus
Best Case	-34%	14.5%	Model – GFDL-ESM2M Consensus - Low
Worst Case	19.1%	8.3%	Model – NorESM1-M Consensus - Moderate
Maximum Consensus	-15.4%	15.2%	Model – GFDL-ESM2M Consensus - Moderate

The model climate inputs were adjusted using the values in Table 5.6 to assess the impact of the "Maximum consensus" climate change scenarios on the Jellinbah Mine site water inventory, uncontrolled and controlled releases.

The mine water inventory forecast results for climate change sensitivity assessment for 50th percentile (median) are shown in Figure 5.7. The sensitivity analysis indicates that mine water inventory reduces under the adopted climate change scenario and the predicted stored water inventories for CNE are lower than those predicted for CN under the adopted climate change scenario.

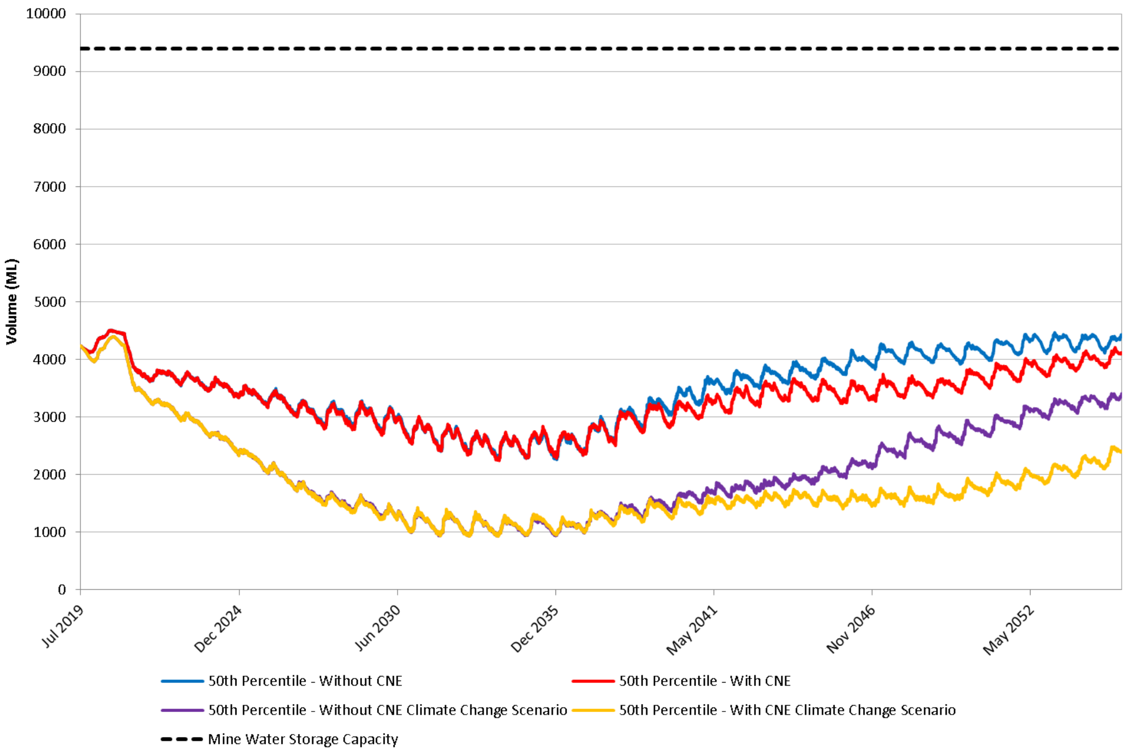

Figure 5.7 Mine Water Inventory Forecast - 50th Percentile Climate Change Sensitivity Assessment

Modelling results (Table 5.7 and Table 5.8) indicate that the estimated volume of uncontrolled or controlled mine water releases does not increase as a result of CNE under the adopted climate change scenario.

The reduced volume of site inventory, uncontrolled and controlled releases for the adopted climate change scenario is directly due to reduced rainfall intensity and increased evaporation.

Table 5.7 Annual Uncontrolled Mine Water Releases (ML) - Climate Change Sensitivity Assessment

Scenario	75th Percentile	95th Percentile	99th Percentile	Max
Without CNE	0	0	25	172
With CNE	0	0	23	167

Table 5.8 Annual Controlled Mine Water Release Potential (ML) - Climate Change Sensitivity Assessment

Scenario	5th Percentile	25th Percentile	50th Percentile	95th Percentile
Without CNE	0	0	257	2303
With CNE	0	0	257	2303

6. MONITORING AND MANAGEMENT

The Jellinbah Mine surface water monitoring program provides a robust dataset of water quality information for site water storages while the Jellinbah Mine Receiving Environment Monitoring Program (REMP) provides surface water quality characteristics for the receiving waterways. These programs will be amended and updated to ensure surface water quality data for the CNE will be collected and documented.

Annual reviews of the water quality data for water storages occurs as part of the annual update to the site water management plan, while surface water quality data for the receiving waterways are reviewed as part of the annual review of the REMP.

The scheduled annual reviews identify any deviations from assumed or predicted water quality and review whether the current management controls are appropriate to meet water quality objectives for environment values within the receiving environment.

In an unlikely event of a non-compliant water release from the Jellinbah Mine water management system, a review of the system operation and performance will be conducted by a suitably qualified and experienced person including recommendations to corrective action and changes to management controls if required.

7. QUALIFICATIONS

a. In preparing this document, including all relevant calculation and modelling, Engeny Water Management (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b. Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

c. Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

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g. This report does not provide legal advice.

8. REFERENCES

AARC (2018) Jellinbah Coal Mine Erosion and Sediment Control Plan, Revision 2. March 2018.

Australasian Groundwater and Environmental Consultants Pty Ltd (2006), *Mackenzie South Project Groundwater Impact Assessment*, February 2006.

Australasian Groundwater and Environmental Consultants Pty Ltd (2013), *Mackenzie North Groundwater Assessment*, June 2013.

Australasian Resource Consultants (2018), *Jellinbah Coal Mine: Receiving Environment Monitoring Program – Progress Report.*

Department of Environment and Heritage Protection (2017), *Environmental Authority EPML00516813 Jellinbah Mine*, prepared for Thiess Pty Ltd, February 2017.

Department of Environment and Heritage Protection (2016), *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures*, Version 5, March 2016.

EGI (2013), Geochemical Assessment of the Mackenzie North Coal Project. Environmental Geochemistry International Pty Ltd. August 2013.

IESC (2019) Advice to decision maker on coal mining project IESC 2019-103: Jellinbah Coal Mine – Central North Extension (EPBC 2018/8139) – Expansion. Date of request 12 April 2019.

JBT Consulting Pty Ltd (2018), *Groundwater Inflow Rate to Final Voids*, report JBT01-061-003, prepared 12 November 2018.

JBT Consulting Pty Ltd (2019), *Groundwater Modelling Jellinbah Central North Extension (CNE) Area*, report JBT01-061-004, prepared 22 March 2019.

Whetton. P., Hennessy, K., Clarke, J., McInnes, K., Kent, D. (2012) Use of Representative Climate Futures in impact and adaptation assessment. Climate Change, December 2012, Volume 115, Issue 3–4, pp 433–442.